PROCEEDINGS OF

THE CONFERENCE ON SUSTAINABLE BUILDING SOUTH-EAST ASIA

(SB07SEA)

Editors

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Published by:

Institute Sultan Iskandar of Urban Habitat & Highrise,

Level 4, Dewan Sultan Iskandar

Universiti Teknologi Malaysia

81310 UTM Skudai

Johor, Malaysia

ISBN: 978-983-2466-08-6

November 2007

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PREFACE

The Conference on Sustainable Building South-East Asia (SB07SEA) is organised by Institute Sultan Iskandar of Urban Habitat & Highrise, IEN Consultant Sdn Bhd, Malaysia in collaboration with The International Council for Research and Innovation in Building and Construction (CIB), The International Initiatives for Sustainable Built Environment (iiSBE), United Nations Environment Programme (UNEP) and United Nations Sustainable Building Construction Initiatives (SBCI).

SB07SEA is hosted by The Ministry of Energy, Water & Communications (Malaysia) with the theme 'Strategies for Implementation'.

SB07SEA is part of the world SB07 series of programme aiming at promoting the implementation of Sustainable Buildings construction practices, technologies and techniques in South-East Asia. In line with the vision of Green Building Mission Malaysia, launched by The Prime Minister of Malaysia in March 2007, this conference strives to bring together construction stakeholders in the region to share and exchange information on sustainable building and construction for mainstreaming and implementing sustainable practices in South-East Asia.

The Conference provides an opportunity for discussion amongst the design and construction community and stakeholders in governments and private sectors to exchange information on sustainable building and construction (SBC), examine critical issues concerning sustainable buildings, share research findings, as well as understanding the challenges and opportunities for mainstreaming SBC in the region.

The proceedings contain papers, addressing multi-faceted issues on sustainable building and construction, presented at the conference. These papers were reviewed by the International Scientific Committee formed within the members of CIB, iiSBE and regional experts.

The Organisers wish to express their sincere gratitude and appreciation to The Sponsors, The International Scientific Committee, Committee Members for their support throughout the planning, preparation and implementation of this event.

Appreciation and thanks are also due to Putrajaya Perdana Berhad, Roxul Asia Sdn Bhd, Ajiya Berhad, Bovis Lend Lease Sdn Bhd, Philips Lighting Malaysia Sdn Bhd, Public Works Department Malaysia, Construction Industry Development Board of Malaysia, The Institution of Engineers Malaysia, Malaysian Institute of Architects , World Green Building Council, Malaysia Energy Centre, keynote speakers and delegates for their valuable contributions leading to the success of this conference.

Assoc.Prof Dr Faridah Shafii
The Chairman
Conference on Sustainable Building South-East Asia (SB07SEA)
November 2007

SUSTAINABLE BUILDINGS IN SOUTH-EAST ASIA: OPPORTUNITIES & IMPLEMENTATIONS

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Abstract

The construction industry plays a major role in improving the quality of the built environment, but it also impacts on the wider environment in a number of ways. Too many buildings are environmentally inefficient and do not make best use of limited resources such as energy and water. The energy used in constructing, occupying and operating buildings contribute to climate change, of which the impacts are clearly showing strains upon the environment.

In this context, sustainable building and construction have the potential to regenerate the natural environment and community culture while enhancing the value of products and services to business, customers and society in general. In order to meet the emerging scientific and technological challenges associated with the concept of sustainability, new design thinking, methods and tools are required.

The Green Building Mission launched recently by the Malaysian Government is an indication of a promising effort to ensure sustainable production and delivery of the construction industry products. Many other initiatives have since been established to propel and facilitate efforts towards a more environmental conscious building and construction industry in the region.

The paper highlights the opportunities for sustainable building and construction in South-East Asia and their implementations. The paper concluded with strategies for implementations and establishing clear policy targets for achieving sustainable development in the region.

KEYWORDS: Sustainable Building, Malaysia, Public initiatives, Private initiatives, Green Building Mission, Policies

1. Introduction

The building and construction sector is a key sector for sustainable development. The “cradle to grave” aspects of building and construction linked to the creation, use and disposal of built facilities generate social and economic benefits to the society however, at the same time constitute negative impacts upon the environment. Areas of main concern include energy use with associated greenhouse gas (GHG) emissions, waste generation, construction materials consumption, water consumption and their discharge, and integration of buildings with other infrastructure and social systems (SBCI-UNEP 2007, van der Putte, 2007). This implies that the construction industry and the sustainability of its products, principally buildings, faces an environmental challenge, greater than any other industrial sector, in order to become more sustainable in the long term. Recent reports (SBCI- UNEP 2007) recommended on the construction of sustainable building as a means to mitigate global warming and climate change.

The benefits of sustainable buildings are widely documented (WBDG, UNEP 2002, Shafii, 2005, Shafii et al. 2006). In Malaysia there is increasing public awareness and interest in how buildings affect the environment, worker productivity and public health. As a result, both the public and private sector are beginning to demand buildings that optimize energy use; promote resource efficiency; and improve indoor environmental quality. Developers, owners, operators, insurers, and the public at large are beginning to value and market the benefits of sustainable building.

The paper describe the opportunities for sustainable buildings in the region and their implementations in the context of the stakeholders perspectives.

2. Movement Towards Sustainability

Whilst in industrialized countries some actions have been taken to encourage the use of sustainable buildings and arrest the implications of resource depletion and environmental degradation caused by construction activities, the situations in developing countries are far more different. In developing countries of South-East Asia, as construction rapidly develops to fulfil the infrastructures needed to support its growth, conflicting issues between the construction industry needs and environmental concerns become constant arguments. The impacts of construction activities upon global warming and the general local environment such as land clearings for construction; pollutions due to materials extraction; pollutions due to manufacturing resulting in air pollution, emissions to water and toxic waste in addition to the respective energy usage for extracting and processing the raw material into the products; all add up to the challenges of implementing sustainable building and construction in these countries (Shafii et. al, 2007).

Sustainability agenda in the region focus on relationship between construction and human development and alleviation of poverty. These together with the lack of resources and capacities to improve technologies tend to marginalise the environmental aspects.

3. Developments of Sustainable Buildings in South-East Asia

The status of Sustainable Building in South-East Asia as reported at the Conference on Sustainable Building South-East Asia (2004 series) and the Asia-Pro Eco Programme (Shafii et. al, 2005) is highlighted below.

3.1 Awareness on sustainable building

Sustainability is still a relatively new concept for the construction industry in the developing countries and has not yet received sufficient attention. However, generally, there is an increase in awareness on sustainable building and construction (SBC) in the region however not across the whole spectrum of the building and construction sector.

Participants highlighted that education about the principles and concepts of sustainable building is most essential in main streaming SBC as it requires changing behaviour which in turn requires changing attitudes. Technical training which follow after education will provide better a understanding of sustainability issues to support implementations. The need for a definition of sustainability and sustainable building in the regional context was highlighted by many stakeholders. Participants expressed about the need for more education (not only for building professionals, but for the public at large) about what sustainability is all about and why we should strive for it in buildings and in general.

Many important stakeholders (contractors, manufacturers, developers) in South-East Asian construction industry are not even aware of the concept of sustainable building, and so are naturally resistant to change. Hence, the greatest barrier to implementation is the lack of understanding of the NEED for sustainable design. The economic barriers are also inextricably linked to the awareness mentioned above, because markets are based on demand.

3.2 Special and cutting edge projects

Majority of sustainable building projects in South-East Asia (SEA) are 'special' and cutting-edge rather than the 'norm'. Currently, the extent of sustainable building practices are limited to office and commercial buildings (Kristenssen, 2005). The sophisticated nature of the projects involved only major organizations/corporations and those with the resources and capability to undertake such major projects.

3.3 Sustainable Housing

In regions marked by poverty and economic problems, it is very difficult to establish environmental sustainability as a national priority. Sustainable construction in South-East Asia tends to focus on the relationship between construction and human development hence marginalising the environmental aspects. The development of sustainable housing projects, as well as related research in this area is still in its infancy. Currently, there is no guideline/policy available to address sustainable housing construction.

3.4 Project delivery

Project delivery is a major issue in developing countries. Due to the fragmented nature of the construction industry, project delivery is complex. Sustainability has added to this complexity. The quality of construction delivered is a major issue which in many respects are linked to the far wider issues of educating the population and promoting investment. Just like developed countries, it need effective procurement and regulations to ensure satisfactory in project delivery.

3.5 Public policies and regulatory frameworks

In some countries, public policies and regulatory frameworks do not encourage the development of the construction sector. Policies that negatively affect the growth of the industry are often related to technology imports, government subsidies for certain materials, distribution and pricing control of the industry.

3.6 Energy efficiency driven

Sustainable building and construction practices concentrated on energy efficiency designs. The cost of sustainable building options is a barrier to the routine use of sustainable strategies in the construction profession. Some respondents quoted “The construction industry won’t go sustainable unless it saves money somehow.” Majority of clients focused on energy efficiency issues, which is believed to lead to an immediate payback.

3.7 Need of demonstration projects

The lack of interest from clients was cited as one of the significant barrier to more widespread sustainable building practice in South-East Asia. There is a clear need of further examples of SBC practices and demo/pilot projects to convince construction stakeholders to adopt sustainable building concepts. Builders and architects illuminate the perceived discord between profits and environmental protection within the construction industry. Many designers, especially from small-medium enterprises (SMEs) perceived sustainable design and construction to involve extra costs, thus reducing the competitiveness of their tenders and potentially resulting in loss of business.

High cost is also the result of unfamiliarity of design teams and contractors with sustainable methods. The lack of education about the economic benefits of this approach is one of the barriers to mainstreaming SBC.

The environmental issues are not yet seen as a central business concern for most small-medium enterprises although lip service was paid to sustainability issues. This is because that small firms are not subjected to the same stakeholder pressure for environmental management of large corporations. Although they acknowledged that their industry should be at the forefront of sustainability, most firms felt they could not push the environmental agenda forward for fear of alienating their clients, who were reportedly driven by commercial rather than environmental or social concerns. Clearly, these market dynamics have a major impact on the supply chain as builders perceived a low demand for sustainable buildings and construction methods, and therefore have no incentive to improve their environmental performance.

Additionally, small firms lack resources and support systems and do not have the capacity to carry out such measures. Whilst it appears that the environment is not a priority for policymakers or stakeholders, hence it become even less priority for small firms. In conclusion, a policy emphasizing on voluntary action tend to place the environment as a peripheral issue.

3.8 Stakeholder involvement at early design stage

In some projects stakeholders participation came at the later stage of construction. Hence, there is a need to make clear the importance of stakeholders involvement in the early design of the project. Implementing sustainability issues starts at the strategic and concept planning and project programming stage where the technical and economic feasibility of alternatives will be compared in order to select the best possible project. Sustainability decisions made at the beginning of a project life cycle have a far greater influence than those made at later stages since design and construction decisions will influence the continuing operating costs and, in many cases, revenues over the building's lifetime.

3.9 Participation of stakeholders in construction process

The participatory approach to sustainable building need to be emphasized to all stakeholders to encourage successful implementation of projects.

3.10 Holistic design concept

There is need to encourage the use of holistic building concept (Integrated Design Process). Basic understanding of the concept will lead to appreciation of integrated design team which encourages involvement of stake holders from the beginning.

3.11 Financial support

Financing of sustainable building projects are major problems facing stakeholders in South-East Asia unless if it is government- driven.

3.12 Public-Private partnership

From case studies in South-East Asia, most economic players agree that to undertake sustainable building projects a "purely public" or "purely private" mechanism will no longer fit the bill. It can be seen that Public-Private Partnerships (PPPs) are not simply a budgetary tool, but a fully-fledged instrument that encourages co-development and contributes at an operational level to general socio-economic growth.

4. Opportunities and strategies for Implementation

Strategies are needed to encourage sustainable building and construction and the first steps involved improving standards in the industry. DTI/DETR (2000) listed the following strategies for implementations:

- Re-use existing built assets
- Design for minimum waste
- Aim for lean construction
- Minimise energy in construction and in building use
- Avoid polluting the environment

- Preserve and enhance bio-diversity
- Conserve water resources
- Respect people and their local environment
- Set targets for benchmarks & performance indicators

Initiatives also need to be taken further with a look to the introduction of more complex sustainability plans, for example in the 'whole life costing' of buildings; implementation of 'site waste management plans' and gaining a wider adoption of key performance indicators throughout industry.

Making buildings and the construction process sustainable and environmentally friendly is a complex process that needs different inputs and skills/expertise from different stakeholders. These stakeholders include mayors and urban managers, government officials (as developers and as regulators), architects, planners, builders, and developers.

Every stakeholder has a role to play in taking different actions at different stages of the life cycle of a building.

Some examples of these roles include:

- Providing opportunities for incorporating sustainability.
- Controlling those conditions and situations that may lead to unsustainability.
- Educating the people and groups they interact with on sustainability principles.
- Programming their projects and work plans to clearly include sustainability.
- Legislating for sustainability, particularly at the local level, with codes, rules and regulations, procedural requirements etc.
- Maintaining a strong commitment to sustainability through development and management systems.
- Financing projects and companies that have a good record in incorporating sustainability.

For the government

Much of the local government's influence in the push towards sustainable building is in governance: rules and regulations, issuance of building permits, and as a major builder itself, demonstrating its greenness by building sustainably, having a green purchasing strategy, working with companies that have ISO14001 rating etc.

For architects, planners, designers, engineers

Architects, designers and engineers have a fundamental role to play in achieving sustainability in the building and construction sector, and a large number of other stakeholders as an extension – building material suppliers, engineering and technology companies etc. Their decisions and choices affect not only the immediate fabric of the building, but also long-term issues with the use of the building.

For building users

Ultimately, the decisions and choices made, and the ethics/values espoused by the user of the building on a daily basis determines on – how to save electricity, reduce waste, use less water, procure recycled goods – that cumulatively helps in a sustainable building achieving its goals.

5. Green Building Mission

Achieving sustainable development requires collaboration among sectors and institutions, and the participation of all stakeholders and individuals. These include campaigning networks, communities of practice, knowledge networks, public-private partnerships, multi-stakeholder partnerships and strategic alliances. These have all become important mechanisms for identifying priorities, undertaking joint research and for engaging other stakeholders in developing workable solutions. By combining these efforts, members of networks and partnerships are able to have a greater impact on policy and practice than they would have on their own.

With these realizations, the Malaysian government launched the Green Building Mission in March 2007 with the aim of raising the level of awareness, promoting and consolidating efforts in achieving sustainable building and construction in Malaysia. The government, private sector and non-profit organisations met to discuss sustainability and environmental issues in construction. At the policy dialogue delegates were asked to deliberate on critical issues, possible solutions and recommendations for sustainable building policies in Malaysia.

Recently, the construction industry has moved a step further to establish the Malaysian Sustainable Building Council, with the aim of supporting the government goals towards sustainable building.

6. International Cooperation

In general the awareness on sustainability issues in the building and construction sector is still low and developing countries like Malaysia have only just began to address the challenges of sustainable construction. There is a need for stimulation of activities for breaking down the barriers which hold back the development of sustainable building and construction in the country.

The initiatives to promote sustainable building and construction (SBC) in Southeast Asia were undertaken through the EU Asia-Pro Eco programme, an international cooperation between European Commission, the United Nations Environment Programme (UNEP) , The United Nations Sustainable Building and Construction Initiatives (SBCI), The International Council for Research and Innovation in Building and Construction (CIB), with Institute Sultan Iskandar, Universiti Teknologi Malaysia, as local host.

The Asia Pro-Eco Programme was aimed to develop Asian-led and Asian-owned action agendas for implementation of SBC practices, methods, policies and market mechanisms in the building and construction sector. A seminar on Mainstreaming SBC in Southeast Asia and The Conference on Sustainable Building Southeast Asia (SB04SEA) were organised to raise awareness amongst construction stakeholders in Malaysia and the region (SBCI 2007). Further to these activities, The Centre for Sustainable Construction & Tall Buildings of Institute Sultan Iskandar, Universiti Teknologi Malaysia, in collaboration with The United Nations SBCI, CIB and iiSBE are organising the next Conference on Sustainable Building Southeast Asia, 2007, as part of the initiatives to promote implementations of SBC in the region and enhancing closer cooperation and networking amongst constructions stakeholders in the region for future development.

7. Recommendations

The importance of appropriate government policies on building codes, energy pricing and financial incentives that encourage sustainable buildings must be taken seriously in taking forward the agendas and implementation of sustainable buildings in South-East Asia. Opportunities exist for Governments, industry and consumers to take appropriate actions during the lifespan of buildings that will help mitigate the impacts of global warming.

Additionally, the building sector stakeholders themselves, including investors, architects, property developers, construction companies, tenants, etc., need to understand and support, such policies in order for them to function effectively.

In order for the construction industry to move towards sustainability, the following recommendations have been proposed.

(a) Education and training should incorporate sustainable development concepts and made it well known and accepted by all people. Education is seen as an important tool in promoting sustainable development and improving the capacity of the people to address environment and development issue. This will increase the level of awareness both among the actors in the entire construction process, as well as the general public.

(b) Initiatives involving planning and construction should be through adapted regulations, standards or fiscal measures and incentives.

(c) Building owners and clients should play important roles in disseminating sustainable construction.

(d) Understanding sustainable construction through common definitions and language to address the issues.

(e) Designers adopting an integrated approach to design (integrated design approach).

(f) Improvement of the building construction process as opposed to the traditional methods

(g) Building users should consider the environmental issues as one aspect of productivity.

(h) Manufacturers of building materials/ products taking life cycle considerations as the basis of product development.

(i) Building maintenance organisations should consider environmental consciousness as a factor of competitiveness

(j) The development of tools to help in decision making. These including development of building rating tools, legislations to raise the standards of building environmental performance.

8. Conclusions

Making buildings and the construction process sustainable and environmentally friendly needs different inputs and skills/expertise from different stakeholders at different stages of the building life cycle. The public and private stakeholders need to work together in implementing SBC.

To develop strategies and recommendations aimed at promoting more sustainable construction in Malaysia,, before addressing further issues, priority need to be given to educate the stakeholders, developing strategies for environmentally friendly construction materials, energy efficiency in buildings and construction and demolition waste management. Clearly, there is a need of technologies and tools in decision making in achieving sustainable building in Malaysia.

The Government plays a crucial role in reversing the trends and ensuring the development of a sustainable construction industry. They can do this both indirectly, through legislation and planning controls, and directly, through their involvement as client, designer, supervisor and/or producer in the construction process itself.

The formulation of general economic and social policies for the enactment and enforcement of legislation ensures that policies are carried out. Therefore, the government can indirectly stimulate construction in the public as well as private sector, through fiscal and monetary policies. It can also influence the construction sector through the enactment and enforcement of building codes and planning legislation that encourages sustainable building.

International cooperation is an important consideration linking local to global initiatives and facilitate collaboration and knowledge sharing between research organisations and role-players in the industry.

Knowledge networks, public-private partnerships, multi-stakeholder partnerships and strategic alliances are important mechanisms for identifying priorities, undertaking joint research and for engaging other stakeholders in developing workable solutions for sustainable building and construction. Most importantly, organisations must possess adaptive capacity that enables them to recognize the need for change and to respond to it appropriately.

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PROJECT SUSTAINABILITY MANAGEMENT – BEYOND THE GREENING OF BUILDING

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Abstract

Establishing global standards for sustainable buildings, including energy performance, is difficult because conditions for buildings vary greatly between countries. Important initiatives are, however, being taken in this direction, especially in the European region. Next to regulatory control, the application of tools based on voluntary approaches has an important role to play. Certifiable rating systems for sustainability and energy performance in buildings – "the greening of buildings" - have proven to be effective in reducing energy consumption and associated GHG emissions.

Critics have however pointed out that most of these systems are not project oriented and have a single building focus.
What is needed is a framework that encourages multi-discipline participation in design and integrates single building projects with infrastructure and communities. To meet this challenge, the engineering sector should alter substantially the way it approaches planning, design, construction and operation.

As an important initiative in this direction, the international Federation of Consulting Engineers has developed the FIDIC Project Sustainability Management (PSM) Guidelines.

1. Introduction

Making economic development sustainable over the long term will require a complete overhaul of our infrastructures, replacing legacy materials, processes, systems, and structures with those that that are increasingly more sustainable. To meet this challenge the engineering community – the sector most qualified to effect this change – must alter substantially the way it approaches planning, design, construction and operation.

Sustainable construction is an important part of sustainable development. The framework of construction and city related sustainability indicators should be based on the viewpoint that sustainable construction brings about the required performance with least unfavourable or the most favourable ecological, economic as well as social and cultural impact both on a local and regional as well as on a global level (ref. 1). The greening of buildings which solely concentrates on the building itself with its environmental and energy aspects will certainly contribute to, but will in the end not result in the required sustainable solutions.

While it is clear that engineering firms will have a role in sustainable development, it is not yet clear what that role will be. Management consultants, accounting firms and architectural firms that design green buildings are currently providing most sustainable engineering services. Today engineering firms are not invited to participate in these projects unless the projects have been broken into pieces, giving the engineering firm those elements that require the application of the more conventional technologies.

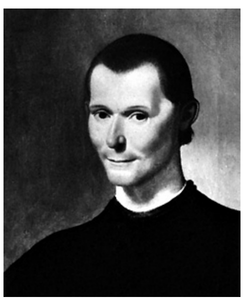
Some engineering firms have created sustainable development practices, but most have yet to define sustainability, establish performance standards, or assemble the required skills to meet client needs.

One of the major problems that is encountered by engineering firms, is that there is a lack of tools to develop, improve and evaluate the sustainability of projects and programmes in an independent way ref. 2).

Another bottleneck is a poor environment for innovation. Making progress in sustainability involves the development and application of new and more sustainable technologies. This requires an environment for innovation: an open environment in which diversity is encouraged, knowledge is exchanged, and risk is shared among the participants (see box 1). Unfortunately, engineers work in a highly litigious environment that avoids risk-taking. Threats of business risks has forced the engineering sector to stick closely to what is known and what can be done well over and over again, working within the boundaries of the current state of practice. Also, engineering disciplines tend to operate in relative isolation, doing their work and passing the results on to other disciplines at the appropriate project moment. This is often done in the name of efficiency, focusing their energies and resources within their own domain. Without some way of recognizing the benefits of cross-business-unit co-operation, each unit tends to seek improvement of its own financial performance even at the expense of others (ref. 3).

Given the urgency and serious consequences of our current non-sustainable operations, it is clear that actions should be taken to remove these barriers and enhance the engineers ability to innovate.

BOX 1



Niccolò Machiavelli (1469-1527)

The Prince (1513), Chapter 6.
``And let it be noted that there is no more delicate matter to take in hand, nor more dangerous to conduct, nor more doubtful in its success, than to set up as the leader in the introduction of changes. For he who innovates will have for his enemies all those who are well off under the existing order of things, and only lukewarm supporters in those who might be better off under the new." ``This indifference arises in part from fear of their adversaries who were favoured by the existing laws, and partly from the incredulity of men who have no faith in anything new that is not the result of well-established experience

2. Warning Signs of Non-Sustainable Development

The symptoms of non-sustainable development are starting to appear in many places and at various scales. At local scales we are confronted with cities with eroding infrastructure and congested highways leading into the cities, poor air quality, lack of access to freshwater in the underdeveloped nations On a larger scale there is the matter of climate change and weather-related natural disasters. Although still controversial, the consensus view is that many of the gases produced primarily through the combustion of fossil fuels are causing an enhanced greenhouse effect that will change climate patterns significantly in this century.

The list of problems is increasing. It is however still not comprehensive enough to argue the larger case that our overall model of economic growth is not sustainable. Projections of resource shortages are often counterbalanced by new resource discoveries or by invention of replacements. Even the north pole is now targeted as an area for new resource discoveries. The most well known predictions are those made in the 1972 report of the Club of Rome called the Limits to Growth. Although the work was criticized, the warnings raised by the authors soon were to appear prophetic. There is now hard evidence that we are approaching the limits of our resources and ecological carrying capacity at all scales.

At the beginning of the 20th century, the human population was not large enough and its technologies not strong enough to have a long lasting effect on the resources and ecological systems at a world scale. This situation has totally changed. World population just reached 6 billion and is expected to reach 9-10 billion by the middle of this century. Population expansion into urban areas presents an additional challenge. While the number of megacities in the developed world is expected to increase only to five, the number of megacities in the developing countries is expected to reach over 50. Most of these cities will be located in coastal areas, making them highly vulnerable to natural disasters and other consequences of climate change (ref. 3) This development will create a major challenge for the engineering community, requiring the design of systems and construction of a new kind of infrastructure to support and provide safety to these huge urban populations.

3. The Building and Construction Sector as a Key Sector in Sustainable Development

The building and construction sector is a key sector for sustainable development. The construction, use and demolition of buildings generate substantial social and economic benefits to society, but may also have serious negative impacts, in particular on the environment. Areas of key concern include energy use with associated greenhouse gas (GHG) emissions, waste generation, construction materials use and recycling, water use and discharge, and integration of buildings with other infrastructure and social systems.

The building and construction sector accounts for the largest share in the use of natural resources, by land use and by materials extraction. Energy use, liquid and solid waste generation, transport of construction materials, and consumption of hazardous materials are other examples of negative environmental impacts from this sector. In OECD (Organisation for Economic Cooperation and Development) countries, buildings are responsible for 25-40% of total energy use. In Europe, buildings account for 40-45% of energy consumption in society, contributing to significant amounts of carbon dioxide (CO_2) emissions. The building sector thus offers the largest single potential for energy efficiency in Europe (ref. 4).

Most (80-90%) of the energy today is used during the operational phase for heating, cooling and lighting of the buildings. Another part of the energy is related to the embodied energy in buildings. The shares of operating energy and embodied energy however will change with the new, low energy or zero energy buildings that are being built. In these zero energy buildings a comfortable interior climate can be maintained without active heating and cooling systems.

In developing general guidelines for energy efficiency in new buildings the following might be considered (ref. 5):

1.The selection of low-embodied energy materials.

2.The introduction of passive solutions at design phase (e.g. natural ventilation and orientation).

3.The selection of high performance materials and technologies, when applicable (such as energy saving equipment – HVAC, lighting, computers, refrigerators, etc – and clean electricity such as PV cells).

4.The introduction of advanced monitoring systems (e.g. to check the use of electricity by the building to detect abnormalities and correct them).

Existing buildings: In the OECD less than 1% of buildings are newly built every year. New buildings use less energy than existing ones and there will be a need for differentiating building codes, with energy requirements for new buildings and those for buildings to be renovated. Considering the rapidly increasing technological developments in this field, the year of construction and the type of building are important indicators in defining the measures and monitoring progress in energy reduction (ref. 6)

4. Progress in the EU in The energy Performance of Buildings

The European Union has made considerable progress in defining a specific action programme targeted at the buildings sector with specific reference to building performance requirements and very low energy buildings ("passive houses") (ref. 7)

The Energy Performance of Buildings Directive (2002/91/EC) can play a key role in realising the savings potential in the buildings sector, which is estimated at 28%, and which can, in turn, reduce total EU final energy consumption by around 11%. (Table 1). The European Commission will propose expanding the scope of the Energy Performance of Buildings Directive substantially in 2009, after its complete implementation. It will also propose EU minimum performance requirements for new and renovated buildings (kWh/m²). For new buildings, the Commission will also, by the end of 2008, develop in dialogue with Member States and key stakeholders, a strategy for very low energy or passive houses – to encourage more widespread deployment of such houses by 2015.

Table 1: Estimates for full energy saving potential in end-use sectors (ref. 7)

Sector	Energy consumption (Mtoe) 2005	Energy Consumption (Mtoe) 2020 (Business as usual)	Energy Saving Potential 2020 (Mtoe)	Full Energy Saving Potential 2020 (%)
Households (residential)	280	338	91	27%
Commercial Buildings (Tertiary)	157	211	63	30%
Transport	332	405	105	26%
Manufacturing Industry	297	382	95	25%

5. Important Role for Sustainability Performance and Rating Systems

The existing standards for sustainable buildings, including energy performance have a strong local, national or regional character, such as those in the EU. Although a complex task, general baselines and guidelines for various aspects of building performance need to be established. These can then be used to develop national and regional standards or legislation. Such baselines should not only emphasize energy efficiency but also climate change impact, materials use and efficiency, waste generation, water efficiency, ease of recycling, replacement and maintenance, integration with social systems, minimum consideration with social systems, minimum considerations with for fragile ecosystems (ref. 8,9).

Next to development of baselines for regulatory control purposes, attention should also be given to the systems based on voluntary approaches. The US experience with promoting Leadership In Energy and Environmental Design (LEED) has proved that market forces are a powerful tool in introducing sustainable and energy efficient buildings (BOX 2). LEED is one of the sustainability rating systems that also include energy performance in buildings. Although criticized as offering an oversimplified and incomplete assessment of contributions to sustainability, LEED appears to be transforming the building market (ref. 3)

First, it is raising stakeholder awareness of the benefits of owning, operating, and working in a green building by introducing life cycle analysis and integrated building design into the purchasing decision.

Second, the LEED rating system and its four levels of certification have stimulated competition to improve building performance. This competition involves not only architects, builders, and owners, but also companies seeking to develop and market high performance building technologies.

Third, LEED certification tends to increase the value of buildings by raising the market awareness of not only the environmental but also the economic and performance benefits of green buildings. Buildings that are more productive and cost less to operate are worth more money to the owner.

Fourth, LEED certification helps to prevent “greenwashing.” By setting standards coupled to a trustworthy certification program, uncertified claims of “greenness” are seen as not credible and are discounted.

Other related initiatives have developed a significant body of knowledge that proves that sustainable behaviour is profitable in many ways – not only in energy savings. It seems that the profit motive is the most powerful motivator known (ref. 5, 8).

The French HQE® method (High Environmental Quality) is a voluntary method that deals with the construction of certified high environmental quality building – using a lifecycle analysis to take into account the direct and associated impacts. This French approach is starting to be adapted and disseminated in other countries.

Other rating systems include Breeam and Ecohomes (UK), SPeAR (UK), ITACA (Italy),Casbee (Japan), EcoEffects (Sweden), Green Building Challenge (International).(ref 6, 8, 10).

BOX 2.
The LEED (Leadership in Energy and Environmental Design) Green Building Rating System is a process for applying and scoring buildings based on a set of project indicators. Developed and administered by the U.S. Green Building Council (USGBC), it offers a framework and procedures for comprehensively evaluating and scoring buildings based on sustainable development principles. Buildings are scored on a point scale ranging from zero to 69 and can achieve four levels of certification.

- LEED certified: 26–32 points
- Silver level: 33–38 points
- Gold level: 39–51 points
- Platinum level: 51+ points (out of 69 possible points)

6. Need for Project Sustainability Management Systems

Certifiable sustainability rating systems have clearly contributed to sustainability approaches in the building sector. Critics have however pointed out that most of these systems are not project oriented and have too much of a single building focus. Generally, indicators are not only needed in order to supply information about the state and condition and causalities, but also to assess the effectiveness of alternative responses. The building sector does not need indicators only to assess and show the environmental quality and energy use of buildings or the built environment, but also to support the planning and design of sustainable buildings.

In Europe work has been performed within the CRISP Network on Construction and City related Sustainability indicators (ref. 1, 11, 12) .

In structuring the indicators according to the sustainable development issue, the following starting point has been taken by the CRISP Network:

1) Environmental: use of natural raw materials and energy, environmental pollution, land use, bio-diversity, odours, noise;

2) Economic: Economic development and finance, Urban and community services, Production and consumption;

3) Social: Access, Safety and security, Health and well-being, Community responses and human capacity, cultural heritage.

The CRISP network members developed sustainability indicators for a wide range of urban developments, from individual buildings to large-scale urban and suburban developments. These indicators covered issues related to the preservation of natural resources, air quality and noise, economic competitiveness, employment and a wide range of other factors. The 24 skilled teams that made up CRISP provided an authoritative consensus on sustainability indicators, with their related methodologies, for use by urban planners, developers and local authorities throughout Europe.

The main result of CRISP network is the collection of sustainability indicators and their related systems into a database, made available for the end-users on the Internet. The database contains more than 500 indicators and 40 systems of indicators, derived from systems in EU countries, Canada and the USA.

In the engineering community, working worldwide, there is not only a need for sustainability indicators for the building activities in the developed regions. These indicators should also cover the less developed regions, as buildings vary greatly depending on local conditions. In addition these indicators should be applicable not only for buildings and building activities, but also for a wide range of engineering projects and development plans. Finally, one of the most important requirements should be met, which is the process of how to use these indicators, having a specific project goal in mind.

This has been one of the reasons that FIDIC has developed its Project Sustainability Management (PSM) Guidelines. In an innovative way, the PSM Guidelines describe how project owners and consulting engineers can incorporate the principles of sustainable development into individual projects. Consideration is not only given to the green environmental elements of projects but also to the economical, social and cultural aspects. With the PSM guidelines also a tool is provided to develop, improve and evaluate the sustainability of projects and programmes in an independent way (ref 2, 3, 10).

The components of the FIDIC PSM system are twofold:

1) a framework of sustainable development goals and the corresponding indicators, both of which map back to the whole-society issues, goals and priorities of Agenda 21, and the corresponding sustainability indicators developed by the United Nations Commission on Sustainable Development; and

2) a process for setting and amending sustainable development project goals and indicators, making them consistent with the vision and goals of the project owner, compliant with Agenda 21, and tailored to local issues, priorities and stakeholder concerns.

FIDIC has developed a set of core sustainable development project goals and indicators organized in a framework which corresponds to the whole-society issues, goals and priorities of Agenda 21. Also, FIDIC has devised a process to amend these goals and indicators, allowing them to be customized to actual project conditions and requirements while retaining its whole-society scope. In addition, the process addresses the full life cycle of the project, from concept development through design, construction, operation, deconstruction and disposal. In this sense, project sustainability goals and indicators become part of the overall project delivery process. The set of sustainability performance indicators can even be adjusted and aligned with other rating systems, creating a flexibility when project owners also want to be certified under an existing certifiable rating system (ref. 8, 10)

While project goals and objectives set the direction, project sustainable development indicators provide the means by which progress can be measured.

The indicator set must be grounded in the overarching principles, goals, and priorities of sustainable development. In addition, it must be sufficiently comprehensive to cover all relevant aspects of sustainability, yet be of a size that is manageable and effective for communication. Also, the indicator set must allow for customization in order to align to local requirements and conditions. Finally, the process by which these accommodations are made must be open and transparent.

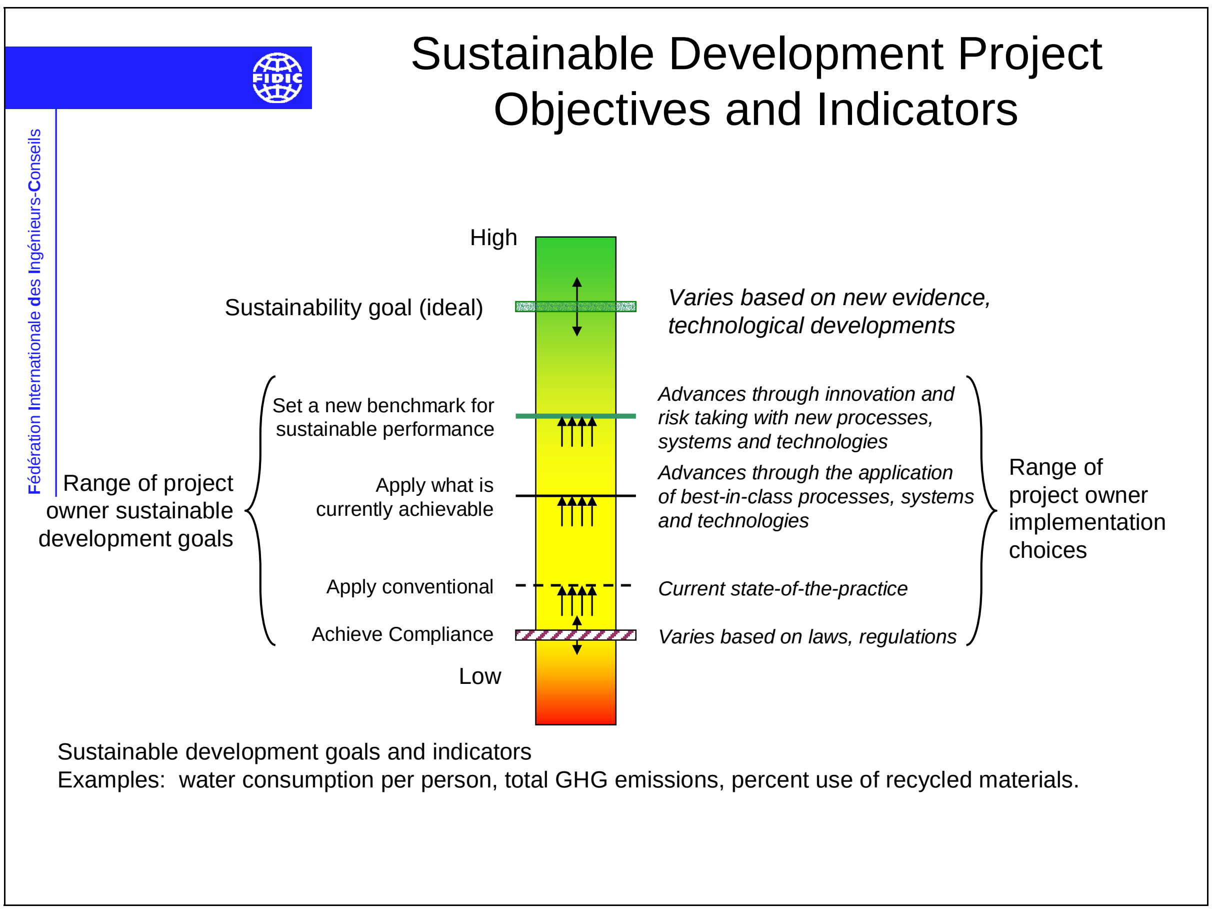
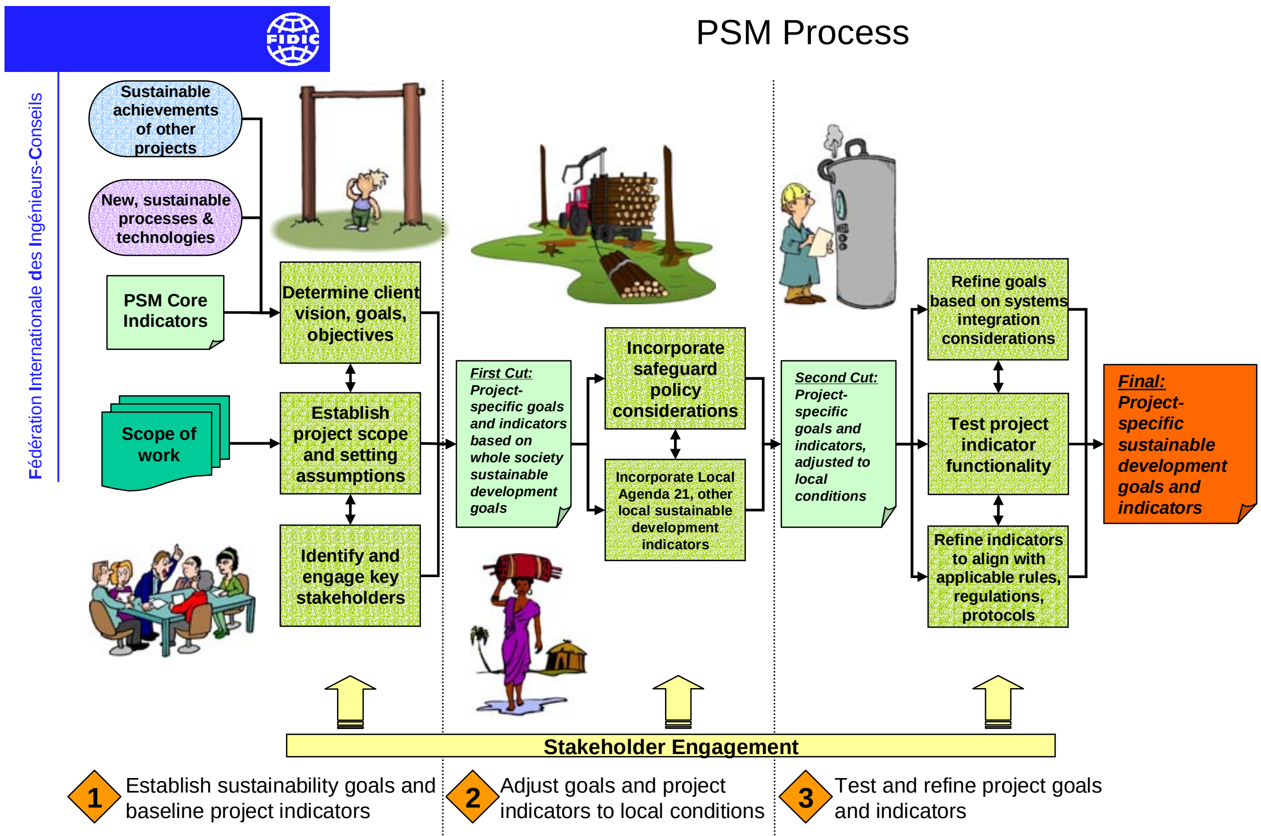


Figure 1 : Sustainable Development objectives and indicators conceptual model. Source: International Federation of Consulting Engineers, Sustainable Development Task Force, *Project Sustainability Management Guidelines (ref. 10).*

A conceptual model of a sustainable development project indicator is presented in Figure 1. In this model, the range of sustainable performance is characterized on a generic scale from high to low. Conditions of sustainability are achieved somewhere in the high range, but that threshold is variable based on local conditions, evidence about resources and carrying capacity, and any technological developments that could alter the definition of sustainability for this particular indicator

The PSM core indicators were derived from the CSD framework. In the FIDIC PSM model, a set of 42 indicators (14 themes and 30 subthemes) was derived from the 65 CSD indicators, based on their relevance



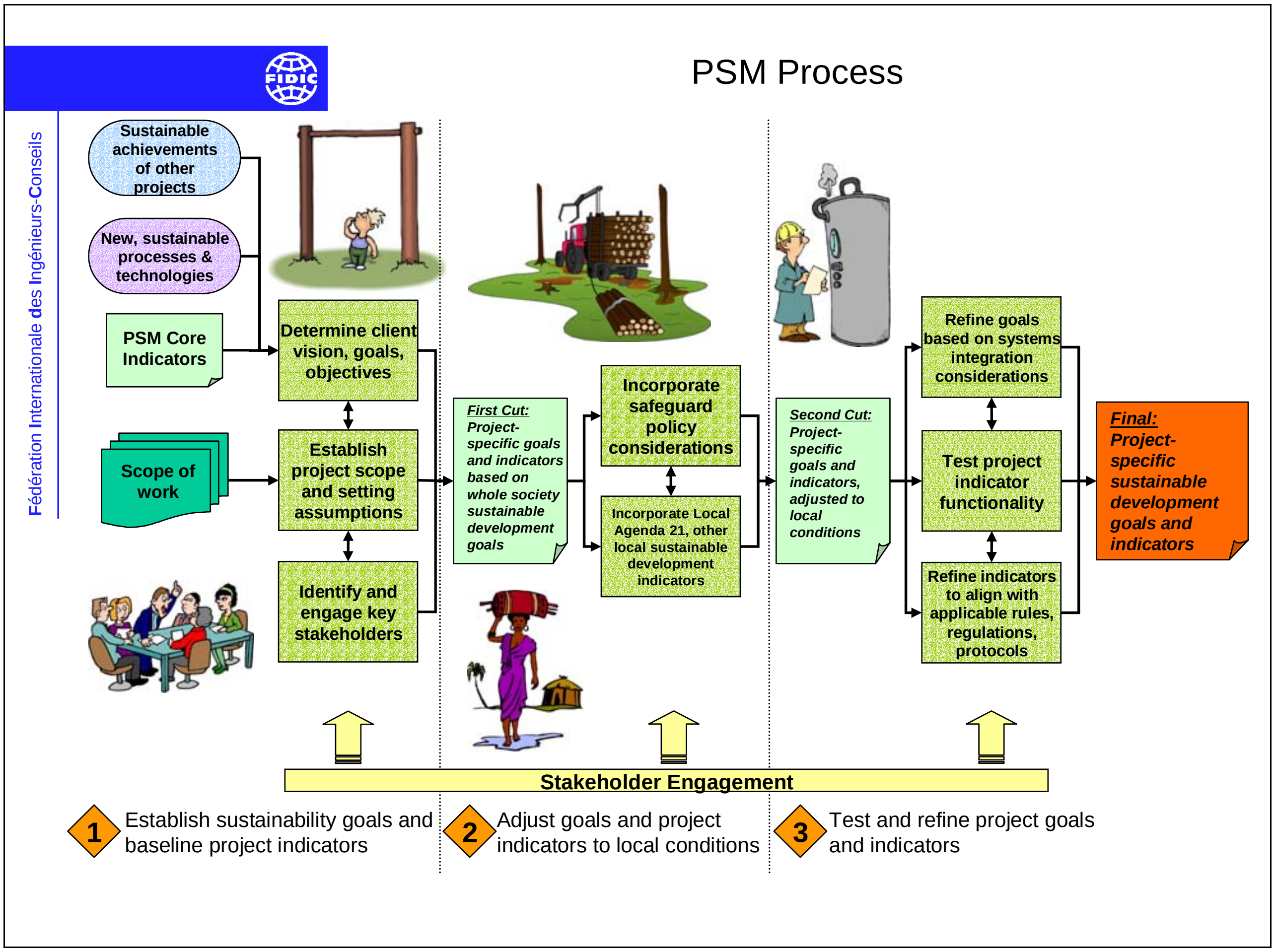


Figure 2 : The Project Sustainability Management (PSM) process. Source: International Federation of Consulting Engineers, Sustainable Development Task Force, *Project Sustainability Management Guidelines (ref. 10).*

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Marrakech Task Force on Sustainable Buildings and Construction

Motto:
Worldwide 30-40% of all energy is used in buildings. Most (80-90%) of this energy is consumed during the operational phase of buildings (heating, cooling, lighting, appliances, demolition). The savings potential is huge. Saving energy saves cost, climate and human health.

Considering the present construction boom in many parts of the world, low-energy construction should be the rule, not the exception! It is low-technology, which is already available! Why don't we mainstream it? How can public policies and legislation promote energy efficiency, energy savings and use of renewable energy in the built environment?

BUILDINGS FOR A BETTER FUTURE – POLICY OPTIONS IN A CHANGING CLIMATE

This paper illustrates the work of the Marrakech Task Force on Sustainable Buildings and Construction, now focussing on public policies to promote sustainability of energy consumption in the built environment. The context and role of the Marrakech Process will be briefly described first, before outlining the present and future work of the Task Force, such as the best policy practices.

THE MARRAKECH PROCESS:
RIO – JOHANNESBURG – MARRAKECH – COSTA RICA – STOCKHOLM –

Changing consumption and production patterns is one of the overarching objectives of and essential requirements for sustainable development. This was recognized by the governments in the final document of the World Summit on Sustainable Development (WSSD) in 2002, the Johannesburg Declaration.

The Johannesburg Plan of Implementation calls in Chapter III for the development of "a 10-year framework of programmes in support of regional and national initiatives to accelerate the shift towards sustainable consumption and production." The framework should strengthen international cooperation and increase exchange of information and best practices to facilitate the implementation of national and regional programmes to promote sustainable consumption and production.[1]

The Marrakech Process on Sustainable Consumption and Production (SCP) was launched at the first international expert meeting on the 10-year framework held in Marrakech, Morocco, June 2003 – a year after the Johannesburg WSSD. The 2nd International Meeting was held in Costa Rica, September 2005, and the third one took place in Stockholm, June 2007.

The Marrakech process will be up for policy review and recommendations in the 2010/2011 cycle of the UN Commission for Sustainable Development (CSD), and it is a cross-cutting issue for each biannual CSD cycle. Task forces linked to the respective substantive themes of each CSD can therefore enrich the respective discussions with the progress achieved and lessons learnt. Sustainable consumption and production aspects of energy and industrial development (2006/2007), agriculture and Africa (2008/2009), transport, chemicals and waste management (2010/2011), forest, biodiversity and tourism (2012/2013) are among the most obvious linkages in that respect.

A Marrakech Task Force (MTF) is a voluntary initiative lead by a country - in cooperation with other partners - committed to carrying out a set of activities which support the implementation of specific projects

[1] Quoted from, also for more information see http://www.un.org/esa/sustdev/sdissues/consumption/Marrakech/conprod10Y.htm

of the Marrakech Process. Any country interested in leading a certain issue on SCP, willing to support activities and to involve other countries, can initiate a task force. The Task Forces co-operate with UNEP and/or UN DESA. The long-term goal is to contribute to both the concept and the substance of the 10 Year Framework Programme (10YFP) of Sustainable Consumption and Production

Buildings, their construction, maintenance, operation, refurbishment and finally demolition have an enormous impact on human health, use of natural resources, national and local economies, employment, and the functioning of societies. The Government of Finland has acknowledged this, and has wanted to highlight the importance of the issue at all levels by offering to coordinate the **Marrakech Task Force on Sustainable Buildings and Construction** (SBC). The Finns pride on a solid tradition of building and land use legislation, as well as cooperation with and within the construction industry.

Fully aware of the complex network of different professions and industries that is required in new construction, maintenance and refurbishment of buildings, the Government of Finland also acknowledges the focal responsibility of **the public sector**. Regional, national and local governments have roles, not only in legislation, regulation, financing and putting policies in place – but also as users of buildings, clients for the construction industry and as real estate owners.

The **participants** of the international core group come from the governments of Australia, Canada, China, France, Lithuania, Mexico, Sweden, the US, and the City of Cape Town. Finland as the lead country has also its own national advisory committee representing various stakeholders of the sector. The Task Force has also a number of observers, most of them representing non-governmental or intergovernmental organizations. The Task Force is also in continuous contact with several related initiatives.

FIRST OUTPUTS OF THE SBC TASK FORCE: BASELINE DATA, POLICY ACTION P0INTS

In cooperation with a parallel initiative, the UNEP Sustainable Buildings and Construction Initiative (SBCI), the Task Force started its work by commissioning a **background report** with baseline data: *Buildings and Climate Change – Status, Challenges and Opportunities*.[2]

As the outcome of its first international workshop of in June 2006 in Helsinki, the Task Force compiled an extremely concise **set of recommendations**: *The Policy Action Points*. The role of the public sector in promoting sustainable construction is outlined in these five bullet points:

- To set an example in energy issues and create markets by encouraging all government agencies and public organizations to initiate and implement energy saving, energy efficiency and renewable energy programmes
- To introduce energy efficiency criteria into public procurement (of construction, buildings, and their maintenance and renovation)
- To integrate climate change and energy efficiency aspects in urban development policies
- To structure financial incentives to support building activities that take a long-term energy efficiency perspective and facilitate the transition to renewable energy sources
- To collect (energy consumption and production) data and establish baseline information in order to assess the impact of policies.

[2] All SBC Task Force publications can be downloaded at the Task Force website www.environment.fi/sbc

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BUILDINGS FOR A BETTER FUTURE – BEST POLICY PRACTICES

Best *Policy* Practices – why not simply best practices? The SBC Task Force began its work by focussing on two key perspectives: the potential of the public sector and energy. Regional, national and local governments and their institutions have several roles: they can regulate, give guidelines, collect taxes, finance and subsidize housing and renovation, invest in research and development and, last but not least, set an example as clients and users.

In order to proactively participate in the discussions of the UN CSD-15 session in May 2007, where policies concerning energy, climate change and industrial production were on the agenda, the Task Force published a compilation of best policies from all around the world, with the title *Buildings for a Better Future.* You can download the publication from the website www.environment.fi/sbc. The mini-cases – some very short, others with a bit more information and links – have been grouped under ten headlines which map out the broad field of construction, policies and energy. The following lists and briefly describes the contents of the publication.

1. NEW CONSTRUCTION

Engineers can calculate the thermal insulating capacity of construction materials, and the industry knows how to produce excellent windows, as examples. But politically, it has not been popular to set ambitious energy targets for new construction, even if every singly new building could be a zero-net-energy building with marginal extra cost. The technologies are here!

It is emblematic that we don't have any best policy practices to show you under this title, yet. Please, make sure that the next edition of this publication will have several! No doubt, several countries have detailed legislation, guidelines and certification systems where also energy efficiency is considered. But we'll need to go far beyond business-as-usual standards – and we'll also have to make sure that there is technical capacity and good governance to secure the implementation.

2. HOUSING

Housing concerns everyone. And the sector is also the highest consumer of energy. Housing links together communities and sustains societies – or accelerates their disintegration.

- Energy efficient housing programme, City of Pune, India
- Housing policies and pilot project, Lithuania
- New apartments with low energy consumption, Landskrona, Sweden
- Technical Sustainability Standards for Housing and Public Buildings, China

3. REFURBISHMENT OF EXISTING BUILDINGS

Every year, new construction adds only a small fragment to the built environment but many existing structures need refurbishment. In more cases than we realize renovating old buildings results in better homes and communities than demolishing them.

- Kuyasa Low-Cost Housing, City of Cape Town, South Africa
- Renovation of Gårdsten apartments to save energy, Sweden

4. ENERGY SAVINGS AND ENERGY EFFICIENCY

What is the cheapest energy available? Saved energy! Talking about new power plants seems to be more respectable, however, than promoting savings and efficiency. If efficiency is discussed, it is often implied that it requires new technologies, and more time. Wrong! Efficiency is efficiency - which of course leads to a smaller growth of energy consumption – but saving energy does not always require hi-tech solutions.

You can switch off the light, you can leave your car in the garage and walk or take the bus, and you can pull off the plug of the mobile phone charger when you don't need it. These require a change in attitude and behaviour. Sorry! You cannot blame your lack of action on an engineer or politician.

- Investment into energy saving in China
- ESCO – Energy Service Company, European Union
- Retrofit of the Parow Municipal Building, City of Cape Town, South Africa

5. RENEWABLE ENERGY SOURCES IN USE

Increasing the proportion of renewable energy sources in energy production is the third pillar of sustainable energy consumption – after savings and increasing efficiency. Because renewables – solar, wind, hydro, geothermal and biomass – are often local energy sources, their use will create local jobs and lessen dependency on energy imports. – Renewables will keep the global CO_2 bookkeeping in balance.

- Brightness programme, China
- Solar Water Heater By-Law, City of Cape Town, South Africa
- Solar Home System Distribution Project, Philippines
- Renewable Energy for Rural Economic Development (RERED) Project, Sri Lanka

6. NATIONAL AND FEDERAL POLICIES, PRACTICES AND PROGRAMMES

National governments must not only regulate, but also lead by example! They have a role in initiating programmes and offering carrots, as well as in promoting research and development**.**

- Climate Investment Programme (KLIMP), Sweden
- Building, Living, Property! – Management for the Future, Sweden
- Using Voluntary Consensus Standards, United States
- Leading by Example: Voluntary Agreement Elevated to Presidential Mandate (EO 13423), United States
- The Interagency Sustainability Working Group, US
- The Whole Building Design Guide, United States
- Policy for Public Buildings and Government Offices, China
- Programme for Ecologically Sustainable Construction, Finland

7. LOCAL-LEVEL POLICIES

If sustainability strategies are not both formulated and implemented at the local level, too, they'll not be implemented at all. In many cases, cities show the way, because they know that there is no alternative.

- Energy labels for buildings in Shanghai
- Energy and Climate Change Strategy, City of Cape Town, South Africa
- Congestion charge in London
- Solar thermal ordinance of the City of Barcelona

- Agència d'energia de Barcelona, Spain
- Local Green Building Programs in the US

8. PUBLIC PROCUREMENT

Public procurement amounts to about 15% of the GDP of OECD countries. If wisely used, it can be a powerful strategic tool to support innovation, decent work and fair trade, and to save energy and other resources.

- Top-Runner Approach in Japan
- Marrakech Task Force on Sustainable Procurement
- Sustainable Procurement Action Plan, UK
- Preventing corruption on construction projects (PACS)
- Executive Order 13423, January 2007, US
- Federal Green Construction Guide for Specifiers, US

9. RESEARCH AND DEVELOPMENT

Quantum leaps in the sustainability of energy use in buildings can be done with the technology that is already available everywhere. Some of it is centuries old, and still valid. Many construction elements and processes are low-tech. However, more research, development, monitoring and reporting are urgently needed.

- TEKES – Public Funding Agency for Technology and Innovation, Finland
- ProGresS, Finland

10. BUILDING CERTIFICATION AND RATING SYSTEMS

We are accustomed to asking for more information when we buy a refrigerator or a car, but not when we buy a house or rent space. Building rating systems are voluntary certification systems for new construction and renovation of buildings. There are several such systems, for more information you'll find several useful links within these chapters.

- PromisE, LEED™, BREEAM, CASBEE, Green Globes™ U.S., SBTool…
- SF GreenPRINT, US

NEXT STEPS OF THE SBC TASK FORCE

The best way to learn is from one's peers: government to government, city to city. We can borrow and steal inspiring practices, processes and policies from each other. The best policy practice publication could be the initial phase of an open clearinghouse, one of the many elements of the future 10YFP. After all, from the process point of view, our main goal is to contribute to the structure, the contents and the targets of the 10YFP.

The Task Force will continue to participate in events all over the world – conferences, seminars, meetings, where people from the buildings and construction sector come together – and organize roundtables to discuss most urgent questions and to expand our internal and external networks.

We'll continue research and exchange of information focussing on the sustainability of energy consumption, but we'll try to focus further – e.g. zero-net-energy construction and energy in housing – and maybe add themes – e.g. criteria for sustainable construction, or construction in developing countries and countries in transition.

We'll continue to look for opportunities to advocate for the need for and for the opportunities inherent in more efficient public policies to save energy, to be more energy efficient, and to utilize more renewable energy sources, in order to fight climate change, but at the same time to reach several other sustainability targets, such as liveable communities, social equity, sustainable financing, fair trade and decent work.

THE DESIGN OF THE ZERO ENERGY OFFICE BUILDING FOR PUSAT TENAGA MALAYSIA

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ABSTRACT

The new headquarter for Pusat Tenaga Malaysia (PTM) is designed to be a Zero Energy Office Building, or a ZEO Building. A full range of passive and active energy efficiency measures are implemented such that the building will need no more electricity than what can be produced via the building's own Building Integrated PV system. The 4,000 m^2 PTM ZEO Building is a pilot project and a research laboratory for tomorrows sustainable non-domestic buildings in the tropics.

The ZEO Building shows implementation of integrated design concepts, where active and passive energy systems are interwoven into the building itself, and where several building elements also serve as energy systems. This helps in bringing the extra costs of the building down. Advanced computer design tools have been used throughout the design process.

The building is lit primarily by daylight, supplemented by electric lighting only during very dark and overcast periods. Extensive active energy efficiency measures are implemented in the building in order to reduce the need for electricity to an absolute minimum, without compromising the request for comfortable temperature and humidity and adequate lighting. These measures include among others high efficiency pumps and fans, and use of energy efficient office equipment.

The buildings PV system is connected to the grid. Solar electricity is exported to the grid during daytime, when there is maximum draw of electricity from the grid. During night time at off peak hours, the electricity is bought back and used to run the chiller. Cooling is stored from nighttime to daytime in the concrete floor slabs and in a phase change thermal storage tank.

The Malaysian Energy Centre, Pusat Tenaga Malaysia, moved into the ZEO building in October 2007. An extensive two year monitoring and fine-tuning program is planned for the ZEO building to optimise the energy performance of the building, to establish the overall performance of the building and to establish the detailed performance of the building and its energy systems. The results of the project will be disseminated, including details of those design elements and energy systems that can be put into use to improve energy efficiency in buildings today.

The ZEO building project was supported by UNDP/GEF and by the EC-ASEAN Energy Facility (Brussels / Jakarta). Without their support, this project could not have been realised.

KEYWORDS: Energy Efficiency. Photovoltaic, Zero Energy, Floor Slab Cooling, Radiant Roof

1. Introduction

In the future, energy consumption for buildings will have to be reduced drastically to combat climate change and to reduce the use of fossil fuels. In 10 – 20 years time, new buildings are likely to have a very low or even a zero consumption of fossil fuels.

Figure 1. The PTM ZEO Building

The new Zero Energy Office Building (ZEO Building) is presently being finalised, and the client, Pusat Tenaga Malaysia, PTM (Malaysian Energy Centre) will move into the building in May 2007. In line with the scope for Pusat Tenaga Malaysia being the research arm of the Ministry of Energy, the new building will itself be a research and demonstration building for new energy technologies in buildings in Malaysia. The new PTM building aims to demonstrate that an office building need not consume any electricity produced from fossil fuels. All electricity needed to run the building is produced by the buildings own Photo-Voltaic System (PV System).

2. How The Zero Energy Consumption is Achieved

In the Design Brief of the ZEO building, the overall energy design objective for the building is formulated as "achieving zero energy consumption at least construction costs". Since PV electricity is still quite expensive, this means that investments in energy saving technologies can be stretched much further than under normal economical conditions. Energy saving technologies that are relatively expensive can be applied.

3. The Key Energy Saving Strategies

Reducing the energy consumption to approximately 40 kWh/m^{2}year is achieved by applying a host of energy saving strategies in building design, design of the mechanical and electric system and in choice of energy efficient office equipment. However, the following areas are the main contributors to the low energy consumption :

- An energy efficient building envelope with energy efficient double glazing and well insulated walls and roofs.
- Use of daylight as the only source of lighting during daytime.
- Use of energy efficient office equipment

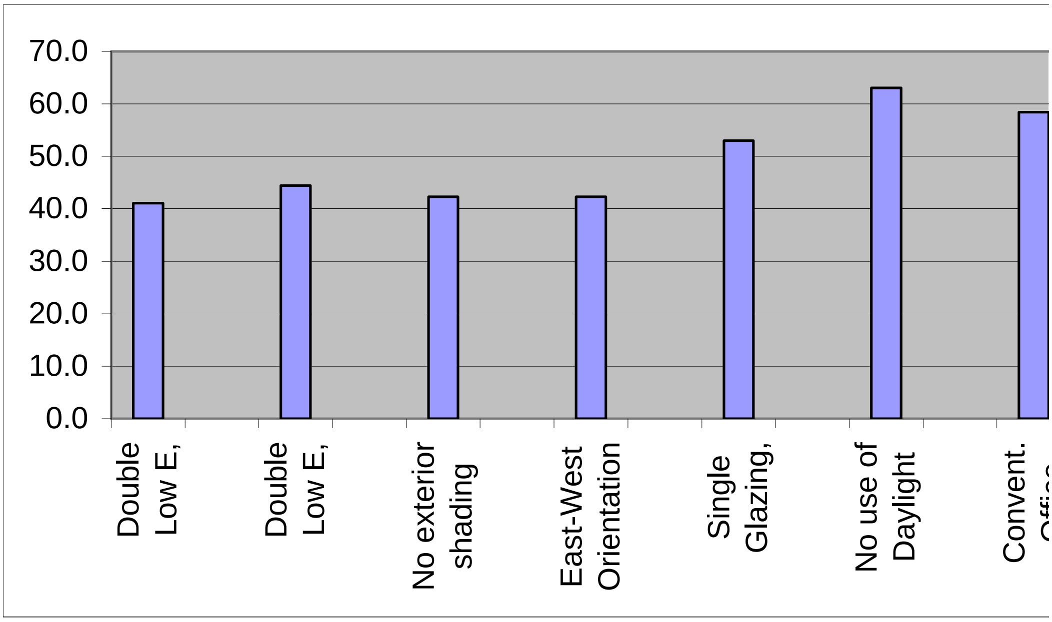


Fig 2. Energy Savings for Various EE Features

The diagram above shows the influence of some of the design parameters of the building. To the left is the Energy Index of the building design as predicted by the computer modelling. Each of the bars shows the influence of changing one parameter from the present building design (the left bar).

The actual design has double glazing with low emissive coating. The daylight transmission coefficient is 50%. If the glazing were traditional double glazing, the energy consumption increases by 8%. If the glazing would only be single glazing, the energy consumption would increase by 22% compared to case 1. It is also seen that if there was no exterior shading in the form of an exterior overhang over the windows, then the energy consumption would increase by 3%, similar to if the building had windows to the east and west instead of to the north and south.

It should be noted, that the influence of orientation and shading would have been much more profound if the base case was not a building with super efficient glazing but a building with single glazing. The high performance glazing reduces the penalty of having a non-ideal orientation or having no exterior shading.

It is noted that if the building did not use 100% daylight during daytime, but had to rely on electric lighting (very energy efficient), then the energy index would increase by 35% !! If traditional office equipment were used instead of energy efficient office equipment, then the energy index would increase by another 30%.

These results of the computer modelling clearly demonstrates the importance of having high performance glazing, using daylight instead of electric lighting and using energy efficient office equipment. Without these key energy saving measures, the necessary PV area would simply be exorbitantly large and very expensive.

4. Building Integrated PV

The PV roof of the building serves multiple purposes. During daytime, the roof becomes the powerplant of the building, and during nighttime, the PV roof becomes the “cooling tower” for the chiller. During nighttime, the roof is be covered by a thin water film, which emits heat from the chiller to the sky by radiation and to the cool night air by evaporation and convection.

Figure 3 : The larger PV roof, 45 kWp polycrystalline, in the foreground : part of thin film 6 kWp

The BIPV system of the new PTM ZEO building is a National Demonstration projects for BIPV under the Malaysian BIPV program. This program is funded by the United Nations Development Program, the Global Environmental Facility, the Government of Malaysia and PV companies in cooperation.

The total installed capacity of four PV systems is 85 kWp, distributed over four areas, one 45 kWp with polycrystalline PV, one 6 kWp with thin film PV, one 25 kWp monocrystalline and 10 kWp semitransparent over the buildings atrium, see picture 4 below.

5. Building 100 % daylit during daytime

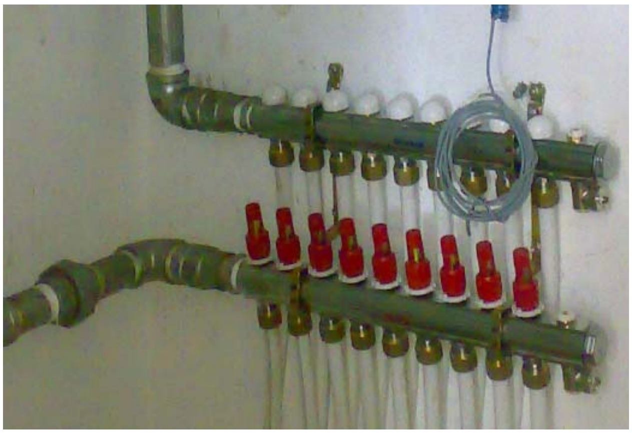
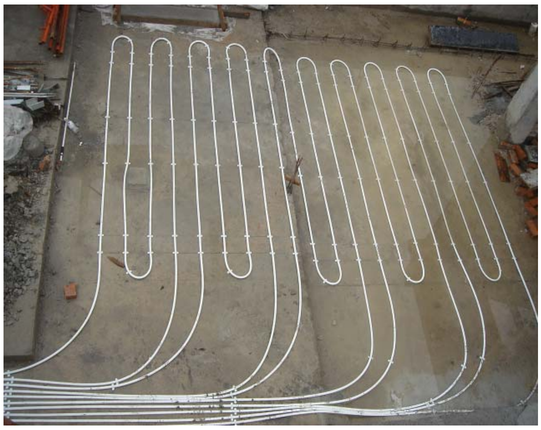
Electricity for lighting in an office building may easily consume 30 – 40 kWh/m^2year. In Malaysia, daylight can potentially cover most of that lighting load, as daylight is abundantly available outside the building throughout normal office hours 08.00 – 18.00. However there are a number of constraints that means that this potential for free daylight is not used in buildings today.
Daylight is easily available near the windows, whereas it is more difficult to provide daylight deep in a building. Furthermore, admission of daylight into a room often causes glare and discomfort due to the high radiation level in Malaysia.

In order to be able to use daylight as the main light source in the PTM building, a new sealed double glazed window with integrated blinds was developed. The blinds protects against direct view of the sky through the upper daylight window. However light is reflected off an exterior light shelf and through the blinds, onto the ceiling and further to the back of the room.


Figure 4 : CK Tang with prototype daylight window, left. Installed window right.

6. Concrete Floor Slabs with Thermal Storage and Radiant Cooling

The chiller of the building runs only during nightime, where the concrete floor slabs with embedded PEX tubes is being cooled down. Cooling is released gradually from the floor slabs to the rooms above and below during daytime.

pouring of concrete.

The concrete floor slabs will provide part of the cooling load to the rooms during daytime. This cooling is supplemented by cooling provided by a conventional air cooling system. This system is however ~ 75% smaller than a conventional system, as this air handling system need only supply fresh and dehumidified air.

The cooling which is provided by the air handling units during daytime is drawn thermal storage tanks with Phase Change Material 10^{o}C as storage medium. So storage of cooling from night to day is provided partially by the floor slabs and partially by thermal storage tank.

7. Trickling Night Cooling Roof

Release of heat from the chillers will normally be via cooling towers. However, for the PTM building, another system has been implemented. The chiller runs only during night time, and the heat is released from the PV roof by trickling water over the slope of the roof. Water is added from manifolds at the ridge of the roof and collected at gutter, from where it returns to the condenser heat exchanger Heat is released from the wet roof through radiation to the night sky, through convection and through evaporation. The water used is rainwater from the rainwater storage tank at the roof of the building.

8. Energy Efficient Office Equipment

By using only the most energy efficient office equipment available, the installed plug load can be reduced to ~ 2.5 W/m^2 against normally 10 – 15 W/m^2. This contributes to reducing the electricity consumption of the building, as shown in figure 2. Hence, the management of PTM decided two years ago that they would from now on only purchase the most energy efficient computers, printers etc. Hence, when PTM migrates to the new building in May 2007,all equipment will be energy efficient.

9. Other Measures to Improve Energy Efficiency.

Beyond the various innovative energy solutions mentioned above, a host of good practice and good housekeeping measures are implemented in the design to reduce energy consumption. However, compared to a traditional well designed building, in this case these good practice measures are being evaluated very carefully, and their performance have typically been chosen to be the best possible on the market. This is because PV electricity is expensive, and therefore more investments in better energy performance of the building can be justified.

These good practice solutions include on the architectural side use of external window shading (the building steps ~ one meter in per floor), and use of well insulated walls and roofs. Within the regime of M&E systems, pumps and fans have very high efficiencies, and pipes and ducts are designed for very low resistances.

The air cooling system is of the Variable Air Volume type, and all pumps and fans will have Variable Speed Drives, measures that already now are now finding its way to more conventional buildings.

The most energy efficient lighting fixtures have been installed, using T5 fluorescent tubes with high frequency ballasts mounted in a very efficient fixtures. This is in order to reduce the electricity bill for lighting even further, beyond what is achieved by the use of daylight as the prime light source. In order to optimise the performance, lighting is controlled according to demand in all zones of the building using a DALI control system. The use of occupancy sensors and daylight sensors assure that lighting is only on when daylight is insufficient and only in those rooms that are occupied.

ACKWNOLOGEMENTS

The PTM ZEO building was developed and designed by a team consisting of RKA Architects, Arup C&S engineers, 5H M&E Engineers and Onions Interior Design, all from Kuala Lumpur. Furthermore, the University of Kaiserslautern and Transsolar Energietechnik from Germany and the International Centre for Indoor Environment and Energy, Technical University of Denmark and IEN Consultants, Virum Denmark, were responsible for developing the integrated energy design of the building. The PV system was designed by the PV team at Pusat Tenaga Malaysia as part of the UNDP/GEF project, see below. The building is built by Putrajaya Perdana Construction.

The ZEO building project was supported by UNDP/GEF and by the EC-ASEAN Energy Facility (Brussels / Jakarta). Without their support, this project could not have been realised.

GROUND COOLING OF VENTILATION AIR FOR ENERGY EFFICIENT HOUSE IN MALAYSIA: A CASE STUDY OF THE COOLTEK HOUSE

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Abstract

The paper presents an analysis of on-site measurements of the ground cooling air duct system of the energy efficient CoolTek house in Melaka, Malaysia. Measurements of temperature, humidity and CO_2 were undertaken indoors, outdoors and inside the ground cooling air duct system during two modes of operation. The first mode of operation was a fully passive mode where the ventilation was driven only by the thermal pull of the solar chimney. The second mode of operation was a hybrid mode where a small fan assisted the solar chimney in ventilating the building. Some improvements of the ground cooled air duct system are suggested on the basis of the analysis.

Keywords: Ground cooling of air, energy efficient tropic housing, CoolTek, solar chimney.

1. Introduction

Year 2004 saw the completion of the energy efficient CoolTek house in Melaka, Malaysia. The 200 m² house is air-conditioned 24-hours, yet, the daily air-conditioning consumption is only 8 kWh – or RM 1.8 in local currency. Insulation, shading, high performance glazing and air-tightness are among the energy efficient features employed in the CoolTek house. The focus of this paper, however, is on the workings of the ground cooled fresh air system for ventilation purposes. Ground cooling of inlet air is known from other climates – in particular in hot and dry climates with high diurnal temperature swings – but is not common in the hot and humid tropical Malaysia. Vernacular Malaysian architecture has high naturally ventilated pitched roof ceilings and big well shaded window openings to harness any breeze while not allowing entry of direct sunlight. In contrast, the CoolTek house has a flat (15° picth) roof with low ceiling and is built very air tight. The only common design element is the wide eves. The design strategy of the CoolTek house is possible due to the emergence of the air-conditioning technology and is intended to minimise its use. The paper investigates whether the ground cooling system of inlet air helps to increase the energy efficiency of the house.

2. Ground Cooled Ventilation System

The CoolTek house does not have any openable windows in the air-conditioned zone and all doors to the outside have double-seals to ensure air tightness of the building envelope. The darkest outdoor surface of the white coloured house is the red brick chimney, which deliberately has not been painted white in order to function as a solar chimney. The warm sun exposed surfaces of solar chimneys cause the air to rise due to the effect of thermal buoyancy, i.e. hot air rises. The air sucked out of the house by the solar chimney is to be replaced by air from the ground cooled ducts with floor level inlet openings in the living room, the corridor and the bedroom. The ground cooled air ducts are all connected to a sub-soil chamber with concrete rods penetrating into the ground. This chamber is again connected with an approximately 10 meter sub-soil duct with an opening below a shaded tree (Fig. 1). It is often fair to assume that the ground temperature equals the annual average ambient temperature, which in case of outdoor temperatures measured at the CoolTek house would be about 26.4°C.

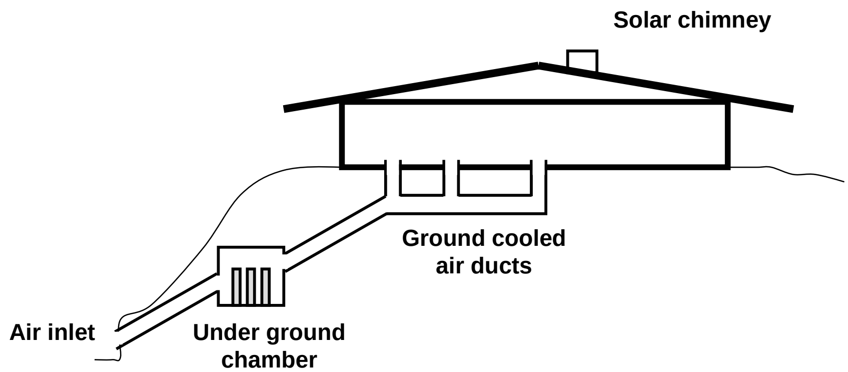

Fig.1 The ground cooled fresh air system of the CoolTek house

It is worth mentioning that the solar chimney is connected to the non-air-conditioned garage via the roof space. The garage, which is fitted with an automatic roller door with rubber seals, is not as air-tight at the remained of the house and will therefore reduce the solar chimney pull on the air-conditioned spaces. The original design of the ventilation system relied solely on passive measure, i.e. the thermal suction of the solar chimney.

Apart from conditioning the air, the ground cooled air ducts were also intended to give a sound proof entry of fresh air to the house. Moreover, the under ground ducting system would also increase the air quality of the inlet air because dust and other particles would be able to settle out of the air before entering the house. Only the energy aspects of the ground cooled fresh air system will be investigated here.

3. Measurements

The performance of the ground cooled ventilation system was monitored with the use of several dataloggers measuring temperature, humidity and CO_2 levels. Only one CO_2 sensor was available, so it was shifted between the measurement locations. The instrumentation used was HOBO dataloggers that were set to log at 15-30 minute intervals; see Table 1 below.

Table 1. Measuring equipment

Instrument	Measurements	Accuracy	Logging interval
HOBO H08-004-02	a) Temperature b) Relative humidity	± 0.5°C ± 2.5%	15-30 min
HOBO U12-012	a) Temperature b) Relative humidity	± 0.35°C ± 2.5%	15-30 min
Telaire 7001	a) CO_2	± 50 ppm	15-30 min

The measuring equipment was placed at three locations to monitor the temperature, humidity and CO_2 levels inside the house, outside the house and inside the ground cooled air ducts connecting the two. Since the CoolTek house is air-conditioned 24-hours the absolute humidity level of the air will be lower indoors than outdoors at all times. Similarly, the CO_2 level will be higher indoors than outdoors because of human occupation of the house. Continuous measurements of these values inside the cooled air duct would therefore give a good indication of the flow direction in the ground cooled air duct across the day. Some of the measurements were repeated one year later after the installation of a 35W auxiliary fan to the solar chimney had been installed at the exhaust from the living room to the solar chimney. The schedule of measurements is shown in Table 2 below.

Table 2. Schedule of measurements

Location	Measurements	Period	Logging interval	Fan operating	House electric consumption	Average outdoor temp.
A: Outdoors	a) Temperature b) Humidity	3 July – 12 August 2006	30 min	No	19.9 kWh / day	26.4°C
B: Inside the house (bedroom)	a) Temperature b) Humidity c) CO_2	3 – 15 July 2006	30 min	No	20.4 kWh / day	26.6°C
C: Inside the house (computer room)	a) Temperature b) Humidity c) CO_2	17 – 29 July 2006	30 min	No	20.1 kWh / day	26.5°C
D: Inside the ground cooled air duct (0.5 m below the floor)	a) Temperature b) Humidity c) CO_2	31 July – 12 August 2006	30 min	No	19.1 kWh / day	26.0°C
E: Inside the ground cooled air duct (0.5 m below the floor)	a) Temperature b) Humidity c) CO_2	19 May – 2 June 2007	15 min	No	-	-
F: Inside the ground cooled air duct (0.5 m below the floor)	a) Temperature b) Humidity c) CO_2	3 – 6 June 2007	15 min	Yes	-	-

Table 2 shows that during the first batch of measurements in year 2006 the electricity consumption was virtually the same during each of the three 2-week periods (B – D) that the measuring equipment was shifted between the three locations. This indicates that the usage of the house was similar during these three periods, which the couple living in the house also could attest to. It can be observed that the slight variation in air-con consumption seems to match the slight variation in average outdoor temperature (Fig. 2).

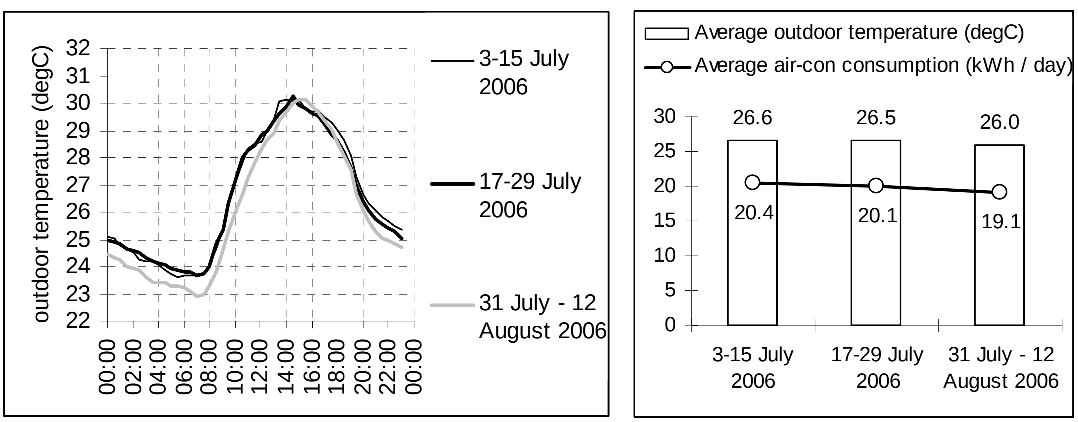

Fig. 2 Mimimal variation in average temperature and air-con usage over three measuring periods

Fig. 2 shows that the variation in climate and house usage is minimal of the measurement periods B-D (Table 2), so it is fair to assume that the measured data for each of the periods can be compared to one another, as will be done in the following section.

4. Results of passively ventilated ground cooled air ducts

The measured variation in temperature, humidity and CO_2 level will now be analysed to evaluate the performance of the ground cooled air duct system when it is passively ventilated by the solar chimney.

4.1 Temperature measurements

The typical temperature profiles were measured to investigate at what hour of the day it will be advantageous to draw air through the ground cooled air duct in order to pre-cool inlet air to the CoolTek house. The average temperature curves are found in Fig. 3 below.

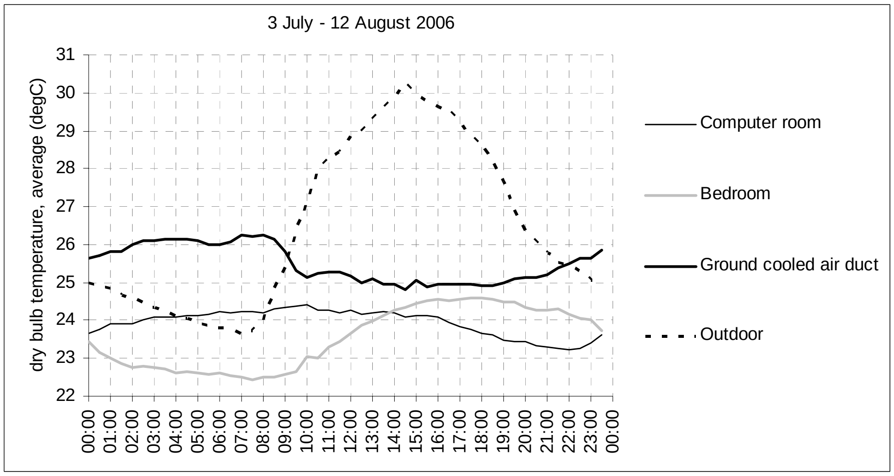

Fig. 3 Average daily temperature measurements (period A – D)

Fig. 3 shows that the indoor temperature, which is air-conditioned 24 hours with a set point of 24°C, is cooler than the outdoor temperature most of the time. The average outdoor temperature shoots up to about 30°C in the afternoon during which time it would be advantageous to draw air through the ground cooled air duct, which theoretically should have an air temperature of 26.4°C (i.e. the average ambient temperature). The average temperature measured in the ground cooled air duct is seen to vary between 25°C (day time) and 26°C (night time). If there was a steady flow of air through the ground cooled air duct to the indoor environment, one would expect the temperatures to be stable or to reflect the outdoor temperature variation, i.e. higher day time values than night time values. However, the opposite seems to be the case indicating either a smaller air flow or a reversed air flow in the ground cooled air duct during the day time.

4.2 CO_2 measurements

In order to determine the flow direction of air in the ground cooled air duct system it is useful to analyse the measured CO2 levels, as they will differ from outdoor to indoors. The outdoor CO2 level is expected to be more or less constant around 350 ppm whereas the indoor CO2 level is expected to be higher indoor the house due to human respiration.

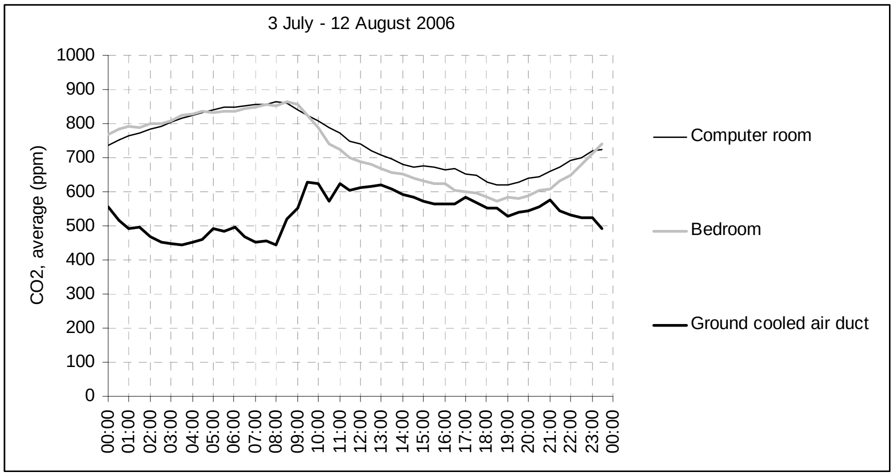

Fig.4 Average CO_2 measurements (B – D) in CoolTek house before installation of fan

Fig. 4 shows as expected that the ground cooled air duct has the lowest CO_2 level, as this is where the supply of fresh air to the house is supposed to occur. The difference in CO_2 levels is particularly high at night, where indoor CO_2 levels are about twice that measure in the ground cooled air duct. In the day time, however, the difference in CO_2 levels is smaller between the three measuring points. Interestingly, the CO_2 level of the ground cooled air duct is seen to increase about 100 ppm from night time levels indicating that the air flow in the pipe has decreased or perhaps reversed during the day time. The CO_2 readings also show that the CoolTek house is adequately ventilated for occupation by two persons as the CO_2 levels stay below the recommended 1000 ppm.

4.3 Absolute humidity measurements

The outdoor absolute humidity levels are more or less constant at 22 g/m³ air, whereas the 24 hour air-conditioned indoor environment of the CoolTek house has a humidity level of about half of that, namely 11.8 g/m³ air. In Fig. 5 below the average absolute humidity measurements are shown.

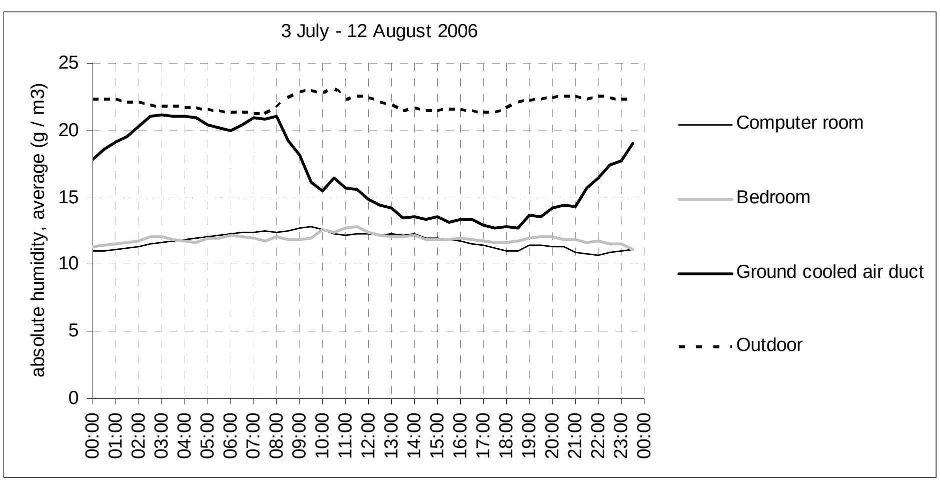

Fig. 5 Average absolute humidity measurements (A – D) in CoolTek house

Fig. 4 shows that the absolute humidity level measured in the ground cooled air duct nearly matches the outdoor level at night time and nearly matches the indoor level in the day time. This indicates that the origin of the air in the ground cooled air duct comes from outdoors in the night time and from indoors in the day time.

The above measurements of temperature, humidity and CO_2 levels all point to the same conclusion, namely that air flows through the ground cooled air duct pipe and into the house during night time and out of the house during the night time. From a thermal buoyancy point of view this is understandable, because the 'thermal pull' delivered by the solar chimney simply is not strong enough to counteract the reverse buoyancy effect delivered by the air-conditioned and 'heavy' air (24°C) that drops out of the floor ventilation pipes and is being replaced by warm and 'light' outdoor air (30°C). Only at night when the temperature difference between indoor and outdoor air is 2°C or less does is the air-flow reverse and fresh air enters through the ground cooled air duct and into the house (Fig. 6).

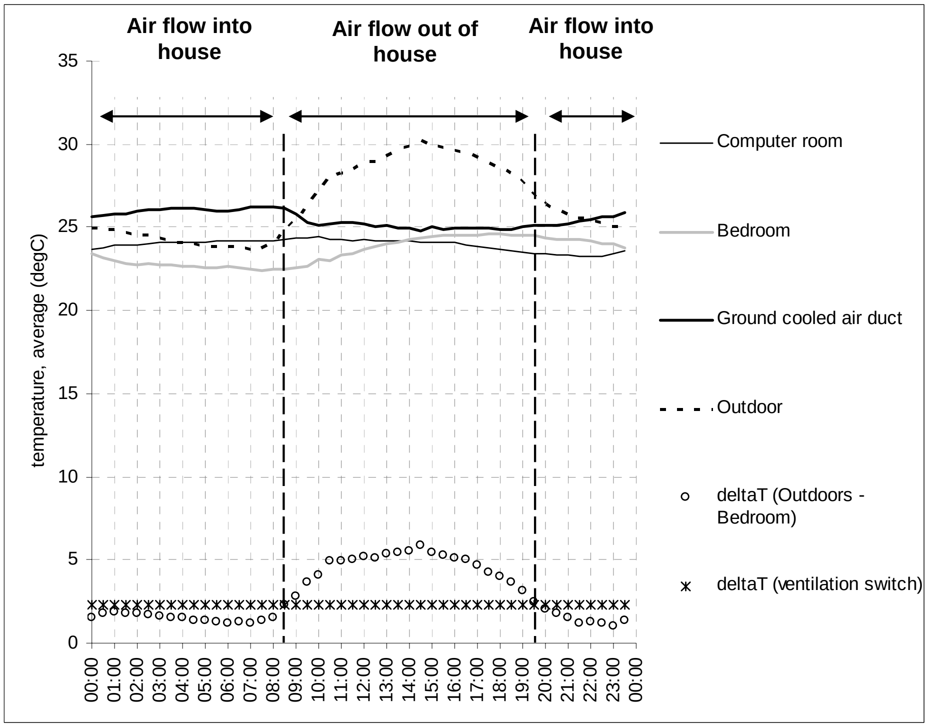

Fig. 6 Switching air flow directions in ground cooled air ducts of CoolTek house

Fig. 6 shows the switching of the air flow in the ground cooled air ducts at about 8:30 and about 19:30 o'clock. The reversal of flow is found to take place when the temperature difference between indoors (bedroom temperature) and outdoors equals 2°C. During the night (19:30 – 8:30) this temperature difference is less than 2°C and air flows from outdoors and into the house. During the day (8:30 – 19:30) the temperature difference is higher than 2°C and air flows from inside to outside. From an energy point of view the ground cooling system does not add to the energy efficiency of the house. On the contrary, when fresh air enters the house through the ground cooled ducts at night the air is 1-2°C warmer than if the air had come directly though the windows (Fig. 6). In the day time, cool air-conditioned air drops through the ground cooled ducts and is replace by outdoor air that penetrates the building envelope – some of which might come from the warm solar chimney. A mechanical fan was mounted as a result of the above findings to assist the solar chimney in driving inlet air through the ground cooled ventilation ducts.

5. Results of mechanically ventilated ground cooled air ducts

A small 35 Watt fan was mounted in the opening between the living room and the solar chimney. This auxiliary fan would assist the solar chimney, so that fresh air could be pulled through the ground cooled ducts in the day time. At the time of writing this paper only a few measured data with the fan in operation were available, as the fan was initially installed without any controls. After continuous operation of the fan for less than three days the occupants switch it off. They found that the fan over-ventilated the indoor space and introduced too much moist outdoor air. Thus, only one full day of continuous fan operation measurements (4 June) has been recorded; (Fig. 7)

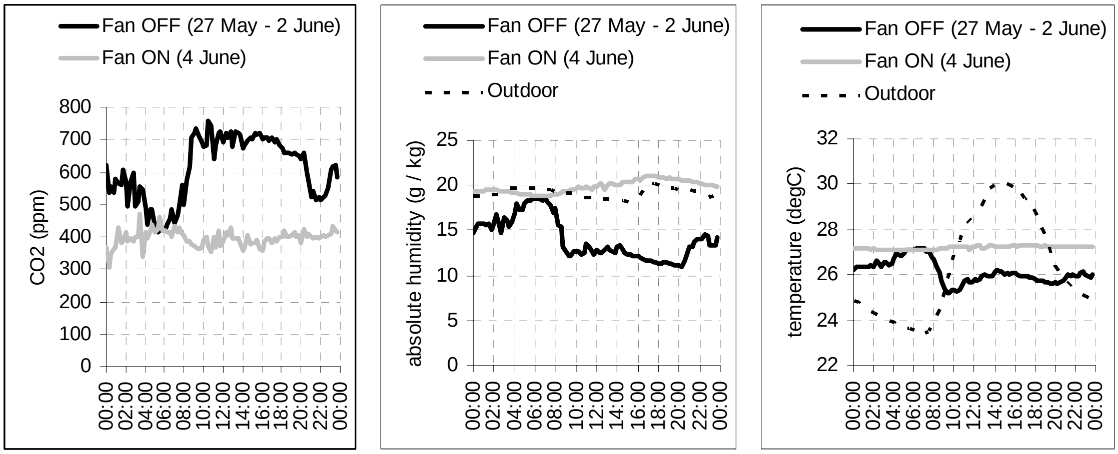

Fig.7 Temperature, humidity and CO_2 in ground cooled air duct with and without fan operation

Fig. 7 shows that the with the installed 35 Watt fan is strong enough to suck fresh air through the ground cooled duct during the day. A clear change in the measured parameters is observed. The CO_2 level is seen to be constantly low at around 400 ppm. The absolute humidity coming out of the ground cooled air duct is stable and is seen to attain slightly higher values than the outdoor levels during the day presumably because the warm outdoor air gets moisturised on its way through the moist ground chamber. The temperature is also seen to be stable around 27.2°C, which shows that the ground cooled air duct effectively can cool the up to 30°C outdoor air.

6. Conclusion

The ground cooled air duct system of the CoolTek house in Melaka, Malaysia, was analysed using continuous datalogging of temperature, humidity and CO2 levels inside the house, outside the house and inside the ground cooled air ducts. Measurements were carried out during two modes of operation, namely when the house was passively ventilated by the solar chimney and when the house was actively ventilated by a small auxiliary fans mounted in the solar chimney.

When the CoolTek house only is ventilated by the solar chimney, the air flow in the ground cooled ducts was found to flow in opposite directions during the day and during the night. In the day time (8:30 – 19:30), outdoor air was not being cooled by the ground cooled duct, as air was flow from indoors to outdoors. Only at night did the flow reverse, when the outdoor temperature was less than 2°C warmer than the indoor temperature (24°C). At this time, however, it would mostly be cooler to get the fresh air directly through the window, as the ground cooled ducts heated the air 1-2°C before it entered the house.
When the CoolTek house is ventilated with an auxiliary fan in the solar chimney an air flow into the house through the ground cooled pipe can be ensured at all times. The ground cooled pipe was seen to deliver a constant 27.2°C air throughout the day even during the warmest time in the afternoon.

Based on the above findings it is recommended to operate the fan when the outdoor temperature exceeds 28°C. The fan should not over-ventilate the indoor space and could be controlled by a CO_2 sensor set to 1000 ppm. The adverse reverse air flow through ground cooling duct during the day time could be stopped by a damper. Alternatively, the outdoor air intake of the ground cooling system could be placed higher than the ceiling of the CoolTek house – an not at the bottom of a hill as is presently the case - to prevent that cool air-conditioned air ‘drops’ out of the house. It is generally concluded that the potential for ground cooled ventilation is relatively small in tropical Malaysia. The difference between the ground temperature and the outdoor peak temperature is not very great. In the case of the CoolTek ground cooling system the air was cooled to 27.2°C, which is not very much considering that peak day time temperatures typically only are 32°C. The bulk of the cooling lies in the latent load, i.e. dehumidification of air.

MICRO-CLIMATE STUDIES FOR HIGH DENSITY AND HIGH RISE SUSTAINABLE PUBLIC HOUSING DEVELOPMENTS IN HONG KONG

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Abstract

Planning and design play an important role in creating a healthy living environment. Hong Kong Housing Authority (HKHA) initiated in 2001 the application of Micro-climate Studies in the planning and design of high density and high rise housing development using latest proven technologies, including computational fluid dynamics simulations, wind tunnel tests and daylight simulation tools, etc. These studies enable holistic consideration to optimize the development potential and enhance the built environment of the neighbourhood. They cover core topics of wind environment, natural ventilation, daylight and solar heat gain, as well as other special topics such as urban heat island effect, pollutant dispersion, etc.

In this Paper, the author introduces the following key initiatives in micro-climate research studies for planning and design, (i) introduction of air ventilation assessment concept to enhance the wind environmental performance in estate planning, (ii) Application of computer fluid dynamics (CFD) technology in passive design approach to enhance natural ventilation and pollutant dispersion of the domestic dwellings and public areas, (iii) Application of computer simulation technology in sun-shading and daylight studies to enhance the master layout and open space planning and (iv) Introduction of environmental façade design concept to mitigate solar heat gain and enhance human comfort for residents.

Micro-climate studies facilitate holistic environmental planning and design of sustainable housing developments. Over 25 public housing projects in Hong Kong have adopted the studies, which provide greater human comfort for residents by enhancing environmental performance of the housing estates with cleaner and greener environment for healthy communities.

Keywords: Healthy Living, Sustainable Community

1. Introduction

In the high-rise, high-density environment of Hong Kong, environmental performance of buildings has a significant impact on the public. High density living has the advantage of efficient land use, public transport and infrastructure, as well as the benefits of closer proximity to daily amenities. We have more than 7 million people living in 1,100 sq. km of which, only about 200 sq. km is developed and another 400 sq. km is devoted to country parks. There is a global trend in the shift from rural to urban populations and the corresponding increase in population densities and urban consumption patterns is reflected in every urban city.

About one-third of Hong Kong's population is residing in public housing. Among the stock of over 2,300,000 permanent residential flats, over 674,000 flats are public rental housing stock under the management of HKHA. It is always HKHA's prime objective to provide healthy living environment in sustainable housing developments. Environmental aspects of sustainable housing design comprises low energy consumption and high performance concept. In 2001, HKHA initiated the application of Micro-climate Studies, based on holistic approach, in the planning and design process of public housing developments to optimize the development potential and enhance the built environment of the neighbourhood. In the ensuing sections of the paper, we present some key features of the micro-climate studies in our planning and design process for enhancing wind profile, natural ventilation, daylight and solar heat gain of the living environment.

2. Wind Environment

We use the micro-climate studies as urban planning tool to optimize estate planning, disposition/orientation of blocks and building permeability to enhance wind environment for the housing development and as-built neighbourhood.

2.1 Site Wind Availability Data

It is necessary to account for the characteristics of the natural wind availability of each housing development site. We make use of wind data from weather stations of local Observatory to qualitatively estimate the prevailing wind directions and magnitudes of the site for evaluation. For sites with weather stations nearby, wind rose with reduced set of prevailing directions covering most of the time in a typical reference year is vital for micro-climate studies whereas for those with specific site topography and being remote from weather stations, wind tunnel simulation test becomes more appropriate.

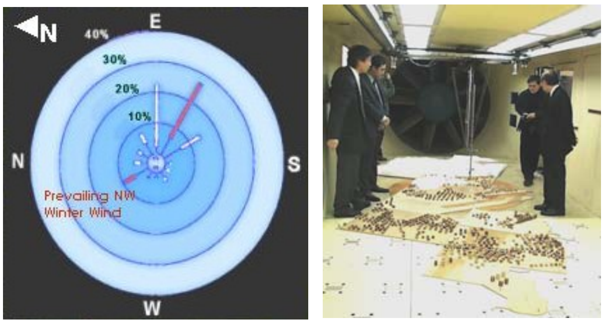

Figure 1 Wind rose Diagram + Wind Tunnel Test

2.2 Air Ventilation Assessment (AVA)

Air ventilation assessment is an indicator to relate the wind availability of a city and the urban geometry, and to assess the built form's capability to optimize the available wind. This indicator addresses what minimum wind environment, and in what form, is needed to guide design and planning so as to achieve a better wind penetration into, and hence, air ventilation of the city, especially at the pedestrian level. It is represented by Wind Velocity Ratio -

$$VR_w = \frac{V_p}{V_\infty}$$

V_∞ *is the wind velocity at the top of the wind boundary layer not affected by the ground roughness, buildings and local site features*

V_p *is the wind velocity at pedestrian level after taking into account the effect of the housing development*

VR_w *indicates how much of the wind availability of a location could be experienced and enjoyed by pedestrians on ground taking into account of the as-built surroundings*

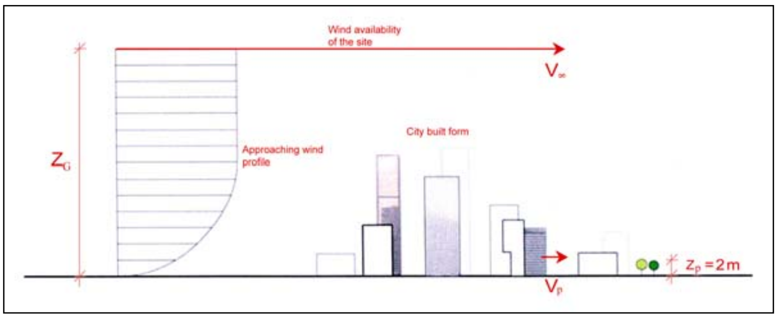

Figure 2 AVA diagram

With test points allocated at strategic site locations, wind velocity ratios at these points are identified to indicate the effects of different planning options of a housing development for comparison purpose. It is through comparison of different planning options in holistic approach that the optimal solution is derived.

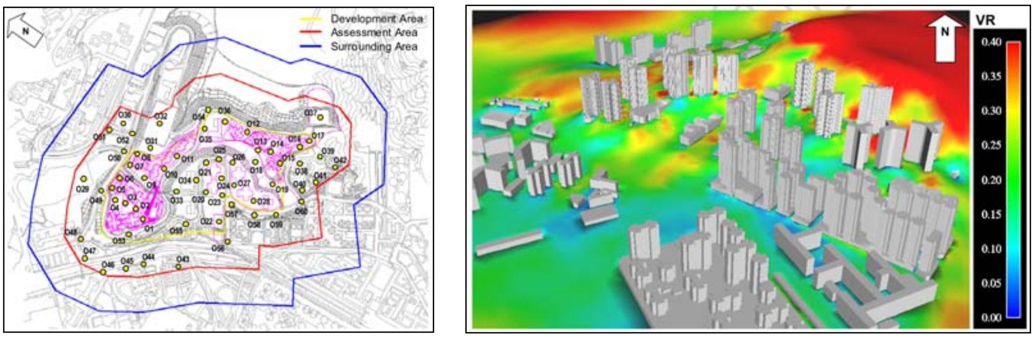

Figure 3 AVA Study for Choi Wan Road Housing Development

2.3 In Tune with the Wind Environmental Initiatives

In achieving the objectives to optimize estate planning, disposition/orientation of blocks and building permeability, we apply computer fluid dynamics (CFD) analysis to study the wind flow pattern and magnitude at low, mid, high zones of the high rise domestic towers for different enhancement measures in site planning and building design options, external circulation and open spaces, and impact on as-built surroundings. By comparing the micro-climate study results of various green initiatives, the most optimal planning and design option is worked out on both qualitative and quantitative basis in a scientific approach -

a) Effectiveness of "Wind Corridor" design, in quantitative terms, for enhancing site permeability for prevailing wind is identified by comparing simulation results of 'Before' and 'After' implementation of the development.

The increase in air velocity with wind corridor under the prevailing East wind condition ranges from 18 to 250%.

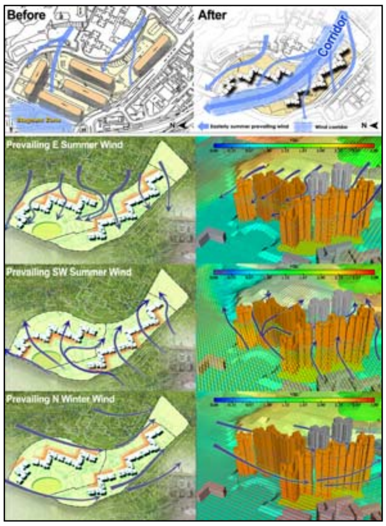

Figure 4 Upper Ngau Tau Kok Phase 2 & 3 Redevelopment project (Before & After of the Redevelopment)

b) For constraint of narrow linear site configuration, design options for disposition and orientation (deviation up to 10 degrees) of domestic towers are compared to streamline the wind flow across the development and the as-built neighbourhood. The wind speed at open space between domestic towers increases substantially by 100 to 133% by adopting Option 2.

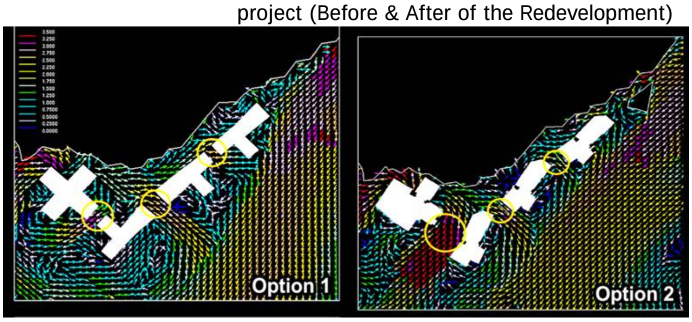

Figure 5 Choi Wan Road Site 3A project
(Comparison of different block types and orientations)

c) CFD analysis is an effective tool for adjustment of variables in building separation and heights on site platforms at different levels to divert winds to lower levels. The wind speed increases substantially by 122 to 500% by adopting the 4-block option.

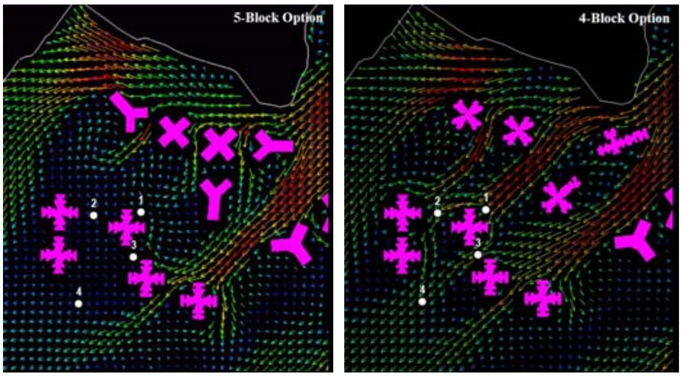

Figure 6 Choi Wan Road Site 3B project
(5 blocks vs 4 blocks option)

d) Site specific design options "with" and "without" podium are compared for identification of the significant variance in building permeability for air ventilation at pedestrian level. The average wind speed and velocity ratio at street level (leeward side) increases by 13% and 14% respectively without podium.

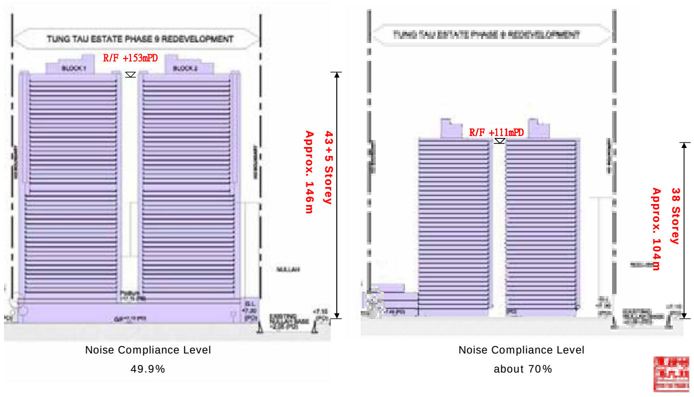

Figure 7 Tung Tau Estate Phase 9 Redevelopment project
(with & without podium design)

e) Urban greening filtrates the air flow and provides shade and cooling. A green deck garden is designed at 1/F level of the high rise domestic tower to enhance the building permeability and extend the external garden into the habitable spaces.

Figure 8 Urban greening design approach in Lam Tin Phase 7 Redevelopment project

3. Natural Ventilation and Pollutant Dispersion

We use the micro-climate studies as building design tool to optimize configuration of blocks, detailed architectural layout and window openings to enhance natural cross ventilation in habitable accommodations, public and circulation areas.

3.1 In Tune with the Ventilation Initiatives

Functional and Cost-effective Design approach is developed to optimize the life cycle costing of public housing in Hong Kong, while meeting the crucial needs – comfort, safety, health and a quality living environment. By simulating the wind flow pattern and magnitude of typical domestic units, lobby and public areas at low, mid and high zones of the high-rise domestic blocks, and ground floor entrance lobby etc., ventilation coefficients are determined to identify the ventilation performance of each design option at scheme design stage and fine tune the detailed design, in quantitative terms, to enhance natural ventilation with effective pollutant dispersion from toilet accommodations and refuse storerooms etc. -

a) Effectiveness of "Cross Ventilation Corridor" design for enhancing building permeability is reflected by quantitative results of 'With' and 'Without' of the ventilation initiative. The increase in air velocity with cross ventilated corridor at selected points around the development, under the prevailing East wind condition ranges from 18 to 250%.

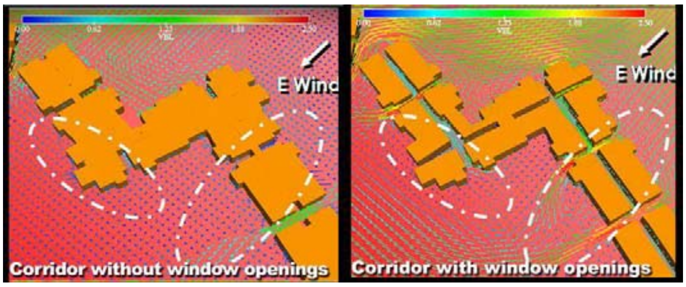

Figure 9 Upper Ngau Tau Kok Phase 2 & 3 Redevelopment project (With & without cross ventilation corridor of the domestic tower)

b) Effectiveness of "Wing Wall as Wind Deflector" for enhancing natural ventilation of domestic blocks at sites with low ventilation rate is reflected by quantitative results of 'With' and 'Without' of the ventilation initiative. Wing wall increases the air velocity inside corridor under the prevailing wind condition by 2.5%.

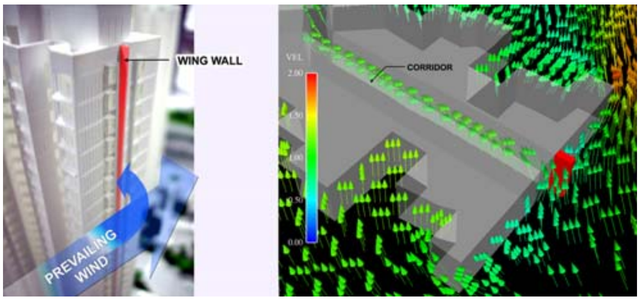

Figure 10 Choi Wan Road Site 1 project (With wing wall of the domestic tower)

c) Effectiveness of "Guiding Panel" for enhancing natural ventilation of re-entrant areas at sites with low ventilation rate is reflected by quantitative results of the ventilation initiative.

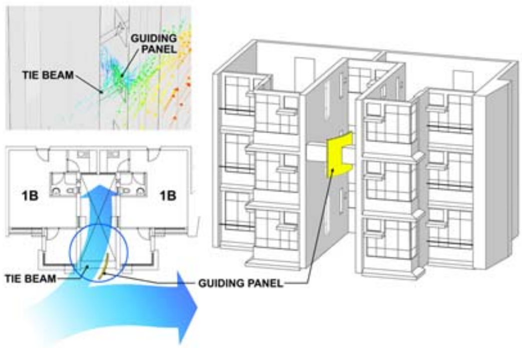

Figure 11 East Harbour Crossing Phase 5 project (With guiding panel of the domestic tower)

d) Effectiveness of "Flat Modular Design" for enhancing natural cross ventilation of domestic flats is reflected by quantitative results of the ventilation initiative. The improvement in air ventilation over conventional standard block design ranges from 163 to 177%.

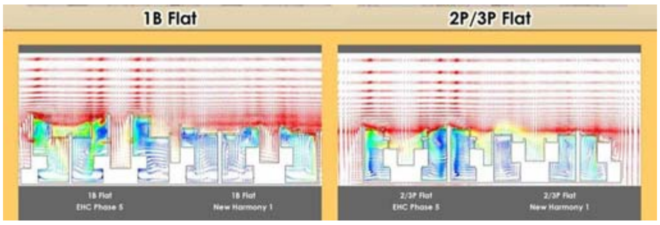

Figure 12 East Harbour Crossing Phase 5 project (With flat modular design of the domestic tower)

4. Daylight and Sun-shading

We use the micro-climate studies as building design tool to optimize daylight penetration in domestic units and public areas of domestic blocks for energy efficiency, comfort and health, and optimize the passive and active open space layout planning within the development.

4.1 In Tune with Natural Lighting Initiatives

Daylight has psychological effects and increases the comfort level of individual space. The amount of daylight on the surface of a building façade is related to the extent of its exposure to the natural environment. In high density and high rise developments, much of the daylight penetrating through window openings at lower floors of the dense, high rise developments come from the reflected light of the surrounding surfaces. We adopt the performance-based approach using "Vertical Daylight Factor (VDF)" (a ratio in percentage of the total amount of illuminance falling onto a vertical surface of a building to the instantaneous horizontal illuminance from an overcast sky) as a design tool for optimizing the natural lighting performance -

a) Effectiveness of "Flat Modular Design" for enhancing daylight penetration into domestic flats is reflected by performance based assessment.

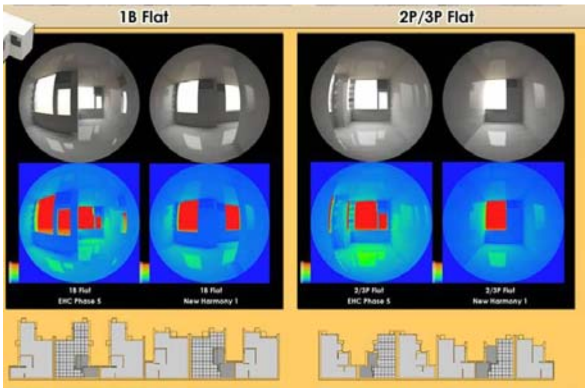

Figure 13 East Harbour Crossing Phase 5 project
(With flat modular design of the domestic tower)

b) Effectiveness of "Cross Ventilation Window Openings" for enhancing daylight penetration into the public areas of high rise domestic towers is reflected by performance based assessment. The windows at cross ventilated corridors bring about 13% saving in lighting cost.

Figure 14 Cross Ventilation Corridor Design

4.2 In Tune with Sun-shading Initiatives

High density and high rise living renders it significant for environmental planning of the open spaces. Simulation of annual 3-D sun path diagram dedicated to Hong Kong context identifies the sunlight and shade pattern at external areas of the proposed housing development at different time of the day and different seasons of the year, taking into account of the site surroundings. It is an integrated design approach for optimizing the sunlight exposure to green areas, morning exercise and outdoor laundry space, sun-shading for leisure sitting, children play and ball courts, particularly for west facing open spaces -

a) Comprehensive performance -based open space planning for a sustainable high density community : Activity areas that desire shading (e.g. children play area and foot massage trial) are planned at adequately shaded area. Area exposed to sun heat most time of the day would be shaded by trees or shelters.

Figure 15 Choi Wan Road Development Site 2, 3A and 3B projects (Sun shading simulation)

b) Detailed study of local landscaping layout by performance based assessment.

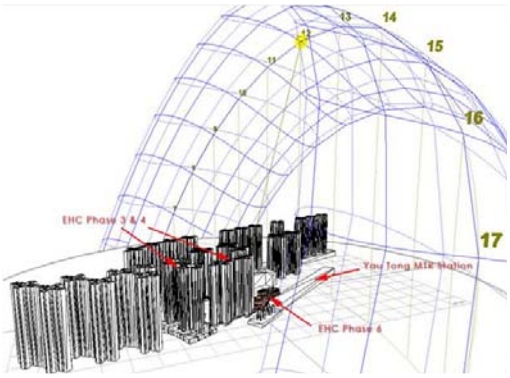

Figure 16 East Harbour Crossing Phase 5 project (Using Stereographic sun path diagrams tp plan for external layout)

5. Solar Heat Gain

Hong Kong lies in the tropical climate zone. We use the micro-climate studies as building design tool to minimize solar heat gain in domestic units in order to have higher energy efficiency and better human comfort.

5.1 OTTV as an Indicator

The façade of a building is a complex system, comprising a range of components which coordinate to create a healthy living environment. Amount of energy saving resulting from a cost-effective and high performance façade design to maintain a thermally acceptable environment could be quantified through Overall Thermal Transfer Value (OTTV) which relates to fabric thermal mass, glazing, passive solar design, window design and shading devices. We have made use of the OTTV, as an effective indicator, for external wall colour scheme design.

Figure 17 OTTV distribution diagram for Lam Tin Estate Phase 7 & 8 along the façade is used for external wall colour scheme design reference

5.2 Environmental Façade Design Initiatives

With the availability of latest proven simulation technology, we apply advanced computer programme which consists of modules of ventilation, thermal comfort and building energy analysis for computing the temperature profile for the internal environment of habitable rooms. Since the façade features that affect cooling load and achievable ventilation rates and daylight illuminance include (but not limited to) wall/roof construction, window/wall area ratio, glazing type, building orientation, configuration and separation, floor level, external wall finishes and colour, shading device etc., it demands an optimization study (e.g. Ant Colony Optimization (ACO) method etc.) taking optimization of the life cycle cost of the high density and high rise public housing blocks. We apply the study to design solar shading devices for reducing solar heat gain both on the building façade and in individual dwelling, to reduce the energy consumption on air conditioning and/or other mechanical ventilation means. In order to optimize the life cycle cost, the shading fins are integrated in the precast façade panels, taking into consideration of the transportation economy and loading for on-site installation.

6. Miscellaneous

6.1 Holistic Environmental Planning and Design Approach

In terms of environmental planning and design, we adopt a holistic approach with balanced considerations on wind environment, natural ventilation and pollutant dispersion, daylight and solar heat gain etc. We apply a scoring system in working out the most optimal solution for the development. On-going researches are being conducted for establishment of local benchmarks. With a common goal and concerted effort by users, academia and researchers, regulators and practitioners, more healthy living environment will be created for now and the future.

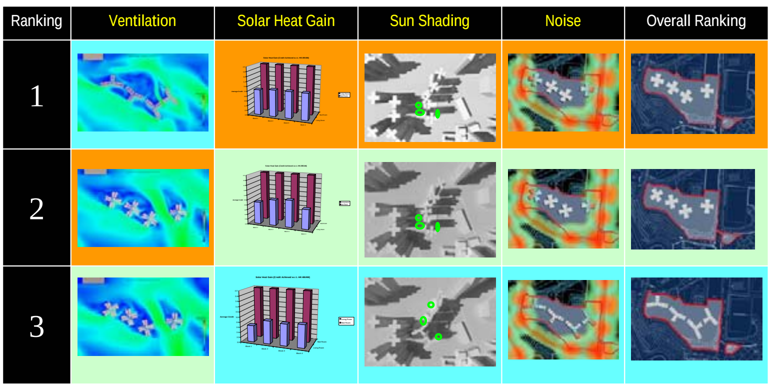

Figure 18 Comparison table of simulation results of different environmental aspects

6.2 Calibration of Simulation Tools

Apart from conducting validation on the simulation tools, we fine-tune the software by model calibration. Two completed high rise public housing developments with different micro-climatic conditions are selected for the model calibration, which is composed of two parts, namely on-site measurement for actual field condition and model simulation for predicted field condition. The calibration exercise demonstrates the high accuracy of the simulation results with the software calibrated to local specific climatic conditions. The discrepancy is generally within 10%.

7. Conclusion

Public housing in Hong Kong has made an enormous contribution towards the well-being of the community. "Healthy Living" with its wide spectrum of coverage, is not only academia's or researchers' input but its collaboration with all stakeholders and residents towards cultivating sustainable awareness and implementation. With the availability of the advanced simulation technology, micro-climate studies offer a scientific platform for practitioners' making the right choice for sustainability. This is a big challenge as well as an excellent opportunity to bridge the gap between policies and practice for the good of the coming generations. We need to continue to engage with all stakeholders to gain their support as we articulate our strategies and lay out a road map in driving sustainability initiatives.

Acknowledgements

CH2M.IDC
Ove Arup & Partners (HK) Ltd.
The Center of Housing Innovations, The Chinese University of Hong Kong

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SINGAPORE HIGH-RISE A SUSTAINABLE HOUSING MODEL

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ABSTRACT

This paper seeks to interrogate the Singapore high-rise, high-density public housing as a model of sustainable development. There is much debate in contemporary planning and urban studies about the concept of high-rise as a sustainable urban form. While cities debate, other cities like Hong Kong, Singapore and Vancouver have made their decisions and adopted high-rise living as the norm. In tropical Singapore, for example, 84% of its 3.4m resident population has moved to live in high-rise public housing over the past four decades. The gross plot ratio of these developments has risen from 1.3 in the 1950s to 4.0-8.4 in the 2000s. The current tallest lived-in public housing building is 40-storey while 50-70-storey residential high-rise are under construction. According to a recent survey, one in three public housing residents have expressed willingness to live on 40-storey or higher. Using empirical data on resident and professional expert opinion, the paper will discuss the lived experience, dwelling on residents' concerns and satisfaction with high-rise and the landscape features that make Singapore high-rise public housing a continually satisfying experience and potential sustainable development model. If more tall buildings are to be built in the future, the Singapore analysis offers insight to a high-rise approach that has gained growing popular acceptance.

Keywords: High-rise, Sustainable development, Singapore

1. Introduction

Cities around the world including those long resistant to high-rise are building new high-rises. According to *Emporis*, there are 128,982 high-rise buildings of 12 floors and higher in 2006 (see http://www.emporis.com/en/bu/sk/ accessed on 11 Sep 2006 12:01pm). They are found in every continent, from Europe, North America and South America to Australia, Africa and Asia. The world's tallest and most active high-rise building construction countries are increasingly in the developing countries of Asia and the Middle East. Many of the buildings are constructed in recent decades post-Sep 11 2001, including for residential living. Vancouver, Hong Kong and Singapore are prime examples in the latter category. These cities have made their decisions and adopted high-rise living as the norm. Their high-rise housing is expanding the verticality. In the case of Hong Kong and Singapore, they are building 70-storey, ranking them among the world's tallest housing. Commonly referred to as supertall buildings, the Council on Tall Buildings and Urban Habitat is predicting "its impending commercial appearance, not too far in the future." (Ali and Armstrong 1995, p15) As the world's urban growth continues, many architects and urban observers are anticipating that high-rise housing will continue to rise in height, fill dense city centre and challenge urban policy (Lacayo, 2004/05; Ali and Armstrong, 1995). As Ali and Armstrong (1995, p3) write,

> Ada Louise Huxtable (1984) points out that the tall building is "the landmark of our age." The tall building represents this century's most stunning architectural phenomenon and its most overwhelming architectural presence. The question of how to design tall buildings, a problem that challenged Sullivan, has never really been resolved. The earliest examples of high-rise buildings were based on historical models which, upon cursory examination, may seem appropriate and even exemplary. But resorting to past vocabularies for a revolutionary building type seemed out of character with the spirit of the new age modernism…

More than ever, under the imminent shadow of supertall building development, understanding high-rise housing is an urgent topic of international interest. Supertall building is a distinct genre of tall buildings, unprecedented in structure and form, carrying opportunities for the quality of urban life (Abel, 2003; Hulme, 2005). In the post-Sep 11 2001 landscape, the international community is committed to re-examining the use and construction of tall buildings (CIB, 2003). Salient to this literature is the inquiry that informs whether people will continue to occupy high-rise. The answer is fundamental to the existence of old and new high-rise. In examining the high-rise housing experience from different perspectives, actors and localities, in this particular instance, the case of Singapore public housing, this paper seeks to enjoin the current high-rise debate and remind urban researchers of the pluralities (time- and place-specific tensions) as well as the unitary culture (the global proliferation and universality) of this urban form. From the urban knowledge and policy perspectives, the emerging research on high-rise living is vital to shifting the focus of discussion beyond technical attempts of sustainability to embody genuine dialogue about hearing and responding to the consumer to produce more sustainable alternatives that commensurate with human needs and aspirations.

This paper reviews the differing global debates of high-rise construction. This will be followed by an analysis of the lived experiences of high-rise public housing residents in Singapore, dwelling on residents' concerns and satisfaction with high-rise and the landscape features that make Singapore high-rise public housing a continually satisfying experience and potential sustainable development model. Professional expert opinion on the critical factors of high-rise living will also be discussed. The argument is not for high-rise but as more and taller buildings are anticipated in the future, the Singapore analysis offers insight to a high-rise approach that has gained growing popular acceptance.

2. To build or not to build high-rise

The emergence of the first tall building and its subsequent evolution and expansion in modern time has been widely documented and requires no repetition (Ford, 1994; Douglas, 1996; Abel, 2003). Of significance to high-rise living discussion is the period of wide experimentation in the post-war decades, 1953-72, to construct affordable, large-scale high-rise public housing in many cities around the world. Embedded in this provision is the dominant if contested belief that direct state intervention could solve housing and other social problems in a planned, rational manner (Harloe, 1995; Turkington et al, 2004). In the United Kingdom, for example, confronted with massive post-war housing shortages, high-rises (generally 18-24 storeys) were built as cheap and affordable public housing, quick-fix to fill the vacuum created by war destruction and deteriorating 19^{th} century housing stock (Doling, 1997; Ravetz, 2001).

Although initially upheld as the ultimate housing choice to replace old slum tenements, their popularity quickly dissipated following the partial collapse of the newly occupied Ronan Point (East London) in 1968 where 3 people were killed and 11 others injured (Nakao, n.d.), and increasing documentation of rising crime, social isolation and other problems of living in high-rise. Sawyers (2005, p15) encapsulates these high-rise housing problems,

> …as cheaper methods of manufacture were used in their design, cut to fit the purse of the local council. And so it all began to go wrong; rain and sun quickly exposed the poor structural qualities of these monoliths, the lobbies and walkways soon suffered for lack of maintenance. Social ills also flourished; the minority quickly spoiling the communal environments for the majority. This was echoed in the exposed open parkland outside, where a lack of care in planning meant these spaces quickly took on the appearance of threatening wilderness. Council housing policies were often crude; transplanting people from one area to another with little choice in the matter. Those who could moved on, their places filled by those in urgent need of housing but with little stake in the idea or history of a community.

These problems greatly weakened public confidence in the new housing. With the decline in public confidence, demand for such housing soon plummeted. With no demand, the high-rise housing stock predictably progressed towards a downward spiral of difficult-to-let estates, high vacancy and increasing neglect that was to become a liability and eventually consecrate its demise. In the past decade, local authorities in United Kingdom have begun to demolish many of the 1960s high-rise. A similar pattern prevails in the United States. Even though United States of America is the birth place of the modern high-rise, its government's high-rise experiments in the 1960s to provide public housing for the poor have also largely resulted in failure. Although the policy motivation may differ, as with United Kingdom developments, many of the American high-rise housing projects (e.g. in Chicago and New York) have degenerated to ghettos and become heavily stigmatised neighbourhoods of crime, drugs and poverty (Harloe, 1995; Doling, 1997). They too are now being demolished and replaced.

The proliferation of the high-rise as a ubiquitous building type is not limited to European and American cities. Sharing the then common philosophy of the state as a provider of housing, high-rise public housing has been similarly constructed in Asia and elsewhere in the 1960s. However, contrary to the United Kingdom and United States experience, the Asian developments seem to enjoy more success. Hong Kong and Singapore are two case examples. Premised on a basic principle of living condition improvement, these high-rise public housing developments have gathered momentum on the wave of positive response and accelerated in both spatial distribution and building height, becoming a principal component of the urban transformation of Asian cities (Castells et al, 1990).

The phase of worldwide high-rise development in the 1960s has created mass urban living conditions that are common to many cities. As Helleman and Wassenberg (2004, p4) write of the European experience,

> Between 1960 and the mid-1970s high-rise buildings were constructed in all Western cities. Peak productions in housing were reached during this period, with a significant part in high-rise…As far as we know, there has never been a period in house building in which the similarities between countries have been as great. High-rise estates dominated

> the building in this era, and these years proved to be the time of peak housing production in the Netherlands and many other European countries.

The text of the completed buildings are often instantly recognizable regardless of their location, bearing similar form (the slab and/or tower block) that communicates the high-rise as a universal public housing vocabulary. The magnitude of repetition has however impacted majority consciousness leading to an upsurge of interest in social research (and wide documentation) on high-rise housing following the large-scale public housing development (Foley, 1980; Power, 1997; Turkington et al, 2004). A large proportion of the research registers criticisms against high-rise living, that it causes increases in crime, delinguency, suicide and neurosis, isolation of people in depersonalised living spaces, loneliness and anxiety, and is not a desired living environment for families and children (see, e.g. Newman, 1973; Young, 1976; Helleman and Wassenberg, 2004).

Even though it may maximise the useability and profitability of land and accommodate as many people as quickly and economically as possible compared to other housing form, the general conclusion of the body of research is that "the benefits of high-rise living do not outweigh the negative effects on people's well-being that are atributed to it." (Young, 1976, p1) In many cases, the high-rise ideal is progressively changed from "a citadel of modernism to that of a problem estate, a place of poverty, of aliens and illegal immigrants, petty crime, unemployment, with a high incidence of truancy and drug abuse" (Helleman and Wassenberg, 2004, p6). Against such negativism, it is no surprise that the resultant response was to halt high-rise public housing construction, and even demolition. With perhaps the exception of Asian cities, Hong Kong and Singapore in particular, high-rise public housing construction was permanently abandoned in Western cities as a residential option (Abel, 2003; Costello, 2005). In Singapore, the gross plot ratio of these developments has risen from 1.3 in the 1950s to 4.0-8.4 in the 2000s. The current tallest lived-in public housing building is 40-storey while 50-70-storey residential high-rise are under construction in the public and private sector. This is an opportune time to examine the Singapore experience of living in high-rise flats, especially when many cities including those who have rejected the 1960s high-rise, for example, Glasgow, London and Melbourne, are once again building high-rises to address housing shortages and redevelopment under current narrative of inner city density and urban sustainability.

3. Singapore high-rise public housing living

With expanding public housing development, 84% of Singapore's 3.4m resident population has moved to live in high-rise public housing over the past four decades. Resident satisfaction surveys have registered continually high satisfaction scores. In particular, the current set of survey results are showing an increasing number of people who have personally chosen high-rise living and the high proportion (82.5%) of households in public housing who have expressed contentment at the idea of always living in public housing flats (Housing and Development Board, 2000a). Against the trend of rising building height, one in three public housing residents surveyed have expressed willingness to live on 40-storey or higher (*The Straits Times*, 22 June 2005). What are the sustaining attractions of Singapore's high-rise public housing?

Right from the outset, public housing in Singapore is comprehensively planned as part of a total living environment that would support quality living, recreation and accessibility to facilities (Urban Redevelopment Authority, 2002, p10). Using the new town model, each new town with an anticipated population of 200,000 to 300,000 is intentionally designed to provide doorstep convenience to such daily life facilities as open spaces, car parks, schools and shops by locating the facilities within an easy access of 5 minutes' walking radius to the resident. In its basic plan, as illustrated in Table 1, about 50% of the new town land is put to residential use and the remaining land for facilities provision.

Table 1: Land use distribution of a prototype new town

Land use	Land area (ha)	%
Town centre and neighbourhood centres	30	4.6
Residential	347	53.4
Schools	62	9.5
Open space	26	4
Sports complex	7	1.1
Institutions	15	2.3
Industry	44	6.8
Major roads	89	13.7
Utilities and other uses	30	4.6
Total	650	100
Gross new town density	92 dwelling units per hectare	

Source: Housing and Development Board (2000b)

Care is taken to provide external public spaces where community life can take place. The range includes the void deck at block level and green spaces distributed throughout the precinct, neighborhood and town. As a public space the void deck is not just for pedestrian movement (to get in and out of the apartment block) but an aspect of everyday social life where children play when they cannot get to outdoor play areas (they are however not allowed to kick ball in the void deck), the elderly meet and talk to one another, relax or just people watch. The active social function has prompted the authorities and local community groups to provide some simple leisure facility such as chess play sets, elderly fitness equipment and sometimes even an old piano and create senior citizens' corner and study corner in the void deck where there is the demand. The concrete spaces between residential blocks including rooftop spaces are increasingly landscaped as green spaces, gardens and parks to create the city in the garden living experience.

As emphasis is on quality living environment, the improvements in housing and environment are not limited to the planning and design stage but continue through the life cycle of the buildings and towns. Older new towns are upgraded under a formal upgrading plan that would last 15 years from 1991, benefit 95 per cent of HDB residents and allow 'a complete change in the perception of public housing' (*The Straits Times*, 12 July 1989). These positive investment could comprise the creation of precincts and facilities (such as barbeque pits, landscaped gardens and children's playgrounds) where they did not exist previously, updating the facilities of markets and lifts (lift stopping on every floor instead of every few floors in the older blocks and clear window panels on lift door to enhance safety in lift travel), architectural improvement to blocks such as including motif, dormer and color to make them individually distinctive and enlargement of individual dwelling units by adding prefabricated spaces such as an utility room or an extra toilet for flats with only one bathroom/toilet. Principally among the planning and design considerations is the creation of clearly defined, thoughtfully located and meaningful spaces, human scale and quality housing environment to encourage residents to use and take control of the public spaces and give the neighborhood a greater sense of belonging. As the Minister for Home Affairs announces, "a design that not only enhances your living environment, but also endows it with an identity and a community spirit all of its own." (Minister's speech at the upgrading and launch ceremony for Indus Precinct on 24 Nov 2000)

Residents are consulted in the upgrading proposals and finally asked to decide on the upgrading by voting for the upgrading which will only proceed if there is a 75% in favor vote. In most cases, residents are not required to relocate during the upgrading process. They are however required to pay a small portion of the upgrading costs, 8-21% depending on the size of their flat, with the government paying the balance. To help residents with the upgrading cost apportionment, easy repayment terms and special assistance measures have been set up for senior citizens and families in financial hardship. Through upgrading residents can therefore continue to dwell in place and not move to new housing areas to enjoy new facilities. Upgrading offers opportunity to re-plan old towns, improve facility provision and create new flats in older estates that would help to stop the decline of older towns (there is a growing tendency for young people to shun the older towns in their preference for a new flat). It is an important measure in managing the dangers of differentiation between older towns and later developments with their improved flats and facilities.

Quality of the environment and its functionality, how it facilitates personal activities (or not) has long been recognized as important to people's housing choice. Power (1997) has found from European high-rise experience that few families would willingly choose to live in poorly located, low quality buildings with inadequate facilities. Our study on residents' perception and satisfaction with high-rise public housing in Singapore has indicated the range of factors that would affect their decision to move to a higher floor flat (Table 2). Besides flat pricing[1], view from the flat and safety consideration are the most frequently mentioned factors.

Table 2: Factors that would affect resident respondents' decision to move to a higher floor (>30 storey)

Factors	**%**
Pricing of the flat	34
View from the flat	19.6
Safety consideration	10.7
Large floor area	8.6
Privacy of the flat	6.1
Design and construction quality	5.8
Dedicated lift service	4.9
Fire protection	2.3
Distance between blocks	1.4
Provision of facilities within the block	1.2
Presence of high speed lift	0.6
Speedy response of agency to maintenance problems	0.6
Good availability of parking space at the block	0.3
Others	4

N=347

Professional expert opinion as revealed through depth interviews with some architects (81% had designed tall buildings in Singapore and abroad) indicated emphasis on fire protection, safety consideration, view, speedy response of agency and design and construction quality in descending order as critical to high-rise living. This finding is not unexpected because the buyers' (in this case, the residents) decision to move higher is often price-driven while the architects as designers were more concerned with safety considerations and design and construction quality. However, they share a common viewpoint in regarding view from the flat as one of the important persuasions of high-rise living. The analysis draws from interviews with a sample of 65 architects and 348 randomly selected households in two Singapore new towns. The residents were interviewed in their homes with the help of a survey questionnaire. Care was taken to include residents living on various floors including the lowest through to the top floor in the tallest blocks of 30-storey (the tallest at the time of survey) and adjoining lower blocks of 12-16-storey. The study employed multiple data collection methods. Prior to the household survey, focus group discussions were held with young people, individual adults and householders. Following the household survey, observations and time-use studies were collected. Details of the questionnaire and research methodology are set out in Yuen et al (2003).

Most of our respondents (66.1%) expressed a preference to live on the 6th to 20th floor of a public housing flat. Very few (3.5%) preferred to live higher than 30th floor. Equally, few (6.2%) preferred to live below 5th floor. There appears to be general comfort with most aspects of high-rise living. As illustrated in Table 3, a third of the respondents were not at all worried over issues of traveling time in lift, height or collapse of building (Table 3). The areas of most concern were those to do with personal safety like lift breakdown, crime in lift, accidental falling off from high-rise.

[1] Prices of flats in the block would vary according to floor levels, the higher the floor level the higher the price, all other things being equal.

Table 3: Respondents' concern with present high-rise living

Concern area/level	**Not at all %**	**A little %**	**Fairly %**	**Much %**	**Very much %**
Traveling time in lift (n=348)	42.2	9.2	24.1	14.9	9.5
Crime in lift (n=348)	32.2	13.2	20.1	17.5	17.0
Breakdown of lift (n=348)	30.7	14.9	14.7	18.7	21.0
Who you have as neighbor (n=347)	34.3	10.7	18.7	19.3	17.0
Accidental falling off (n=346)	33.8	18.2	23.1	12.4	12.4
Height of building (n=348)	40.5	17.5	26.4	12.1	3.4
Fire risk (n=348)	31.0	17.2	21.3	20.4	10.1
Power failure (n=348)	34.2	19.0	17.8	19.8	9.2
Collapse of building (n=347)	40.3	21.3	14.4	11.5	12.4
Walking along common corridor (n=348)	45.7	20.4	21.8	8.6	3.4
Lack of neighborhood facilities (n=347)	25.6	8.4	19.6	27.1	19.3
Others (n=14)	35.7	14.3	7.1	21.4	21.4

The evidence seems to indicate an inclination towards more acceptances of high-rise living over time with familiarity. As one resident shared with us, she was previously afraid of tall building but this was overcome after she actually made a visit to a friend staying on high floor and found the height acceptable. The common reason rendered by those respondents who were not willing to live very high were psychological barriers---scared of height, never visited such high places before. Repeatedly, we find high floor residents more willing to live on higher floors and low floor residents less willing than high floor residents to live on high floors. Although there were more among the architect respondents who were willing to live above 30-storey, several of them would qualify that willingness with conditions such as if 'the view is outstanding' or 'the building is well crafted' and 'integrated with the surrounding'. The tentative suggestion is that if residents were similarly convinced of the good quality and view as well as affordability of dwelling unit more might be willing to live higher too.

4. Conclusion

The high-rise is fast becoming a ubiquitous feature of the urban landscape with globalization. Many cities including those who have no high-rise buildings at all now have many while others who have abandoned high-rise development are re-visiting and proposing high-rises in their urban regeneration agenda. While cities debate, other cities like Hong Kong, Singapore and Vancouver have made their decisions and adopted high-rise living as the norm. In Singapore, high-rise living is the familiar housing for the majority---84% in public sector and 6% in private sector. Right from the outset, it has carefully and comprehensively planned its public high-rises to provide quality living environment. The public high-rises are well-serviced by facilities, maintained and upgraded with resident input to provide responsive environments. Creating a bond between resident and high-rise is critical. In consequence, these high-rises have not degenerated to vertical slums but present a continuing solution to the expanding population, suggesting alternative means of living in the city and designing socially acceptable towers. Designing socially acceptable high-rise is not without its challenge but if the Singapore experience is any indication, improving the quality of high-rise living is possible.

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HOUSING BY COMPLEXITY – THE "OTHER" SUSTAINABLE DESIGN

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Abstract

In respond to the urge of compact living by sustainable development on the one hand and the flexibility for individual adaptations as advocated by Open Building ideas on the other hand, this paper attempts a method to deal with the complexity in new housing design which incorporates two seemingly discordant intents: high density and high flexibility. Learning from stimulating cases of complex form such as Kowloon Walled quarter in Hong Kong, Muslim town, and habitat of formicary and beehive, principles for organizing private units, common spaces, and circulation paths are found, which guide the formulation of methodic rules for the housing design in question. A design project is outlined to demonstrate the process of controlling density effectively with endowments of capacity for change.

Keywords: Complexity, Design Method, High Density Housing, Housing Design, Sustainable Development

1. Introduction

The legacy of Modernist housing design has been criticized, noteworthy by the Open Building advocators since 1970s, for its inflexibility to accommodate the varieties of user needs. Stereotypical layouts and invariable construction are antagonistic to the individual adaptation that is already a basic dwelling requirement in an increasingly dynamic society. On the other hand, the contemporary concerns for sustainability re-direct housing developments toward compact form of living, which is congenial to the emerging ethic of new environments. High density and high flexibility are therefore conceived two fundamentals for the future housing design. However, these two trends are disparate demands normally considered incompatible to each other. The resolution of conflict calls for new perception of complexity.

2. Forms of Complexity

1960s is the flush time for theory of systems and idea of complexity. Complexity is generally perceived as the variability and diversity derived from the interactions among various elements and levels in system. In 1990s there are renewed interests as inspired by computational theories such as automata and fractal. Fractal structure is a kind of complex system, which is characterized by the recursive mechanism of self-similarity that can make the part isomorphic to the whole. Automata depicts a different picture of complexity in terms of cells, the constituents of the system, and rules that govern the interactions among cells, which will yield a kind of life form evolving over time. Four cases pertaining to different organizations of complexity are observed as follows to offer some insight for the formation of method to deal with variations in compact housing design. They are beehive, formicary, Muslim urban forms and Kowloon walled quarter.

2.1 Beehive

Cell, honeycomb and beehive form a 3-tier structure. The cell, the smallest unit of beehive, has hexagonal shape that economizes the use of space and materials so that cells can be tightly composed and efficiently built (Fig. 1). Fig. 2 illustrates the compact growth of cells, which is governed by the virtue of hexagon geometry: the single-side, the double-side, and the three-side connection. As exemplified by the structure of wasp hive, there are three components in the beehive construction: 1). the apex that bears the whole load of beehive against the gravity; 2). the suspending pillars that hold honeycombs from one layer to another layer (Fig. 3); and 3). the exterior covering that terminates the growth of beehive by a thick coating to keep warm in and keep rain out, but allows direct entry from the bottom. Once inside the hive, the horizontal distribution makes a very efficient circulation system (Fig. 4).

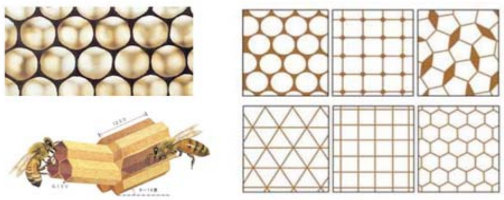

Fig. 1 Basic Spatial Unit of Beehive – Cell Unit

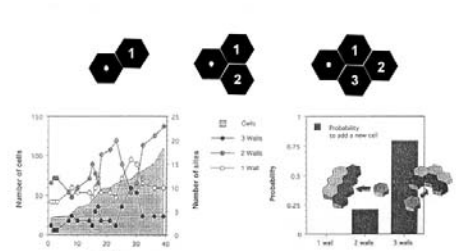

Fig. 2 Growing Rule of Cell Units (Bonabeau, 1999)

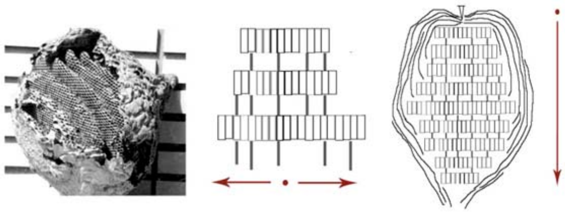

Fig. 3 The Horizontal Honeycomb and Suspending Pillar

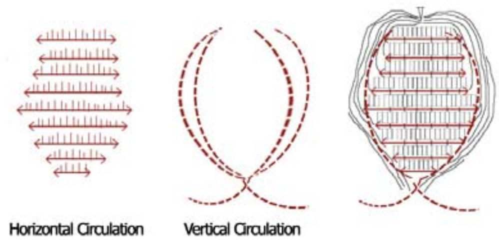

Fig. 4 Section and Circulation System of Beehive

2.2 Formicary

Ants, the insect who can form a well-organized society, can build equally sophisticated. Despite different kinds of species and variety of constructions, all formicaries are built by two basic components: the chamber and the channel (Fig. 5). Take the underground type formicary for instance, the chamber unit can have various shape, size and distance from each other according use functions and restricted by geological conditions. Channels connect one chamber to another, which form a complicate network of link-node cluster. The chamber that has more connecting channels is more public, and is likely to become the core of cluster. The pattern of formicary growth is cluster by cluster as population demands, and a labyrinth city under the ground can be created as result. Two features serve to characterize the complexity of the formicary structure: 1) It is a low-density high-linkage network system. Low density that due to geological constraint on excavation chambers is compensated by sufficient channels to link scattered chambers together. 2) It is a cluster based growth process in piecemeal manner with open end. This organic form of expansion may endlessly continue until the site capacities are exhausted. (Fig. 6).

Fig. 5 Section of the Formicary

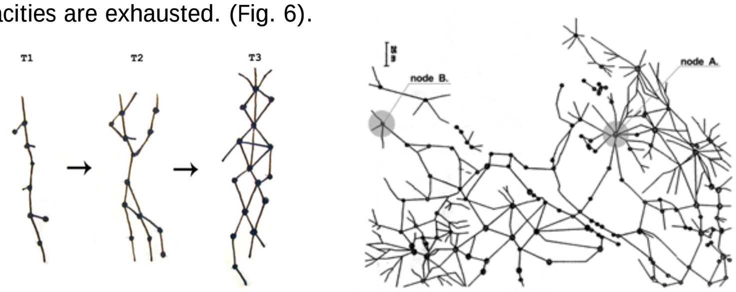

Fig. 6 The Dynamic Developing Process of a Formicary (Bonabeau, 1999)

2.3 Muslim Town

Courtyard is the spatial schema extensively used in Muslim built environments. Courtyard variations in size, shape, and use are observed: modest size in C-shape for residential; middle size in ㄇ-shape for shops and markets, and grand size in ◎-shape for significant buildings such as mosques and palaces（Fig. 7）. These three kinds of built forms are tightly grouped, with hierarchy of path systems, into a townscape of picturesque disorder. The unevenly distributed streets, lanes, and blind alleys are resulted from mixing grid structure and tree structure of circulation (Fig. 8). As compare to the beautiful Islamic geometry patterns, the townscape as such is definitely not an intentional elaboration (Fig. 9). This phenomenon has been convincingly explicated, not as a designed chaos, but as an outcome of underlying mechanism regarding the use, control and ownership of land, (Akbar, 1984) which adds the social dimension to the understanding of built complexities.

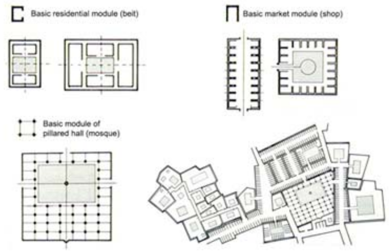

Fig. 7 The Three Kinds of Built Form in Muslim Town (Bianca, 2000)

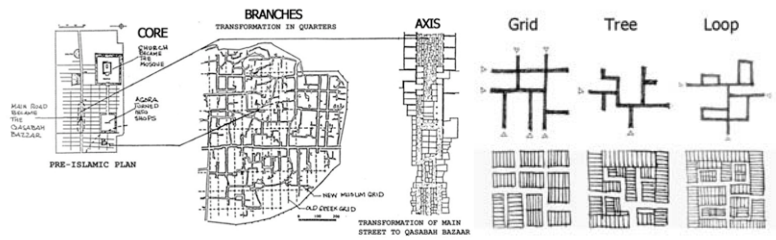

Fig. 8 Basic Path Forms in Muslim Town (Wineman, 1986)

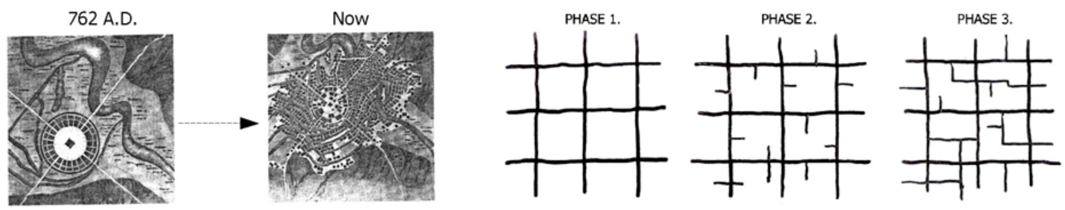

Fig. 9 Developed Processes of Street Systems in Baghdad

2.4 Kowloon Welled Quarter

Kowloon Walled Quarter was phenomenal both in social and architectural sense. The site began as a stronghold defending Hong Kong from overseas invaders by Chinese government in 19th century, and ended as a park after the British administration's torn-down in 1993. The place grew into the notorious place known as "The Dark City" after WWII when the site became an anarchic territory as abandoned by the Chinese, the British and the Hong Kong Government. It was an instant paradise for the homeless as well as refugees, a cradle for criminals, and a kaleidoscope of all sort of social malaises. During the period of 1965~1985, there were 35,000 people cramped in 500 or more buildings of generally 10 to 14-story high. Its density soared to the world record at the time of its doom: 50,000 people in 2.5 hectare, in other words, 1.9 million person in 1 km²（Fig. 10）.

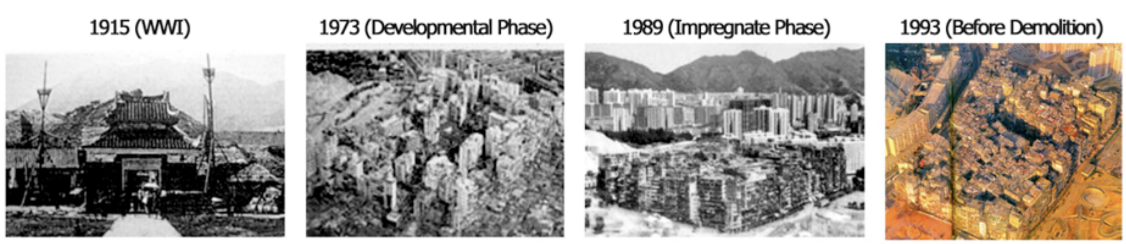

Fig. 10 Kowloon Walled Quarter (1915~1993)

Fig. 11 Development of Spatial Structure in Kowloon Walled Quarter

A relatively small central place with five main paths formed the spatial structure of Kowloon Walled Quarter（Fig. 11）. The central place was occupied by public buildings, such as temples and Ching-Dynasty offices that adapted for elderly use, kindergarten and missionary house. The main entrance at the South Gate leads to the east-west main road that intersects with four north-south roads. As in the later developments more lanes and blind alleys are stemmed from these main paths to form a maze-like network, which is not unlike those of Muslim towns. When the buildings went up, the network extended vertically that a three-dimension maze was created eventually and inadvertently. The increasing of density is simply by multiplying dwelling units and extending in all possible ways straightforwardly. It is too luxurious to grow by delicate arrangement in terms of hierarchy of public and territory of privacy. All sort of space uses and activities are dynamically distributed almost everywhere in the whole complex（Fig. 12）. There are air nodes and air bridges that make buildings also accessible to one another from air（Fig. 13）. These air nodes are not fixed, they can be substituted, hidden or reopened in accordance with uses required, which contributed in great deal to the dynamic character of this fabulous disorder（Fig. 14）.

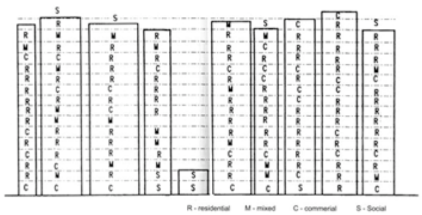

Fig. 12 Activities in Walled Quarter (Liew, 1995)

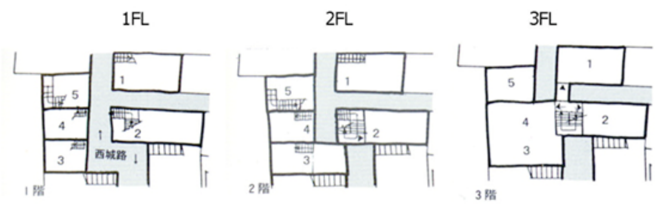

Fig. 13 Air Nodes among Different Buildings (Suzuki, 1994)

Fig. 14 The Largest Predicted Scope of Horizontal Connections among the Different Buildings by Air Nodes

All these cases offer stimulating points to the understanding of complexity in built form that worth remarking: i). A complex form is composed by two basic components: the cell, or the adaptable unit, and the channel, or the circulation element. Although cell and channel are related, it is important to see that each component is an independent system that controls its own structure of growth. ii). As of independent, component systems can enjoy the freedom of pairing. For instance, formicary cell with beehive channel, or Muslim cell with formicary channel, and so on. Various pairings generate various built forms with inherent properties of the component system employed. For instance, beehive cell plus Kowloon channel will create an anomalous form, which is extremely compact and extremely confusing. iii). As warned by system philosophers, there might exist occult phenomena, such as butterfly effects, in any complex system when outsized, The lessons learned from the case studies suggest that built forms should be diversified by adopting different systems when quantity demands increase beyond manageable level.

3. Simplex Cube: the Methodic Element for Complex Housing Design

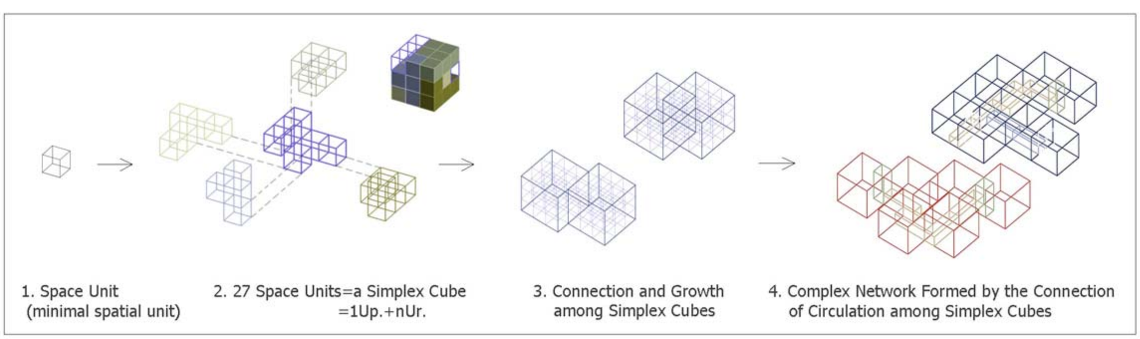

Fig. 15 The Process from Minimal Unit Space to Compact Housing Space

The central idea to approach the design of flexible and compact housing structure is a conceptual model called “simplex cube”, that integrates both the “cell” and the “channel” into one spatial volume. A simplex cube is composed by 27 unit spaces in cubic form (3*3*3=27), and the nominal dimension for each unit space is 3.6 cubic meters（Fig. 15）. Within the module the spatial contents are only two kinds in terms of use: the "public unit" (Up), primarily refers to circulation or other public uses, and the "resident unit" (Ur) for private uses. Conceivably, there are enormous amount of Up/Ur proportions within the 27-unit cube that can generate almost countless number of different simplex cubes. Considering the normal requirements of size for residential and circulation use, there are two rules to reduce the number of simplex cube to be generated by Up/Ur combinations:

(1) 3 unit spaces ≤ Up. ≤ 7 unit spaces； 3 unit spaces ≤ Ur. ≤ 7 unit spaces
(2) A Simplex Cube＝1Up.＋nUr., and 3 ≤ n ≤ 6

(Rule 1) says that each public unit and residential unit can have different sizes made by 3 to 7 pieces of unit spaces, in other words, there are only 5 different kinds of Up or Ur in terms of size, i.e. 3-piece, 4-piece, 5-piece, 6-piece, and 7-piece.

(Rule 2) says that each simplex cube should have at least 1 public unit, while the rest space can apply for residential use that varied from 3 units to 6 units.

The followings are 30 possible combinations of (1Up. + nUr.) in one simplex cube, which all conform the above rules（Fig. 16）.

＊（1Up.＋3Ur）in one unit group (1)

｛7,7,7,6｝

＊（1Up.＋4Ur）in one unit group (11)

｛7,7,7,3,3｝

｛7,7,5,5,3｝ ｛7,7,5,4,4｝

｛7,7,6,4,3｝

｛7,6,6,4,4｝ ｛7,6,6,5,3｝

｛7,6,5,5,4｝ ｛7,5,5,5,5｝

＊（1Up.＋5Ur） in one unit group (10)

｛7,5,5,4,3,3｝ ｛7,5,4,4,4,3｝

｛6,6,6,3,3,3｝

｛6,6,5,4,3,3｝ ｛6,6,4,4,4,3｝

｛6,5,5,5,3,3｝ ｛6,5,5,4,4,3｝

｛6,5,4,4,4,4｝

｛5,5,5,5,4,3｝ ｛5,5,5,4,4,4｝

＊（1Up.＋5Ur）in one unit group (8)

｛7,5,3,3,3,3,3｝ ｛7,4,4,3,3,3,3｝

｛6,5,4,3,3,3,3｝ ｛6,4,4,4,3,3,3｝

｛5,5,5,3,3,3,3｝ ｛5,5,4,4,3,3,3｝

｛5,4,4,4,4,3,3｝

｛4,4,4,4,4,4,3｝

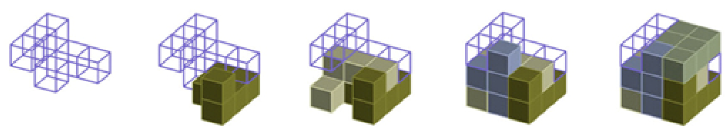

Fig.16 The illustration of a simplex cube（7,6,5,5,4）7-piece(p.u.) + 6-piece(r.u.) + 5-piece(r.u.) + 4-piece(r.u.) + 5-piece(r.u.)

There are six basic types of public unit, as described in Fig. 17, that are defined in terms of the distribution of public circulation within the simplex cube. It is required that public circulation must traverse the whole module to provide accesses to the inside spaces and to make outside connection possible. Logically, 3 types are along horizontal axis, which are Type A, Type B, and Type C, and three on the vertical axis, i.e. Type A', Type B', and Type C'.

Horizontal Axis

Vertical Axis

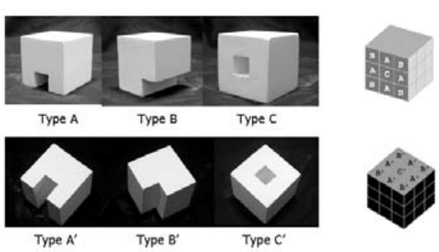

Fig. 17 Six Basic Types of UP.

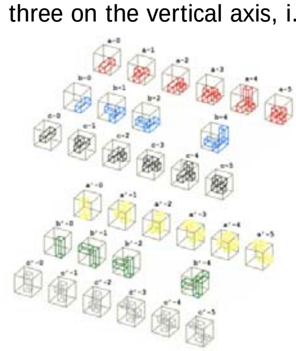

Fig. 18 Thirty Derived Types of Up.

30 derived types of public unit are obtained if each public unit of the basic type may add 1 to 4 unit space. These add-up spaces are still used for circulation or other required public functions. Every basic type (x-0) can be developed into five derived types (x-1~5) because b-0, b-1, b-3,

b-5, b’-s and b’-5 are deleted due to their contradiction against rules (1) and (2). Hence, there are 30 derived types of Up.(Fig.18). The principles applied for the derivation are as follows:

(x-0) p.u.=3	only main public circulation system {(a-0), (b-0), (c-0), (a’-0), (b’-0), (c’-0) }
(x-1) p.u.=4, 5	one or two units are added to the end of public circulation { (a-1), (b-1), (c-1), (a’-1), (b’-1), (c’-1) }
(x-2) p.u.=4, 5	one or two units are added to the centre of public circulation { (a-2), (b-2), (c-2), (a’-2), (b’-2), (c’-2) }
(x-3) p.u.=5	one unit is added at the end and the other in the center of the public circulation, each with 90-degree angle. { (a-3), (c-3), (a’-3), (c’-3) }
(x-4) p.u.=5, 6, 7	two, three or four units are added to the end and in the center of the public circulation, each with 90-degree angle. { (a-4), (b-4), (c-4), (a’-4), (b’-4), (c’-4) }
(x-5) p.u.=5	a unit is added to both sides of the public circulation with 180-degree angle. { (a-5), (c-5), (a’-5), (c’-5) }

4. Complexity Created by Simplex Cubes

The aforementioned 30 derived types of public unit in terms of arrangement variety can be considered as 30 different simplex cubes for design operation. By these 30 simplex cubes a huge amount of interesting compositions can be explored. In principle the simplex cubes can be connected horizontally as well as vertically in any possible ways to fit use programs with the support of adequate building technologies. Given that possibilities, only 8 different connection modes, 5 horizontal and 3 vertical, are selected for design demonstrations with regards to some general considerations for lighting, ventilation, and building height in housing environment (Fig. 19). The connected portion between two simplex cubes can be elaborated in many ways to satisfy specific environmental requirements in different situations. For any two connected simplex cubes there exist only 4 relations between the circulation space, i.e. the public unit, in each cube: butt-link, corner-link, T-link, and side-link (Fig. 20). Two adjacent simplex cubes may not have connected circulations, but simplex cubes connected by their circulations are always adjacent. By manipulating circulation paths the use activities in the housing complex can be effectively.

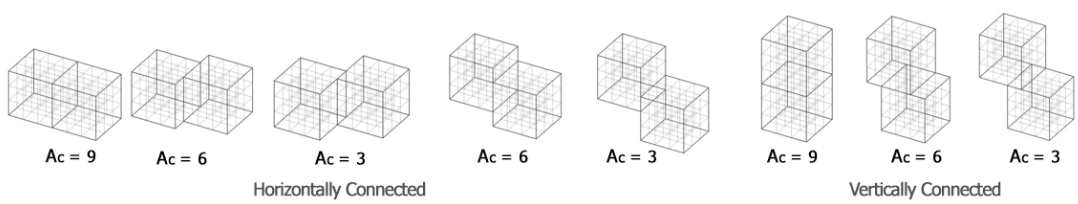

Fig. 19 The Interface Relation among Simplex Cubes

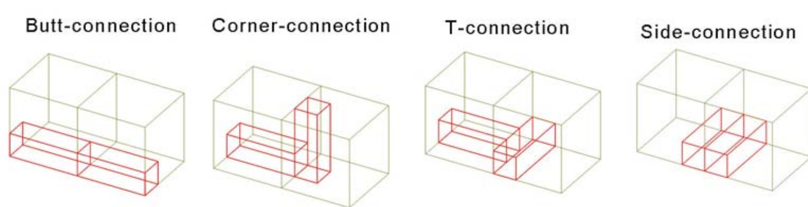

Fig. 20 Connection of Circulations among Simplex Cubes

These 30 different simplex cubes are the methodic starting point for the compact housing design. For a given site and use program, design proceeds in steps as follows (Fig. 21):

i). Select appropriate simplex cubes and quantities that fit program requirements (Formula C). ii). Arrange simplex cubes on the site to make sensible environment. iii). Connect or disconnect circulation paths to support intended activities. iv). Divide each simplex cube to produce required amount of resident units and examine alternative possibilities. v). Choose suitable construction system and materials vi). Design facades as culturally responsive and environmentally sensitive.

It should be noticed that the simplex cubes are only conceptual cube to serve methodic functions, they are not architectural substances, and therefore should be deformed or transformed when they are realized in reality.

Formula A and B are induced by rule(1) and rule(2)

$$[3(Xr.u.)+4(Yr.u.)+5(Zr.u.)+6(Rr.u.)+7(Sr.u.)] + [3(Xp.u.)+4(Yp.u.)+5(Zp.u.)+6(Rp.u.)+7(Sp.u.)] = 27(N)$$ …… (Formula A) （Xr.u.∽Sr.u.、Xp.u.∽Sp.u. can all be 0）

$$(Xp.u.+Yp.u.+Zp.u.+Rp.u.+Sp.u.)=(N)$$ ……（Formula B）

By incorporating Formula B to Formula A, therefore we obtain Formula C.

$$3(Xr.u.)+4(Yr.u.)+5(Zr.u.)+6(Rr.u.)+7(Sr.u.)= 24(Xp.u.)+23(Yp.u.)+22(Zp.u.)+21(Rp.u.)+20(Sp.u.)$$ ……（Formula C）

X= the amount of 3units; Y= the amount of 4units; Z= the amount of 5units; R= the amount of 6units; S= the amount of 7units; N= the amount of unit group p.u. : Public Unit （ public space + circulation system ）； r.u. : Residential unit

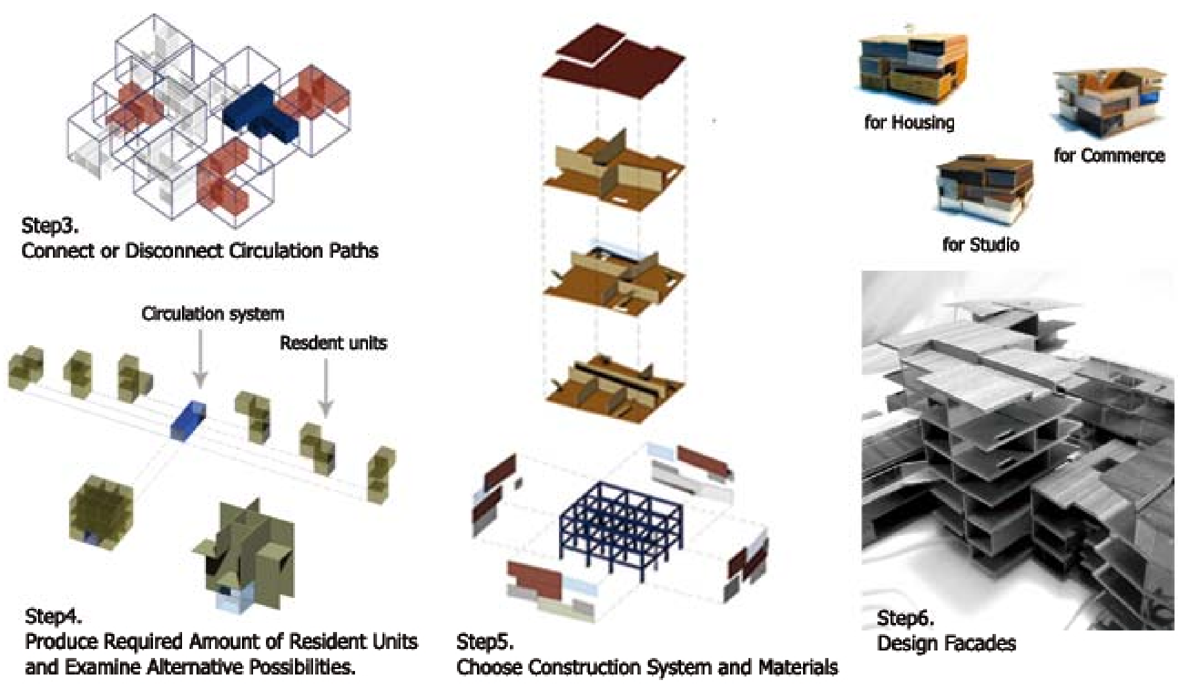

Fig. 21 The Design Procedure

5. Conclusion

Compact living and flexible dwelling are two major tends in housing design with sustainability in mind. This design research provides a method to respond the challenges. It is found, through theoretical discourses and case observations, that a complex form can be generated by a rather simple mechanism. The issue of complexity as addressed here is about compactness and flexibility. The genuine idea in the methodology is to integrate the circulation and the dwelling unit into one generic space module. This simplex cube is the key element and a very handy tool for designing complex form.

As proposed by this method, 30 different simplex cubes, each with certain capacities for variation and is characterized by specific circulation pattern, are sufficient to build exuberant varieties as have been demonstrated. It is vindicated that complexity can be approached in simple way and by simple means such as simplex cubes.

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A TYPOLOGICAL STUDY ON THE CREATIVE NUCLEUS OF MALAY HOUSES

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Abstract

Cultural sustainability can benefit from re-learning traditional houses that require systematic studies. This study attempts to explore the creative nucleus of Malay houses by a typological methodology. More than 200 cases were studied through the following operations: i). Encoding by typological description, ii). Finding variations in house-building, iii). Formulating typological rules, iv). Proposing "generating mechanism" and "screening mechanism" as the creative nucleus embedded in Malaysian architectural traditions.

In respond to the current urge of sustainable development, these studies highlights the heritage of Malay houses and the creative applications of its typological potentials in the contemporary context.

Keywords: Malay house, creative nucleus, typological study, house type.

1. Introduction

Paul Ricoeur, world reknowned philosopher, said in 1961 that universalization brought progress of human beings on one hand, and the destruction of creative nucleus of some great cultures on the other hand. This statement is particularly alarming in this century of globalization, in which we all experienced the dark side as well as the bright side of the universality. With this regards, this paper addresses the issues related to the notion of creative nucleus by presenting a typological method to the study, and the future development of Malay houses.

The house types in Southeast Asia, although lack no commonality such as raised footing, boat image, decorative gables, etc. (Waterson, 1990), have some obvious disparities, such as big roof vs. small roof, heavy wood vs. light wood construction, multi-family single building vs. detached houses etc. Within these various house types of Southeast Asia, the houses in Peninsula Malaysia exhibit some distinctive characteristics: the stilts footing, non-boat image, small roof, and light wood construction (as compared to Batak Karo and Tongkonan houses), and compound buildings with central main house for single family.

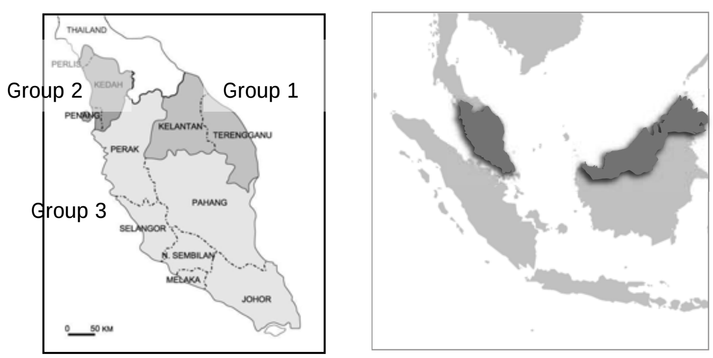
The main house (rumah ibu), the distinctive built volume in Malay houses, is always located at the front. The ridge of the main house is usually parallel with the street and perpendicular to the entry gate. The main house has largest volume and highest roof that constructed with two different slopes. Behind the main house locates one or more sub-houses with descending roof heights. The floor heights also decrease from the main house, sub-houses, to the kitchen (dapur), which is usually on the ground (Teh, 1996). There are three major spaces in Malay houses: *serambi* (reception area), *rumah ibu* (core space), and *dapur*. The spatial sequence in Malay houses is clear and strict: from outside to the inside in the order of *serambi*, *rumah ibu*, and *dapur*. Guests are only invited to *serambi*, while relatives can enter *rumah ibu*. Dining with the guests also takes place in *serambi*. Usually, the front half of the house (front yard and *serambi*) is the living space for male, and the back part (back yard and *dapur*) for female (Ariffin, 2001).

Spatial form and construction language are considered two fundamental aspects for house type studies. The two interact in various ways. Spatial form is deeply embedded in the culture while the construction language may travel from one culture to another. The change of spatial form, as results of the change of life demands or outside environments, may require transformations of construction languages accordingly, which may reciprocally entail related changes in spatial form. It is hypothesized that each culture has its house genotypes from which many typological varieties are derived (Wang, 2002). The methodological goal of the typological study is to formulate a set of rules that can account for all possibilities as well as existing houses of the culture under study. These typological rules may reveal the wisdoms that are congenial to the notion of *creative nucleus* of the culture.

2. Materials and Method

There are two sources of data in this study. One is KALAM Centre (Pusat Kajian Alam Bina Dunia Melayu, Centre for the Study of Built Environment in the Malay World) at the architecture department of Universiti Teknologi Malaysia (UTM), whose architectural research, surveying and mapping have been collected for decades. The other is the field survey on Peninsula Malaysia conducted in 2005 and 2006 by National Cheng Kung University group from Taiwan.

The house type data of the Peninsula Malaysia are classified into three groups: Group 1: Kelantan and part of Terengganu, Group 2: Kedah and Perlis, Group 3: Other than those mentioned in Group 1 and 2. Group 1 features the special courtyard space (jemuran) in Malay houses, and the combination of the derivative space and volume. Group 2 is a longitudinal longhouse which deserves a new category. Group 3 contains large number of cases, including the houses in Perak in the mid-north, Pahang, Selangor, Negeri Sembilan, Melaka in the middle, and Johor in the south. The paper focuses on the cases in the vast areas of the mid-north, middle, and south of Peninsula Malaysia in Group 3. (Map 1)



Map 1. Groups of Malay houses in Peninsula Malaysia

3. Malay House Types

There are two major methodological components in this typological study: 1). the descriptive system to encode all features significant to Malay houses, and 2) the generating mechanism capable of producing all possible cases of Malay house.

3.1. Descriptive System

A descriptive system is formulated for the Malay houses under study. The system addresses three aspects of the house type: house grouping, spatial structure, and construction. Shorthand names are used in the description.

3.1.1. House Grouping. “Twelve-column house (rumah tiang dua delas)” is the first and the main unit which has two spans in the front and 3 in depth. This 12-column form is considered to be the prototype of Malay house. In order to meet the needs of families of various scales and to show the characteristics of diverse regions, the extension of main house is essential during the derivation of Malay houses. The types of extension include increasing the span number in depth (E1), decreasing the span number in depth (E2) increasing the span number in width (E3), increasing floors (E4), increasing *anjung* (the extruding quantity in the front of the main house) (E5), increasing the width of *serambi* (E6), expanding *rumah tangga* (the staircase space at the entrance) (E7) (Lim, 1987). The sub-house unit, conceivably built after the main house, has independant structural system and is usually but not necessarily a single building. Attchment (At) is the structure that can be attached to the main or sub-houses but cannot exist alone (Fig.1).

There are connections between main house and sub-house, sub-house and sub-house, or house and attachment that are positioned in four different ways: 1). Eave to eave (C1): Connecting a gap between parallel eaves, with a gutter to drain rainwater out, forming a part of interior space. 2). *Pelantar* (C2): The separation of parallel eaves forms an outdoor space like an indoor courtyard. 3). *Selang* (C3): A corridor built by adding a longitudinal roof upon the larger distance between two roofs, serves as indoor or semi-outdoor space. 4). Attached shelter (C4): attach to the main unit or sub-houses. In addition, three possible locations of the joints: at central back (@p1), at side of back (@p2), at side (@p3). (Fig.2)

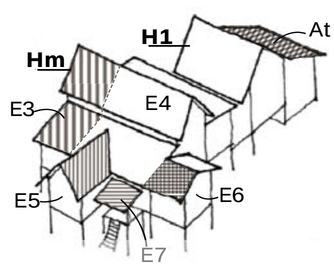


Fig.1 Extensions of main house

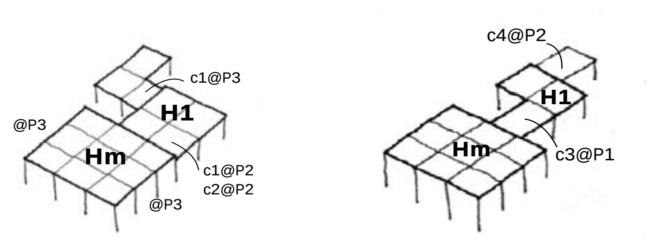


Fig.2 Connections of houses

3.1.2. Spatial structure. In addition to afore mentioned *serambi* (S), *rumah ibu* (RI), and *dapur* (D), other interior spaces that feature the Malay house type are as follows: *bilik tidur* (bedroom), *rumah tengah* (rumah ibu), *selang* (corridor), *pelantar* (inner courtyard), *anjung*, *rumah tangga* (stairway space). The spaces are positioned according to the following arrangement rules: 1). the main house is originally composed of *serambi*, *rumah ibu*, and *bilik tidur*. 2). *serambi*, *anjung*, and *rumah tangga* are located in the front of the house. 3). *selang* and *pelantar* are both connecting space. 4). *dapur* are located in the back.

3.1.3. Construction. Basically there are two types of construction.

Construction 1 (Cons.1): The original "six-column house (rumah tiang enam)" contains three columns at two sides, each with a flat-beam (beam with flat rectangular section) on top, and another 3 vertical flat-beams (level 2) at the 3 pairs of columns on top of these two parallel flat-beams (level 1). Locate the post in the middle of the three flat-beams (level 2) and put the oblique beams at the two terminals of the post and the flat-beam to form the prototype of the oblique roof (Fig. 3). In case of extension, one (3 columns) or two rows (6 columns) of columns parallel to the house ridge are added to expand one or two more spans. This is a technical way of building the attachment. The oblique beam that supports the roof of the attachment is connected to the added column, level 1 flat-beam or columns on the main house. The main house of such style contains the pitch roof with double slope, composed of one "six-column house" and "two attachments" and forms "twelve-column house" (rumah tiang dua delas). The roof in the middle of the house is more slanting than those of the sides. The preceding description is about the constructional prototype of the Malay houses.

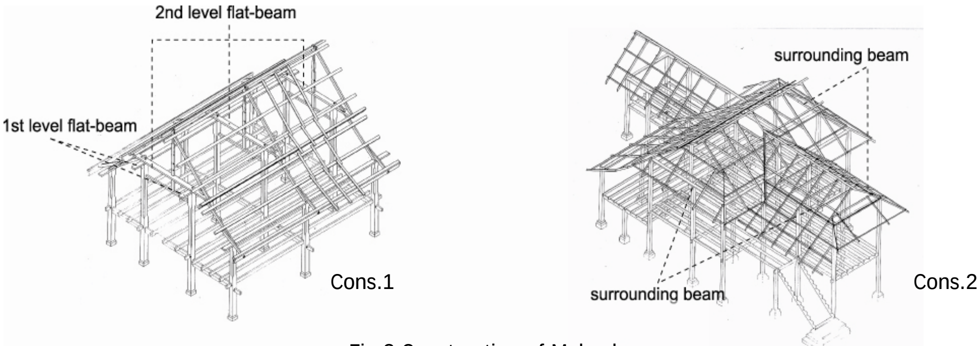
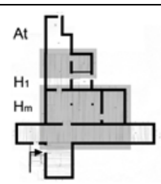
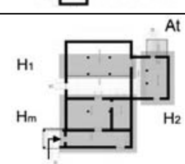
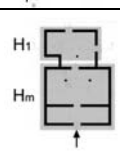
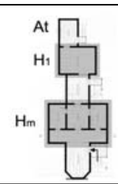
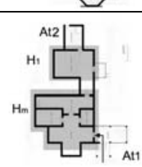


Fig.3 Construction of Malay houses

Construction 2 (Cons.2): This construction is without parallel flat-beams. The columns surrounding the house support the beams around. Horizontal beams are supported by the rows of columns, and the post on top of the beams supports the spinal beam. Because of the beams around, an oblique rafter can be put on each roof of elevation to connect the surrounding beams and spinal beams and form the hip roof. But this technique excludes the roof variation of double slope and adopts smaller slope, not resembling the image of the main house in Malay house prototype. (Fig. 3)

The middle, mid-northern, and southern parts of Peninsula Malaysia are the three main areas where the Malay house types are studied. From each of the following states one house is selected to demonstrate the typological features as analyzed above: Negeri Sembilan, Melaka, Pahang, Perak, and Johor. (Table 1)

Table 1. Descriptions of Malay houses. (grey parts represent the house volumes; white, the attachments)

Negeri Sembilan _Rumah Dato'muda Haji Omar Bin Lajim_1747		Hm (E3,E5,E6) 【C1@p2】 H1 【C4@p2】 At Cons.1
Melaka_Rumah Encik Husin Be_1900		Hm (E3,E6,E7) 【 C1@p1 】 H1 【 C2@p3 】 H2 【C4@p1】 At Cons.1
Pahang_Rumah Hajjah Zaleha BT. Haji Mat_1895		Hm (E3,E4) 【C1@p1】 H1 Cons.1
Perak_Rumah Haji Mohamad Jali		Hm (E2,E3,E5,E7) 【C3@p1】 H1 【C4@p2】 At Cons.2
Johor_Rumah Haji Ahmad_1918		At1 【 C4@p3 】 Hm (E3,E5,E7,E8) 【 C3@p2 】 H1 【C4@p1】 At2 Cons.2

3.2. Capacity of Variations

The main house unit can enjoy the freedom of enlarging and reducing through the rules from E1 to E7. The sub-house and attachment can be increased or reduced according to their position rules. There also exists flexibility for grouping different house units as vindicated by three places for connection (@P1, @p2, @P3) by four ways (C1~C4). *Rumah ibu* is a multi-functional interior space which is recognized by the free plan arrangement. As for construction, both Cons.1 and Cons.2 have their own technical freedom. In Cons.1, the main columns under the flat-beams can be put in the front or back to allow the column spans in the main house be adjusted flexibly. So are the column spans in the sub-houses. Observably, the roof structure of equilateral triangle will be maintained while the rafters can be placed freely. The slope of roof can be changed as free as the height of the floors.

In Cons.1, there are four components, columns, oblique beams, roofing, and floors, that can be placed in various ways. In Cons.2, only two principles are applied: the exterior columns outline the house with beams on top, and the interior and exterior columns support the roof structure collaboratively. In this way, the top of the roof structure defines the house ridge. Rafters are located between the roof ridge and the surrounding beam. With the same slope, various kinds of hip roof can be constructed. The placing of columns, roofing, and floors is quite free as the principles allow. In addition, various materials can be used. For instance, wooden boards, woven bamboo stripes, and palm leaves (atap) can apply both to the wall and roofing systems. Galvanized corrugated iron sheets often replace the palm leaves as the roofing material.

3.3. Typological Rule

Three main formal features can be identified in Malay houses: 1) the composition of space *serambi*, *rumah ibu*, and *dapur* as a generic whole; 2) the parallel flat-beams are adopted in Cons.1; 3) the double-slope pitch roof is designed to constitute a strong image of main house. These features can be viewed as typological rules which govern the production of Malay houses. Rules are layered to reveal their varieties in application.

From all the cases under study, it is found that the “S, RI, D composition” is the fundamental rule shared by Malay houses without exception. The second-level typological rules are “Cons.1 or Cons.2” and “main-house image”. For instance, Perak houses, while complying with the “S, RI, D composition” rule, adopt “Cons.2” and produce the “main-sub-house integrated image” as result. The rule regarding “back or side extension and connection” also belongs to the second-level. The constructors of Negeri Sembilan houses prefer the sub-houses to be in alignment with the sides. The sub-houses in Melaka can exceed the left or right side lines of the main house. The *selang* of Perak houses are connected with mid-back of the main house. The above arrangements, as spatial interpretations of “back or side extension and connection”, constitute the category of the third-level typological rules. Negeri Sembilan houses have Minangkabau-style bull-horn ridge, which are the result of applying “Cons.1” and “main-house image”. Minangkabau’s roof can also be considered as an instance of the third-level rules. The 3-bay façade of Perak houses with middle bay elaborated by *anjung* method is another case of the third-level rules. (Table 2)

In Johor area, there are houses as generated by the second-level typological rules of “Cons.1”and “main-house image” resemble those in the middle area. There are also Johor houses as produced by the second-level rules of “Cons.2” and “integrated main-sub-house image” resemble those in the Perak area. Nevertheless, *ruang tangga*, a special attachment to the sides of Johor main houses, represents the third-level typological rules. The short stilts of Johor houses can also be considered as the third-level rules.

Table 2. Typological rules

1^{st}-level rule	2^{nd}-level rules	3^{rd}-level rules
Spatial hierarchy of S, RI, D	Back or side extension and connection Cons.1 with main-house image	Sub-houses exceeding the side line of the main house
		Sub-houses in alignment with one side Minangkabau's roof
	Back or side extension and connection Cons.2 with main-sub-house integrated image	*Selang* connected at central bay *Anjung* at front central bay
		Ruang tangga at main house's side Low stilts

4. Generating Mechanism

Malay houses have endowed with great capacity of variations by 4 different classes: the house grouping, the spatial layout, the construction methods, and the building materials. Each class has certain alternative choices, and all together can generate multiple combinations. The combination possibilities can be calculated in greater detail by the following parameters from X_1 to X_6:

x_1= E1~E7, main house extension;

x_2= C1~C4, connecting way of main house, sub-house and attachment;

x_3=@p1, ~@p3, connecting position;

x_4= more than 9 spatial elements;

x_5= column, obligue beam, roofing, floor (construction elements);

x_6=materials.

These 6 parameters constitute the generating mechanism of Malay house variations. The generating process of a Malay house may begin with the prototype, *rumah ibu*, also known as the main house, which triggers the generating processes to produce great amount of house groupings through the parameters, x_1, x_2, and x_3. The selected house grouping offers many spatial layout possibilities through the arrangements of different spatial elements as defined by parameter x_4. Each layout plan can be built by alternative construction systems as prescribed by the parameter x_5. Then, various materials as described by the parameter x_6 can be applied to complete the house.

Fig.4 is a demonstration of possible variations of Malay house by manipulating only parameter X_3: @p1, @p2, @p3, i.e. three different eave-to-eave connecting positions, under Cons.1 while fixing all other parameters. This demonstration shows only the tip of iceberg of all possibilities when the generating mechanism reveals its full power.

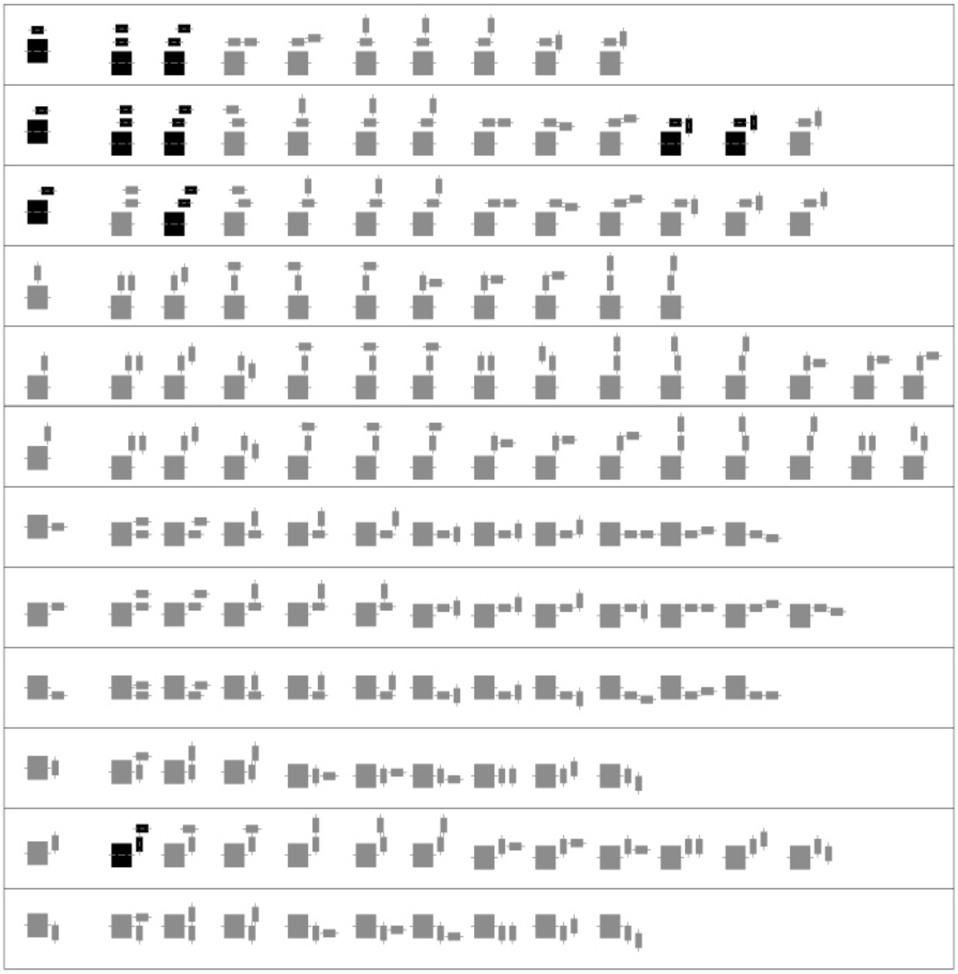


Fig.4 Generated cases by eave to eave connection at p1, p2, p3

In Fig.4, black diagrams represent existing cases, grey ones represent speculation cases which do not exist as yet either in literature or in field. Conceivably, a sort of *screening mechanism* may exist to prohibit certain variations from emerging, though they are admitted by the generating mechanism. What is the structure of this screening mechanism is a question that beyond this investigation and capacity. However, we can speculate that it might relate to two cultural factors: one is that there are certain inherent forbidden rules in the building process to exclude some variations. The other may be called 'system bias' or tradition preference which encourage only some variations rather than others.

5. Conclusion: Creative Nucleus of Malay Houses

Every Malay house has an innate genotype, which is basically described by the first-level typological rule. Houses are not Malay house if the first-level rule is violated. The various combinations of the second- and third-level typological rules can lead to different sub-types of Malay house. Take Acehnese house as an example. It conforms to the first-level rule but not the second- and the third-level rules, therefore, it becomes another sub-type of Malay house.

As observations turned away from Peninsula Malaysia, some interesting findings emerge. A domestic house at Kakunodate, Akida, Japan, as shown in Fig.5a, shares some characteristics of Malay house. By the afore mentioned *Descriptive System*, this Japanese house can be coded as a main house extension with Hm(E1, E3, E5, E7), five sub-houses (H1~H5), three attachment (At1~At3), four connecting ways (C1~C4), and three kinds of connecting points (@p1~@p3), as shown in Fig.5b.

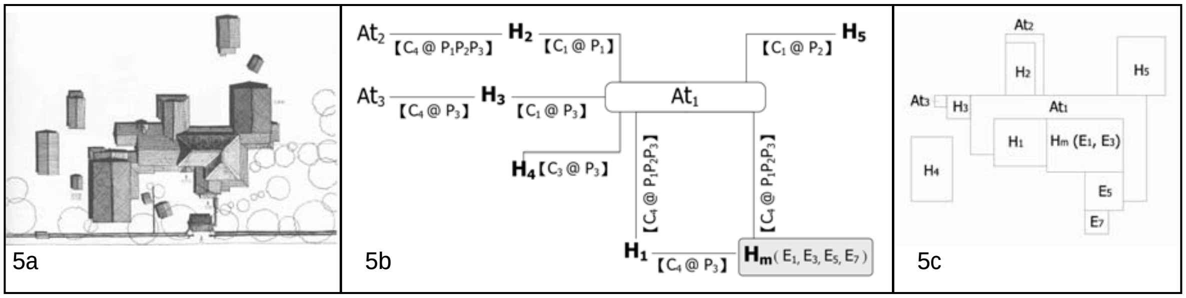


Fig. 5 Japanese house presented with the descriptive system of Malay house

Fig.5c shows the way of coding the Kakunodate house as those shown in Fig.4. By comparing these two codings, i.e. Fig.5b and Fig.5c, it is interesting to find that the Japanese house can qualify to be another type of Malay house if add three revisions to the descriptive system of Malay houses:

1). Change linear connection into network connection.

2). Define connecting positions more specific.

3). *Selang* may connect the houses perpendicularly and also in parallel as the veranda in Japanese house.

This example has no intention to compare the similarities and differences between Malay house and Japanese house, nor to search for the origins of these houses, although we may speculate their evolutionary relevance. This serves to demonstrate the productivity of the generating mechanism of Malay house, from which many variations can be generated even beyond our wild imaginations.

In respond to the current urge of sustainable development, this paper concerns not only the heritage of Malay house but also the creative applications of its typological potentials in the contemporary context. It is expected that more original researches will continue along this line to improve and refine the current findings. Hence the creative nucleus of the Malay house is opened for further discovery and exploration.

Acknowledgements

Appreciation is especially dedicated to the professors and professionals of KALAM Centre and Department of Architecture, Universiti Teknologi Malaysia, and the architectural students working on numerous measured drawings of traditional Malay houses. This study has been made possible with their consistent contribution since 1975.

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DEVELOPMENT OF AN ENERGY RATING SYSTEM FOR OFFICE BUILDINGS

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Abstract
The paper reviews the two important parameters used to assess the energy performance of office buildings – one at the design stage and the other at the operational stage. The building envelope includes all external elements of the building and the performance measure generally covers both the heat conduction and solar transmission aspects. The Overall Thermal Transfer Value (OTTV) is a single number index that measures the resistance of the building envelope to heat gains. The OTTV is performance based and allows professionals responsible for the design and construction of buildings freedom to innovate and vary important envelope components so as to reduce the heat gain to the building from the exterior to a minimum. The operational performance of the building is measured by the Building Energy Index (BEI) which is the total annual energy consumed by the building per unit air conditioned area. The paper examines how these two indexes can be combined to derive an energy rating system for office buildings.

Keywords: Energy performance; Overall Thermal Transfer Value; Building Energy Index.

1. Introduction

The aim of a green building design is to minimize the demand on non-renewable resources, maximize the utilization efficiency of these resources, when in use, and maximize the reuse, recycling, and utilization of renewable resources. It maximizes the use of efficient building materials and construction practices; optimizes the use of on-site sources and sinks by bio-climatic architectural practices; uses minimum energy to power itself; uses efficient equipment to meet its lighting, air-conditioning, and other needs; maximizes the use of renewable sources of energy; uses efficient waste and water management practices; and provides comfortable and hygienic indoor working conditions.

Green building rating is now being implemented in many countries. Singapore's Building & Construction Authority (BCA) has launched the BCA Green mark which is a green building rating system to evaluate a building for its environmental impact and performance. Buildings are awarded the BCA Green Mark based on five key criteria:

- Energy efficiency
- Water efficiency
- Site/Project Development & Management(Building Management & Operation for existing buildings)
- Good Indoor Environmental Quality & Environmental Protection
- Environmental Innovation

In North America, US Green Building Council developed the LEED rating system with a market-driven strategy to accelerate green building practices. The categories of assessment include:

- Sustainable site
- Water efficiency
- Energy and atmosphere
- Materials and resources
- Indoor environmental quality
- Innovation and design process

With the current trend of rising energy prices and increasing interest in environmentally responsible "green" buildings, it is critical that such buildings be energy efficient. Hence a major proportion of the points awarded in the assessment for green buildings should go towards energy efficiency. Energy efficiency is important not only because of the environmental concerns surrounding energy use, but because among all potential environment facets of a green building it provides by far the most economic return. Energy efficiency is easy to implement and practice both at the design stage and the operational stage. It is therefore necessary to develop a realistic building energy efficiency rating system especially for office buildings.

2. Overall Thermal Transfer Value (OTTV)

The solar heat gain through the building envelope constitutes a substantial share of cooling load in an air-conditioned building. Whereas, in non air-conditioned buildings, the solar heat gain causes thermal discomfort. To minimise solar heat gain into a building is, therefore, a very important consideration in the design of an energy efficient building.

A design criterion for building envelope known as the overall thermal transfer value (OTTV) has been adopted in Malaysia. The OTTV requirement is simple, and applies only to air-conditioned buildings. The OTTV aims at achieving the design of building envelope to cut down external heat gain and hence reduce the cooling load of the air-conditioning system. The building envelope includes all external elements of the building and the performance measure generally covers both the heat conduction and solar transmission aspects. The OTTV is a single number index that measures the resistance of the building envelope to heat gains. The OTTV formulation is performance based. Its formulation allows professionals responsible for the design and construction of buildings freedom to innovate and vary important envelope components such as type of glazing, window size, external shading to windows, wall colour and wall type to meet the maximum OTTV criteria.

The Malaysian OTTV formula takes into consideration two basic components of heat gain through the external walls and windows of a building. These are:

Heat conduction through opaque walls
Solar radiation through glass windows

The original Malaysian OTTV formula as developed by J.J. Deringer et al April (1987) and specified in "MS 1525:2001 Code of Practice on Energy efficiency and use of renewable energy for non-residential buildings" published by the Department of Standards Malaysia (2001), is as follows:

$OTTV_i$ for a fenestration at a given orientation i is,

$$OTTV_i = 19.1\alpha\,(1 - WWR)\,U_w + (194 \times CF \times WWR \times SC) \qquad \text{Eq. 1}$$

Where,

α	is the solar absorptivity of the opaque exterior wall
WWR	is the window-to-gross exterior wall area ratio for the orientation under consideration.
U_w	is the thermal transmittance of opaque wall (W/m^2K)
CF	is the solar correction factor
SC	is the shading coefficient of the fenestration system

The OTTV is the area-weighted average of the $OTTV_i$ for the different orientations.

The MS 1525:2001 specifies that the OTTV of building envelope for a building, having a total air-conditioned area exceeding 4000 m^2 and above, shall not exceed 45 W/m^2.

The inclusion of solar absorptance (α) was new (included as typical Malaysian construction practice use little or no insulation in the walls) and in the interest of developing an equation that is both accurate and simple to use, the OTTV formula omitted the input for the U-value for glazed area as analysis indicated that conductance (as distinct from radiative) gains through windows do not contribute substantially to changes in energy use for the Malaysian climate conditions.

The Malaysian OTTV is related to the chiller load according to the following equation:

$$\text{Chiller load} = k_1 + k_2\,(OTTV) \qquad \text{Eq. 2}$$

where k_1 and k_2 are regression coefficients. The coefficients were determined by the method of least squares. The constant k_1 embodies internal gains from lights people, equipment etc. Since the value of the Solar Factor (SF) is known, the k_2 constant can be isolated from each physical coefficient in the OTTV equation, revealing the estimated values of the indoor-outdoor temperature for the fenestration (ΔT) and equivalent indoor-outdoor temperature difference for the opaque wall (ΔT_{eq}). Simulation studies were performed with data from a wide variety of buildings and using hourly weather data. For Malaysian climate, which is constant throughout the year, the values of (ΔT) and (ΔT_{eq}) show very little variation. Hence, the OTTV can be taken as most appropriate to reflect the impact of the building envelope on the energy use for air conditioning the building. It is noted that ASHRAE Standard 90.1-1989 has replaced OTTV with prescriptive criteria for window-wall ratio and thermal transmittance of envelope elements as stated in the work by Yik and Wan (2004). Also mentioned in the work by Yik and Wan (2004) is that for buildings situated in a sub-tropical climate region like Hong Kong, research studies showed that acceptable correlation between OTTV and energy use for air conditioning (with all other things being equal) could be achieved only if the heat transfer in buildings during the cold months were ignored.

When the MS 1525 was recently updated in June 2007 the OTTV formula was revised as:

For a fenestration at a given orientation,

$$OTTV_i = 15\ \alpha\ (1 - WWR)\ U_w + 6(WWR)U_f + (194 \times CF \times WWR \times SC) \qquad \text{Eq. 3}$$

where,

U_f is the thermal transmittance of fenestration system ($W/m^2\ K$);

The limit for the OTTV of building envelope for a building, having a total air-conditioned area exceeding 4000 m^2 and above was revised to 50 W/m^2.

Whilst the solar absorptance was maintained an additional term to include the solar conductance through the fenestration was introduced. This was to improve the accuracy of the equation and also accommodate new technologies such as double glazing, which would not have been reflected in the previous formula.

The Low Energy Office (LEO) of the Ministry of Energy, Water and Communications completed in September 2004, being the showcase of energy efficient building in Malaysia with the most energy efficient features has an OTTV of 31.4 W/m^2.

3. Building Energy Index (BEI)

Building operational energy efficiency is measured by the Building Energy Index (BEI). The BEI is the global yearly energy consumption of the entire building divided by the air conditioned floor area. The target of the LEO was 100 $kWh/m^2/yr$, and the reference value is 275 $kWh/m^2/yr$. Figure 1 shows different key figures of building energy indexes.

In the "*Guidelines for Energy Efficiency in Buildings-1989*" published by the then Ministry of Energy, Telecommunications and Posts (December 1989), four typical buildings are defined to represent different expected levels of energy use in Malaysia. These four levels are: worst case, base case, proposed standard case and good practice case.

- The worst case represents buildings that are among the most energy intensive buildings that might be encountered in Malaysia today. BEI = 240 $kWh/m^2/yr$.
- The base case building reflect a typical range of construction and energy use features now prevalent in Malaysian new commercial building construction. BEI = 166 $kWh/m^2/yr$.
- The proposed standard reflects the level of energy efficiency expected to be achieved by the proposed Guidelines. BEI = 136 $kWh/m^2/yr$.
- The good practice represents a combination of energy efficient practice (including daylighting) that surpasses the requirements of the Guidelines proposed. BEI = 98 $kWh/m^2/yr$.

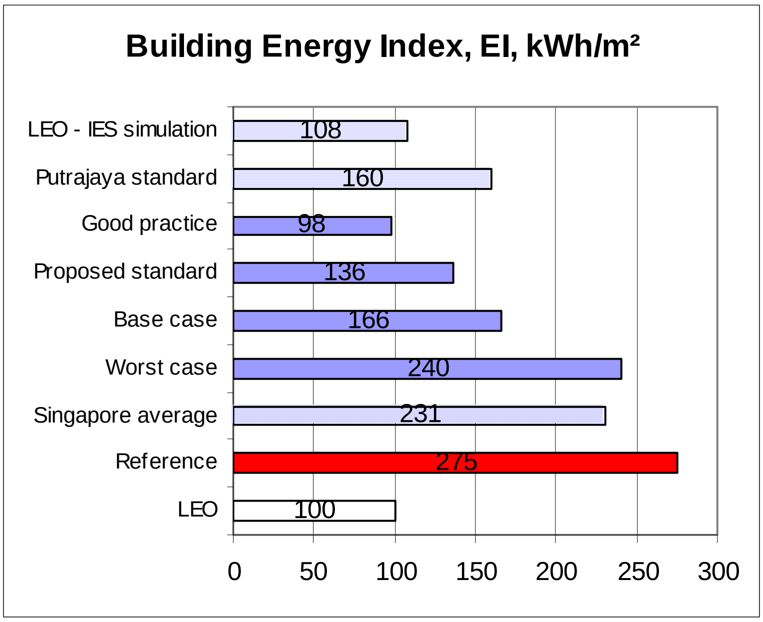

Figure 1: Different values of BEI.

The BEI is used as the indicator for the LEO energy efficiency. The energy consumption of LEO was reduced by installing a number of different energy savings technologies in the building. After one year of monitoring and fine tuning, calculations have shown an BEI of 108 kWh/m²/yr for the LEO. To estimate the savings of the extra energy efficient technologies a reference energy consumption has been defined. The different reference consumptions are described below.

During the design period of the LEO building the building energy index was estimated as 100 kWh/m²/yr and it has been set as a target energy index. Also in the design phase a reference BEI of 275 kWh/m²/yr was estimated according to inefficient practice for new office buildings. The calculation of the reference BEI has been done by running the same model but without any energy savings initiatives. That means an energy saving of 64% has been estimated for the LEO building compared with the reference building. The estimated distribution of the energy consumption for cooling, lighting and equipment (including office appliances) is shown in Figure 2. Both indexes are calculated with the simulation tool – ENERGY-10 with Kuala Lumpur weather as input to the model.

ENERGY-10 is a conceptual design tool for low-energy buildings. It is the software component of a project called Designing Low-Energy Buildings with ENERGY-10, conducted for the U.S. Department of Energy (DOE). The program does hour-by-hour simulations for a typical year.

The BEI is an operational index which indicates the specific energy consumption of the building. In many instances it is used as the performance indicator. It represents the energy consumed by the air conditioning, lighting, office equipment, etc. It was well verified that floor area is a major indicator of energy consumption in commercial buildings, as stated by Lee (2005). The justification for basing the BEI on the conditioned area is that in office buildings the major energy end use is air conditioning and all the service activities take place in the air-conditioned area. Energy consumption is also dependent on the number of hours of operation of the equipment. In the original OTTV analysis, operation hours are taken as 55 hours per week and 50 weeks per year (allowing for two weeks of holidays) resulting in 2750 hours per year.

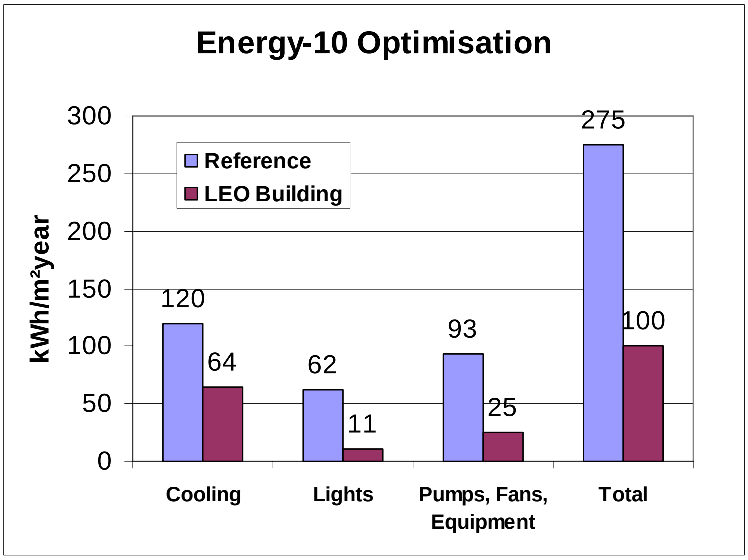

Figure 2: Distribution of the LEO Building energy index

4. Energy Rating System

Both the OTTV and the BEI can be varied during the life time of the building. Major retrofit to the building envelope such as change in the fenestration will change the OTTV. Replacement of equipment/appliances with energy efficient ones, retrofit of lighting and air conditioning systems will change the BEI.

An energy rating system is proposed which will have to incorporate both the OTTV and the BEI. OTTV is representative of the passive features and BEI is representative of the active features. Whereas OTTV is independent of the number of operation hours, BEI will increase with number of operating hours. A specific BEI needs to be introduced which is the BEI divided by the number of operating hours. The weighting of the OTTV and the specific BEI to the energy rating system needs to be considered. It is suggested that the weighting be 30% of OTTV and 70% of specific BEI i.e.

$$\text{Energy rating index} = 0.3(\text{OTTV}) + 0.7\,(\text{specific BEI}) \text{ in units W/m}^2 \qquad \text{Eq. 4}$$

For example, the building conforming to the MS 1525:2001 will have:
Energy rating index = 0.3(45) + 0.7(136 x 1000/2750)
= 48.1 W/m^2

For the LEO building,
Energy rating index = 0.3(31.4) + 0.7 (108 x 1000/2400) based on 2400 operation hours
= 40.92 W/ m^2

Following this, the energy rating system proposed is as in Table 1

Table 1: Proposed Energy Rating System

Energy rating index	Indication	Energy Efficiency Rating
< 45 W/m^2	Very efficient	A
44 W/m^2 - 50 W/m^2	Efficient	B
49 W/m^2 – 60 W/m^2	Satisfactory	C
> 60 W/m^2	Inefficient	D

It must be stressed that rating indicators are intended to allow comparison of energy performance between similar typical buildings. The 'inefficient' performers are most likely to offer the best cost effective opportunities but improvement should even be possible for those classified as 'efficient' and 'very efficient'. As the average performance of buildings continues to improve, what is today considered 'efficient' may eventually be regarded as 'satisfactory' or 'inefficient'. Users should not therefore be content simply because a classification of 'efficient' is achieved under the present ratings, but should maintain efforts to improve efficiency.

5. Conclusion

A building energy rating system for Malaysian office buildings is proposed combining both the Overall Thermal Transfer Value (OTTV) and the Building Energy Index (BEI). The proposal needs to be applied to a number of office buildings before it can be implemented. What is important is that it reflects the contribution of the passive and active elements of the building to its energy performance. It is necessary to emphasize that "green buildings' must be energy efficient and for this purpose at least 30% of the weightage for assessment of "green buildings' should be given to energy efficiency. It is encouraging to note that the Singapore Green Mark criteria has allocated 35% points for energy efficiency.

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EXPERIENCES FROM ENERGY CERTIFICATION OF EXISTING BUILDINGS

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Abstract

Heating and cooling of buildings puts a heavy stain on the energy budget of almost every country. In several European countries 40% to 50% of all energy is spent on controlling the indoor climate (mainly the temperature level) of buildings. Through several research studies it has been found that energy can be saved both for new and existing buildings but actual savings are only realized if they are identified and prioritized by the house owners etc. An important measure in identifying potential savings in buildings is energy certification in which an energy expert examines buildings and provides written documentation of potential savings. Energy certificates for buildings are part of the legislative framework and are implemented all over Europe these years. This paper provides an overview of different building energy certification systems in Europe as well as it highlights positive and negative experiences gained working with energy certificates.

Keywords: Energy certification, Building renovation, Energy savings, Legislative framework

1. Introduction

Energy efficiency is an area of growing interest in many countries worldwide. Europe with its 27 countries consumes 20% of the world's annual oil production only has 1% of the known oil reserves (EIA, 2007) and is thus dependent on import of energy to keep the economy running and growing. Currently, Europe imports 50% of its energy, and it is expected that Europe's import will increase to 70% within the next two decades if no measures are taken (European Commission, 2000). Table 1 shows the proven reserves, production and consumption of oil and natural gas for a number of countries/regions.

Table 1. Proven reserves, consumption of oil and natural gas (EIA, 2007)

Country/region	Oil			Natural gas		
	Proven reserves [10^9 bbl]	Consumption [10^3 bbl/day]	Reserves-to-consumption [years]	Proven reserves [10^{12} ft^3]	Consumption [10^9 ft^3/year]	Reserves-to-consumption [years]
World	1317.0	82594	44	6182.0	1037000	60
Europe	15.8	16307	3	180.3	20362	9
Denmark	1.3	185	19	2.5	176	14
Germany	0.4	2650	<1	9.0	3566	3
Asia&Oceanica	33.4	23341	4	419.5	14586	29
China	16.0	6400	7	80.0	1655	48
India	5.6	2450	6	38.0	1269	30
Japan	<0.1	5353	<<1	1.4	3081	<1

Malaysia	3.0	515	16	75.0	1172	64
Indonesia	4.3	1200	10	97.8	1325	74
Philippines	0.1	342	1	3.5	102	34

Of the countries/regions shown in Table 1, very few have oil and gas reserves that will last more than a generation. Countries like Denmark and Malaysia which are current net-exporters of oil and natural gas will within the next 15-20 years depend on import of energy which will cause a deficit in the balance of payment.

The single largest contributor to the energy consumption is buildings (European Council 2002). 41% of Europe's energy consumption is spent in buildings (private houses, offices etc.) – of which the majority is assumed to be used for maintaining the indoor temperature. This does not even cover energy spent on heating/cooling of buildings in which industrial processes takes place (e.g. a factory or offices in connection with factories). Therefore, the percentage of energy spent on heating/cooling of buildings may well be well further up into the 40ies.

In order to postpone the day when energy reserves run dry, it is important to obtain savings on the energy demand. Figure 1 shows that it is possible to obtain the economical growth (shown in GDP = Gross Domestic Product – market value of products/services) while keeping the energy consumption at a constant level.

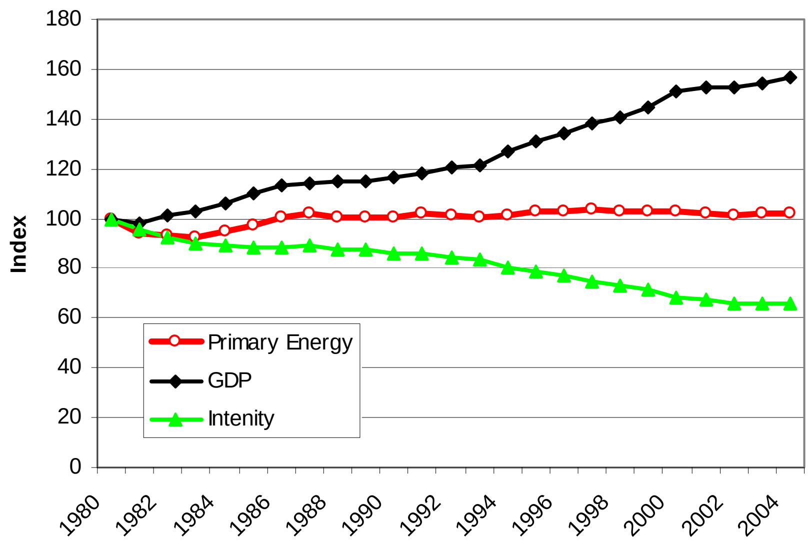

Fig. 1 GDP and primary energy consumption for Denmark year 1980-2005 (Danish Energy Authority 2006a)

Figure 1 shows constant energy consumption throughout the years despite economical growth and is a result of continuous focus on energy savings in both households and industry. Energy savings do not happen automatically but require awareness. One way to bring awareness to the potential savings is to create an energy certificate.

Energy labels are made for a large variety of items e.g. household appliances (refrigerators, washing machines, ovens etc.). In periods, the best products on the Danish market have been subsidised. This has really created a pull from the market is refrigerators. Figure 2 shows the share of sales of refrigerators with different energy efficiencies.

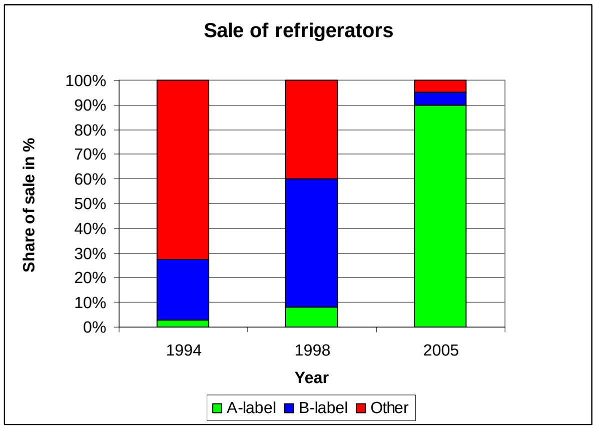

Fig. 2 Share of sales of refrigerators with different energy certificates

The energy label of a refrigerator shows an energy related ranking with a scale from “A” to “G” with “A” being best; “G” being worst. Energy labels for refrigerators were introduced in the early 1990ies. By the end of the 1990ies, a Danish Electricity Saving Trust (funded by electricity consumers) was founded which, through PR (television spots, commercials etc.) and subsidies created awareness of energy certificates for such household appliances.

Energy labels for refrigerators, freezers and other household appliances turned out to be very useful in providing information to consumers and providing a good basis for PR campaigns etc. As result, the energy labels are very well known by European consumers.

2. Framework for energy certification of buildings

With the adoption of a common European directive on the energy performance of buildings (European Council, 2002) energy certification of buildings became mandatory in the member states of the European Union. Being mandatory, the content of the directive had to be implemented in all member states. The directive contains demands that saving proposals are to be provided in connection with energy certification. However, the directive does not contain specific requirements for calculation methodology, content of energy certificates etc. but provides a framework on which the member states can perform their own modification. Energy certification of buildings is therefore not performed in the same way in the 27 member states of the European Union.

The framework developed by the European Union requires (among others) that:

1. The energy performance of buildings must be calculated based on a calculation methodology which takes into account factors that play an important role of the energy consumption of a building. Such factors are thermal insulation, heating and air-conditioning installations, renewable energy sources and design of the building.

2. When buildings are constructed, sold or rented an energy certificate is made available to the owner/prospective buyer/tenant. The energy certificate must include an energy-related benchmark (so consumers can compare and assess the energy performance of buildings) and must be accompanied by recommendations for cost-effective improvements of the energy performance.

3. Calculation methodology for calculation of energy performance of buildings

According to the European directive on energy performance of buildings, an energy performance calculation has to be completed for all buildings when constructed, sold or rented. Based on a description/inspection of a building the energy performance of a building must be calculated with the end-result expressed in an easy-to-understand way. A suggestion provided by the directive itself is to report the energy performance of a building as a CO_2 emission indicator (either in actual numbers (e.g. tons/year) or on an "A" to "G" scale as known from other energy certificates).

There are no specific rules for the calculation of energy performance of buildings, but the directive states that a number of important aspects must be included in the calculation. It is therefore up to the member states of the European Union to detail (and also increase the number of) these aspects. The aspects (written in *italic* with additional comments in plain text) to be included in an energy performance calculation are:

- *Thermal characteristics of the building (shell and internal partitions, etc.). These characteristics may also include air-tightness.*
  Includes information on transmission area and U-value/R-value (Thermal transmission coefficient or thermal resistance) of different building parts. Furthermore, energy-related and optical parameters for windows should normally be taken into account.

- *Heating installations and hot water supply, including their insulation characteristics*
  Type of heating installations (gas/oil burner, electrical heater), efficiency of heating installations, installations for domestic hot water including transmission losses from boilers, storages and pipes.

- *Air-conditioning installations*
  Efficiency of air-conditioning installations.

- *Ventilation*
  Ventilation strategy (mechanical/natural ventilation system), air volumes, heat exchanger (if applicable).

- *Built-in lighting installation (mainly the non-residential sector)*
  Includes information on areas of the building with lighting, lighting control (manual/on-off/continuous), daylight level, lighting usage (users turn off lighting when leaving the room) and power consumption of lighting system.

- *Positioning and orientation of buildings, including outdoor climate, passive solar systems and solar protection*
  Mainly relevant to transparent components (windows/doors) due to calculation of energy gained from the sun. It may also be relevant to e.g. roofs with low insulation levels as the sun may heat the building. The outdoor climate may be based on hourly, daily or monthly averages of temperature, sun intensity and other climatic parameters.
  Passive solar systems are mainly characterised by a solar shading factor and by the control strategy (manual/automatic).

- *Indoor climate conditions, including the designed indoor climate*
  Temperature setting(s) in the building (heated/cooled and unheated/un-cooled spaces). Temperatures may be provided for day/night situations as well as set points for cooling and additional mechanical ventilation.

Besides these aspects, the directive specifies that the positive effect of active solar systems (solar collector or PV cells) and other systems based on renewable energy and district/block heating/cooling systems should also be taken into account.

The formulation in the directive on energy performance of buildings has led to the development of revised national building codes in the various countries which in turn has led to the development of a number of software tools aiming at calculating the energy performance of buildings. A collection of these tools (for Denmark, Germany, and France etc.) is available at the Building Energy Software Tools Directory (DOE, 2007). These tools are only applicable in the country of their origin as they are closely linked to the national building code which is (most likely) different from that of neighbouring countries.

4. Energy certification of buildings in Denmark

As stated, an energy certificate has to be issued when a building is constructed, rented or sold. The energy certificate is based on an onsite inspection by a qualified and/or accredited expert where the current energy-related state (to the extent possible) of the building is examined. The actual energy performance of the existing building design is compared with current benchmarks (e.g. the "A" to "G" scale) which enable consumers to compare energy performance of different buildings. As benchmark for the energy performance, the "A" to "G" scale, however slightly more detailed, is used as the scale is well-known by consumers from e.g. refrigerators. Furthermore, the energy certificate must include recommendations for cost-effective improvement of the energy performance of the building (showing what is to be improved, its implication on the energy performance and the cost of improvement).

Figure 3, 4 and 5 show cut-outs from an example of an energy certificate (according to Danish legislation).

Reported energy consumption for heating

- **Costs including VAT and duties:** 293.000 DKK/year
- **Consumption:** 526 MWh/year
- **Reported for the period:**
January 1st 2005 – December 31st 2005

The reported energy consumption and costs are climate corrected by the energy consultant. Thus, the figures express an average year temperature-wise.

Energy label

Low consumption

High consumption

A1 is the best energy label that can be achieved, then A2, then B1, etc. G2 is the worst.

Fig. 3 Current energy consumption/cost of a building according to Danish example energy certificate

Building inspection

Building parts

- **Loft and roof**

Status:	The loft is not insulated except for a layer of clay pugging. The loft space is inaccessible for which reason the above-mentioned information is based on an estimate of the construction year of the building, etc.
	Building parts against the space under the roof space is inaccessible for which reason the above-mentioned information is based on an estimate of the construction year of the building, etc.
	Attics on the top floor are un-insulated.
Proposal 2:	It is recommended to insulate the walls of the space under the roof space and the partition against this space with at least 250 mm mineral wool. In particular, good insulation behind the radiators is essential.

Fig. 4 Building inspector's description of building parts according to Danish example energy certificate

Cost-effective savings

Here are the energy consultant's proposals to reduce the energy and water consumption in the building. There may be more proposals on the next page. The proposals below are elaborated in the building inspection section.

	Savings proposals	Annual savings in energy units	Annual savings in DKK including VAT	Estimated investment including VAT	Payback period
1	Thermovalves	15 MWh heat	8.000 DKK	15.000 DKK	2 years
2	Insulation of space under the roof space	50 MWh heat	26.000 DKK	113.000 DKK	4 years
3	District heating alternator	8 MWh heat 1300 kWh elec-tricity	7.000 DKK	50.000 DKK	7 years
4	Low-energy light bulbs	1.800 kWh elec-	3.000 DKK	3.000 DKK	1 year

Fig. 5 Cost-effective saving proposals for a building according to a Danish example on energy certificate

The current energy consumption of the building (Fig. 3) is provided for a "normal year" meaning that the stated consumption is increased/lowered depending on whether the stated period was exceptionally warm or cold. To provide consumers with a benchmark to compare the existing building with, an "A1" to "G2" scale is used showing the ranking of the building. Since energy labels were already well-known to the Danish public due to the success of energy labels for household appliances, energy certificates of buildings are issued using the same platform (graphical identity, ranking (from "A" to "G" etc.). As a comparison, the demand for new buildings in Denmark is equivalent to "B1".

During the physical inspection by the qualified expert, comments on the current state of the building are noted and provided in the energy certificate (Fig. 4). The qualified expert writes in plain language on the energy related aspects of the different building parts possible ventilation system, heating/cooling system, lighting and larger household appliances (refrigerator, washing machine etc.). Furthermore, comments are added regarding to water consumption (e.g. if replacement of old toilet is economical feasible). Besides the current state of the building and building parts, the qualified expert also provides suggested improvement to the building parts (not shown in Fig. 4) which will improve the energy performance of the building (e.g. adding insulation to the loft, replacing windows, installing thermo valves etc.).

The suggested improvements are shown in Fig. 5. Each improvement shows the estimated annual savings in heating and electricity (MWh, GJ or equivalent), savings in monetary units, estimated investment cost and payback period. The energy certificate also contains information on the combination of the individual improvements (as the total savings are not necessarily equal to the sum of the savings of the individual improvements). Costs of the different improvements are based on judgement from the qualified expert. The suggested improvements (Fig. 5) are items which should be completed as soon as possible as it is profitable to perform the improvement. If the building has to undergo a renovation for to other reasons it is often profitable to incorporate energy savings in the renovation. An example is a change of roof covering in which added insulation on the roof may often be profitable (judged by the marginal cost of the insulation) as the roof covering had to be paid anyway. Such information is also included in the energy certificate, based on the observations of the qualified expert.

4. Lessons learned regarding energy certification of buildings

Energy certification of buildings following the framework of the European Commissions (2002) directive on energy performance of buildings has been in force in a number of European countries for some years. The experience gained is summarised in the following:

- *Energy certificates identify a lot of potential savings*
  Due to the inspections, a lot of potential savings are identified, savings which would else have been hard to find if the consumer himself is not aware of the energy performance of the building. Consumers have a tendency of underestimate potential savings, and rather invest their money elsewhere in the building (new kitchen, bathroom etc.). The energy certificate brings the potential savings out in the open.

- *Energy certificates can be used as basis of campaigns*
  Since energy certificates and energy labels are well-known by consumers, they can be used in campaign material to create awareness of specific issues (insulation, pumps, boilers etc.) within energy upgrading of existing buildings.

Although the general feedback on energy certificates for buildings is positive (Jensen et al) a number of observations are highlighted.

- *Energy certificates do not work by themselves – other means should also be introduced*
  Although energy certificates provide useful information on the current energy performance of a building and profitable improvements of the energy performance (either as an isolated task or in connection with future renovation) the energy certificate has to be linked to other (perhaps financial) initiatives. The energy certificate does not in itself yield energy savings. Energy savings are not gained until improvements mentioned in the certificate are completed. It is therefore crucial that it is easy for consumers to initiate the profitable improvements perhaps by linking the energy certificate with a loan guarantee (payments for the loan can be taken from the savings on the energy bill) or contact information to the contractor etc. Otherwise, the energy certificate may as well be forgotten.

- *Energy certificates do not necessarily provide a consumer with the correct consumption*
  In cases where the energy efficiency of a building is based on a calculation using a piece of software it is rarely the case that actual energy consumption of the building corresponds with the calculated consumption. The Danish Energy Authority (2006b) initiated an investigation of this and concluded that the calculated heating consumption of a building was often more than 35% higher than the stated consumption. As profitable savings are calculated based on a calculated consumption, the profitability of the improvements may in some instances be questionable.

- *Existing owner is paying – but the new owner gets the benefits*
  As mentioned previously, the directive of the European Commission (2002) states that an energy certificate must be issued when a building is constructed/sold/rented. Typically, the cost of such an energy certificate (expenses for the qualified expert etc.) is covered by the existing owner of the building whereas the content of the energy certificate is of benefit to the potential owner (if the content is used). The existing owner has (often) very little interest in the certificate (but has to pay) and the potential owner (should) have.

5. The potential savings in the housing stock

As buildings have to undergo a regular inspection by a qualified expert in connection with the issuing of an energy certificate and a copy of the energy certificate may be kept at a government database, the energy certification scheme provides statistical data on the potential savings on heating etc. of the building stock.

In a Danish study more than 200,000 (Wittchen, 2004) energy certificates from small buildings were analysed and potential energy savings on space heating were calculated under three assumptions: 1) 50%

of external walls and floors with the poorest thermal performance (U-value) were upgraded to reasonable insulation level, 2) 50% of all roofs with the poorest thermal performance were upgraded to today's standard and 3) All windows were upgraded to today's standard. This study showed that 30% of the energy consumption for space heating in Danish residential houses could be saved.

The question remains if energy certification schemes can be relevant in hot climates. The main goal of an energy certificate is to provide information on profitable improvements to the energy performance of a building which is also relevant to the climate in South East Asia. Profitable improvements to the energy performance of a building also exist in warm climates, which have been documented in a number of studies by Roxul Asia (2006). Here, the energy consumption of a typical semi-detached house was reduced by around one third by insulation of roof and wall construction, reducing thermal transmittance of windows and installing a high-performance air-conditioning system.

Such savings would not have been realised if focus had not been on the subject of energy savings, and energy certificate is about creating focus.

6. Conclusions

It cannot be questioned that within the next decade or two many countries/regions will change from being energy exporters to becoming energy importers. As buildings are a major consumer of energy (40% of the consumption of most countries), energy savings within this sector is an important means to prolong the reserves of energy. A first step towards obtaining savings on the heating/cooling of existing buildings is awareness that improvements (quite often profitable) of the energy performance of building are possible. Energy certification of buildings, highlighting the current energy performance of buildings as well as profitable energy savings, has proven to be a good instrument in informing building owners.

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LEED IMPLEMENTATION STRATEGY FOR NEW SONGDO CITY INTERNATIONAL BUSINESS DISTRCIT DEVELOPMENT, REPUBLIC OF KOREA

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Abstract

This paper will share the LEED (Leadership in Energy and Environmental Design) implementation strategy for New Songdo City International Business District Development, Republic of Korea, which includes the first LEED-registered projects in Korea.

This 1500 acre private development of 350 buildings is a master-planned new city of commercial, institutional, retail, and residential facilities. It is a LEED-ND (Neighborhood Development) Pilot Project. The introduction of LEED in Korea for this city, schematically designed in the US and constructed by Korean contractors, provides an opportunity to enhance the global market for environmentally sensitive design, construction materials and methods, and building operation.

The implementation strategy addresses LEED documentation, which is new to Korean designers, contractors, and materials manufacturers. Gathering materials data and incorporating a new system into an established construction culture is challenging. The strategy is developed within a framework of goals, organization, communications, education, research, knowledge management and execution, all aimed at client and team success in achieving LEED Certification in concurrence with Korea's Green Building Certification System (GBCS).

Keywords: US Green Building Council, LEED, Korean Green Building Certification System, New Songdo City International Business District Development, Gale International, PB

1.0 Introduction

Over the last decade many agencies and not-for-profit organizations have moved the design and construction industry closer to sustainable practices by pursuing means and methods to define Sustainable Buildings (SB). In order to get these SB-defining initiatives started, there has been focus on the supporting science, technical issues, and design criteria to create policy, standards, and regulations, which has resulted in programs such as BREEAM, HK-BEAM, Green Star, NABERS, CASBEE, Korea's Green Building Certification System (GBCS), and LEED.

Many conferences over the globe offer a platform for sharing information on SB programs; however, sessions handling the details of implementation of the programs are rare and conferences focused on implementation are even rarer. And it is no wonder; implementation of these systems is not tidy. The systems are often new and undergo change to reflect best practice and improvements based on prior utilization. The systems often leave room for interpretation and misunderstanding, and implementation of systems covering the project from conception to operation is labor intensive.

A private joint venture (JV) between US developer Gale International and Korean contractor POSCO E&C is developing a new city on a blank slate in the Republic of Korea.

New Songdo City International Business District Development (New Songdo City) is a master-planned, high-tech, international business center on 607 hectares (1,500 acres) of reclaimed land along Incheon's waterfront, 64 kilometers (40 miles) south west of Seoul and is to be connected to the Incheon International Airport by a 6-mile bridge, which is under construction as a separate project outside of the JV. New Songdo City, with an estimated cost of 25-30 billion USD, is the largest private development project ever undertaken in the world and a ten-year project. Consisting of a convention center, retail and residential mixed use, international schools, hotels, hospital, offices, retail space, cultural and leisure venues, and neighborhood development facilities, New Songdo City is in an International Free Economic Zone (IFEZ) to attract multi-national corporations and foreign direct investment. Three hundred fifty buildings, a canal, and a central park will comprise the city. The project is in the early stage of construction with six buildings underway.

While best-practice urban planning was utilized for the master plan and high-quality building designs were placed for bid, the JV decided to seek LEED Silver certification for each of the buildings in the city and concurrently achieve GBCS for the residential structures while the first buildings were in early construction. The city is also a LEED for Neighborhood Development Pilot Project which is not covered by this paper.

LEED implementation involves adherence to a specific SB standard across three phases: design, construction, and operation, and must maintain the overall web of connections through each of the phases for documentation and review for certification.

The design and construction effort to build New Songdo City spans two continents and embraces the best practices of the US and Korea. There are three milestones in the process. Design starts in New York, USA with master planning, programming, schematic design and design development. The end of design development is the first milestone as the effort is moved to Korea. Korean architectural and engineering firms transform the design development package into construction documents adequate for tender. Award of the construction contract to a Korean engineering and construction firm is the second milestone. Completion of construction, commissioning and hand-over is the third milestone which starts operation.

The U.S. Green Building Council (USGBC), a non-profit organization of industry leaders, has developed the LEED (Leadership in Energy and Environmental Design) Green Building Rating System to define green buildings in a quantifiable manner. There are several LEED programs that cover different building types including Existing Buildings, Core and Shell, Commercial Interiors, Homes, Schools, Retail, Neighborhood Development, and New Construction. Implementation of LEED for New Construction or LEED-NC will be the focus of this paper, although there are some buildings registered with the USGBC as LEED for Core and Shell (LEED-CS). LEED-NC has eight prerequisites, including the most recently membership-approved requirement for 14% improvement in energy efficiency over base-line ASHRAE 90.1-2004. The balance of up to 69 points can be obtained as the project allows covering five main areas of environmental impact: sustainable sites, water efficiency, energy and atmosphere, materials and resources, and indoor environmental quality. The team works together to reach certification on an ascending scale from certification to silver, gold, and platinum.

Buildings seeking LEED certification are first registered with the USGBC by the project's LEED Administrator. For New Songdo City, these US-based designers are called LEED Facilitators. They handle the LEED Administration from registration to certification through USGBC's LEED-Online website, assigning documentation duties to responsible team members. After the project is registered, the project team must document per LEED and submit the documentation to the USGBC using LEED-Online. Designers, contractors and the JV will be involved in the documentation process by either tracking or uploading data directly to LEED-Online or providing documentation to those that upload. When the documentation process is complete, the LEED Administrator submits the application to the USGBC. If approved, the project will be

LEED Certified. By mid-2007, there were nearly 8,000 commercial and more than 6,000 residential LEED-registered buildings. More than 1,000 of those are LEED certified but only 44 are certified platinum, according to the USGBC.

The Korean Green Building Council (KGBC) was founded in 2000 and is a non-profit organization centered on promoting sustainable buildings. By the end of 2000 the Green Building Certification System, (GBCS) was established. Most residential buildings at New Songdo City will be certified under GBCS. GBCS implementation will not be covered by this paper.

PB is one of the world's leading planning, engineering, and program and construction management organizations and is headquartered in New York, New York. PB is contracted to perform combinations of construction management and construction services for four of the six buildings under construction. PB's CM and CS roles will not be discussed in this paper. In spring of 2007, PB was approached by the JV to direct the LEED documentation process for the construction side including researching construction materials and methods and educating the Korean design and construction team on LEED for all projects in New Songdo City.

PB's LEED Project Director joined the regularly occurring LEED coordination meetings at Gale International in New York in April of 2007. Those meetings turned into a focused team called the LEED Advisory Committee whose purpose is to keep the project moving forward on big ideas and identify challenges that need to be addressed through other venues. The LEED Advisory Committee meets bi-weekly via conference call and approximately every month at live meetings.

As the need for focused research and team coordination grew, PB added a LEED In-country Coordinator as full-time staff to the New Songdo City project office. This person supports the LEED Project Director and provides guidance to two support staff, LEED In-country Deputy Coordinators.

2.0 Opportunity Comes with Challenges

The opportunity at hand is to participate on an international team to realize the JV's desire to achieve LEED-ND certification for a new city with all buildings certified by the USGBC. This has not been done before. The combination of LEED-ND and LEED-NC is new to the USGBC, this large-scale LEED-NC registration by one owner is new, and LEED in Korea is new.

The challenges of LEED implementation for New Songdo City are complex. Using LEED for the first time in Korea, concurrent implementation of LEED with three tiers of design and construction, the decision to use LEED after ground breaking, and the intersection of cultures and languages builds upon one another to create a situation that calls for deliberate means and methods for team organization to meet LEED implementation.

Using LEED for the First Time in Korea. LEED is not vague in its requirements for materials and methods documentation. Asking a contractor to use an eco-friendly product is not enough to reach LEED certification. The designers must conceive their buildings with available materials in mind, and write the specifications in a way that will procure materials that meet LEED criteria. The team should make certain that there are at least three venders of each product available in Korea so that a competitive bid is received.

At New Songdo City, the material and methods need to be understood on two levels. First, for the buildings that are in construction, and secondly for buildings that are still in design in the US. This second level ties into the work being done by YRG Sustainability Consultants, commissioned by Gale International, for a LEED guidebook that will be delivered to third-party developers to guide them in reaching LEED certification for their buildings.

When PB's LEED Project Director was brought on board, the challenge of identifying suitable materials was evident. It is customary for LEED projects to procure materials that are extracted, processed and manufactured within an 804 kilometer (500 mile) radius to support local industries and reduce transportation. It was not known what materials were available in Korea namely with documented data on Solar Reflectance Index, plumbing fixture water flow, refrigerants for HVAC and fire suppression materials, recycled content, materials harvested within a ten-year cycle, and VOC (volatile organic compound) content for adhesives and sealants, paints and coatings, carpet systems, and composite wood and agrifiber products.

Under PB's direction, the Construction Materials and Methods in Korea (CMMK) research encompass construction and operation methods with respect to LEED such as the proper approach for construction activity pollution prevention and construction waste management and availability of Renewable Energy Certificates (RECs) for green power. A recently added feature of the CMMK spreadsheet is a tab for every LEED credit that captures the lessons learned by the entire team.

The difficulty of a US-based CM team extracting product data from manufacturers for the CMMK was identified early. In Korea, products are certified by the government for use in construction. Once certified, there is no need for product data sheets unlike the US market where all manufacturers have prepared data sheets for use by designers and contractors. An unexpected cultural challenge emerged. The Korean CMMK research team has been ingrained with the idea of certified products and it was very difficult to explain the need for the product data. Researchers were discussing a Memorandum of Understanding (MOU) between a Korean certification organization and international parties as method to reach LEED product certification. It was explained that LEED is a certification process for an entire building system and is not concerned with certification of products. Of course, for every rule there is an exception as found in LEED's requirement for Forest Stewardship Council (FSC) certified wood, the Carpet and Rug Institute Green Label Plus certification program and in Green-e certified RECs.

Korea does have a certification program that is useful in gathering lists of potential products. The Korea Eco-products Institute has established the Eco-Label program. This program identifies criteria used to analyze the qualities of the products. Certified products are added to an online-database. The standards and list of product categories are available in English, but the detailed information required by designers in the US such as product name, contact information, and specifics of the product is in Korean. This lead to the clear need for an international effort for the CMMK.

The Korean design and construction teams went into the development with the understanding that the projects would be designed in English in the US and translated in Korea and assigned personnel accordingly. When those teams were brought onto the project, there was no discussion of LEED since it had not yet been embraced by the JV. When the JV started to discuss the implementation of LEED, there was a sense of panic from the Korean team since they perceived that they would be doing more to comply with an unknown SB rating system, and rightfully so; LEED documentation does add to the construction documentation although it is interwoven into the drawings and specifications. In this case, since LEED was adopted after groundbreaking, it is unfortunately viewed as a separate, resource consuming program that competes against the design and construction duties. This challenge required an implementation strategy that is not only physical, but handles the emotional charge of the situation.

Concurrent Implementation of LEED with Three Tiers of Design and Construction. There are three tiers of projects: Tier 1 includes buildings that are currently under construction. Tier 2 includes buildings that are currently in the design stage in Korea and will be moving toward the construction stage, and Tier 3 includes buildings that are in the conceptual design stage in the US. The approach for requests for information and documentation of research findings must be clearly understood in relation to the tier structure. For example, a request for an update on available materials from the contractors is typically much more time-sensitive than requests coming from the US design team for buildings that are not expected to reach the construction contract stage within a year. Tier one projects have held LEED kick-off meetings and several full-days of LEED workshops were held in late August 2007 to accelerate the LEED process. These workshops were followed by shorter LEED workshops for each building.

Using LEED after Ground-breaking. Most LEED projects are programmed with LEED in mind, providing the design team ample time to integrate LEED requirements into the construction documents. The front end of the specifications contains Section 018113, Sustainable Design Requirements, which describe the submittals required by the contractor; The LEED Action Plan provides the contractor with a platform to propose how LEED will be achieved and also allows the design team to provide feedback and guidance; the LEED Progress Report updates the Action Plan with each Pay Application; and, woven within the full specifications are LEED Documentation Submittals to cover continuous metering product data, waste haul tickets, recycled content for products, regional materials product data, construction indoor-air-quality management plan, building air flush-out procedures, adhesives and sealants product data, carpet product data, paints and coatings product data, and composite wood or agrifiber products product data. LEED submittals are reviewed under the same process as any other submittal.

The construction at New Songdo City is fast-track and resembles design-build. When the JV decided to have all buildings LEED Certified, it was understood that it would take place in the form of Potential Change Orders (PCOs) because the original contract documents do not contain references to LEED and need to be amended via the implementation process. Fundamental building commissioning is a pre-requisite to LEED. In order to get a commissioning agent (CxA) on board quickly, the JV asked the engineers of record of the commercial buildings to be the CxA of the residential buildings and the engineers of record for the residential buildings to be the CxA of the commercial buildings. The contract for CxA services on the construction side is yet to be determined.

The Intersection of Cultures and Languages. It is a serious challenge when an entire city is selected to be LEED certified in a country that has no experience with LEED and has a different construction management system and another language.

The Lonely Planet guidebook explains that Korea is a Confucian nation with roots established in 2333 BC. The results of centuries-old behavior based on strict guidelines that call for high-levels of respect to be paid to men and the elderly makes following loose guidelines from outside of the Korean relationship hierarchy difficult. There is no denial that the Koreans take great pride in their strong work ethic and ability to survive against the odds. There is pleasure taken in team success though the risk of making mistakes along the way can often freeze the potential for junior staff to initiative problem solving without a supervisor's direction. The Asian culture of keeping face and not outdoing one's superior is to be found in Korea and from the US point of view is a limiting factor.

US team members are generally less structured and thrive on system flexibility. American slogans such as "Good old American Know-how" and "Necessity is the Mother of Invention" epitomize the US approach to the project. The team moves forward and when an obstacle is found, all are encouraged to offer ideas to overcome the issue at hand. Senior level staff appreciates junior staff taking initiative and generally encourages the spirit of entrepreneurship and rewards accordingly. A team leader of a group of successful individuals looks good in the American system. Pride is found in being a member of the team that reaches success. The work ethic may be characterized by being enticed to participate in projects that make positive changes or provide a personal connection to the worker. The US is considered to be a very young and inexperienced country at just over 200 years old and somewhat of a child compared to ancient cultures such as Korean.

3.0 A Successful Implementation Strategy

A successful implementation strategy transforms challenges into building blocks. Gathering materials data and incorporating a new system into an established construction culture is challenging.

The LEED Implementation Strategy. New Songdo City has a long term action plan to achieve LEED certification for 350 buildings. The plan integrates the efforts of teams on two continents to document the LEED criterion during design and construction. The three core elements of the plan are captured in the verbs: Align, Know, and Do.

Align the organization of the team to accomplish the work. Task organization tailors the team to meet the needs of the projects. This framework establishes the line of communication and supervision and is flexible, adaptable, expandable, and customized.

Know how and where collaboration, coordination and communications occur. Tracking and visibility are critical to sustain focus. Focused efforts lead to results and success.

Do the work that needs to be done. Well-defined steps executed consistently in sequence accomplish the work allowing for reproduction of results.

4.0 Discussion

Comparison of measurements and standards brought unforeseen complications. For example, when the CMMK team researched the VOC levels of adhesives there was no equal basis between LEED and Eco-label. LEED measures VOCs in grams per liter, while the Eco-label certification standard *EL251. Adhesives* notes that qualified products have VOC levels at 0.1% of weight or below. This means that for the researchers to be sure about the LEED applicability of an adhesive, they either need to get the g/l information from the manufacturer, or find out what the weight of each Eco-label product is to determine the maximum amount of VOCs to convert to the LEED measurement. The sales staff does not have product data information and referred the CMMK researcher to the manufacturers' research and development (R&D) department. The manufacturers' R&D staff is mostly unwilling to provide data for their proprietary products. In their defense, the products are certified by the Korean government and possibly Eco-label, so there should be no question of the quality of products. The activity of selecting potential products to convert to the LEED measurement is time consumptive, but for instances where inquiries of the team has been fruitless, they have chosen to convert the VOC levels to LEED equivalents to support the JV's goal for LEED certification.

Align. In order to inform and invite the engineering and construction (E&C) teams to join the CMMK, PB's LEED Project Director presented *LEED Program Management for Construction* at New Songdo City to representatives of the JV, construction managers, construction supervisors, and contractors. At the end of the meeting, each company selected one person to join the newly founded CMMK team and has since worked to further develop the CMMK spreadsheet started by PB. This research is then a shared resource between the US and Korean teams for all phases of the projects, linked by the LEED Project Director who acts as a bridge.

Know. The decision to use LEED after ground breaking raised a challenge concerning low-flow plumbing fixtures. The residential show rooms were constructed before LEED was adopted for the projects. Units have sold with the understanding that the owners would receive what they saw in the show room. Changing the materials of the units would require a change to contract, which is a complex issue that the JV did not want to administer. Tracking and visibility of the CMMK gave the team the understanding that fixture flow was of interest to others, and allows a platform for identifying the conflict for the construction team and recording data on the most efficient fixtures for projects to be designed. Tracking and visibility encourages the team to think clearly and then anticipate, simplify, coordinate, and recommend.

Do. Education is a large part of the implementation plan. On-the-job training is the primary technique for becoming an effective practitioner. "Learn by doing" is the reality of the implementation strategy. LEED Accredited Professionals (AP) are recognized by examination of a defined body of knowledge through the USGBC. The LEED APs know that successful LEED implementation is in parallel to and embedded in existing design and construction protocols. The LEED APs at New Songdo City conducted the LEED workshops to provide a tailored approach including project-specific details and Korean translation.

After the workshop, the Korean team is ready to systematically collect documentation to support verification. LEED credit templates organize the information used in verifying a prerequisite or credit. Additionally, supporting documentation is organized and collected for reference, all using LEED-Online.

Education and application of the criterion eliminate the anxiety of the unknown. Application of the criterion, documentation, submission and verification reinforce the understanding that LEED process implementation techniques are easily embedded in existing design and construction practices.

Communication. The team language on both the US and Korean side is English. Contracts are signed in English, but executed via plans, specifications, and submittals in Korean to accommodate the majority of laborers. Several established forms of electronic communication exist, and some are in flux. There is no central system that allows all team members access across the time frame of the development.

In the US, Gale International has an in-house server that allows knowledge transfer within their organization. Information that is to be shared with and among the LEED Advisory Committee is currently uploaded to a simple FTP site that has a basic folder structure that is pliable by all members of the community. There is no notice application or ability to hold threaded discussions. To answer the call for a more robust system, PB instigated their secure proprietary system, ProjectSolve[2], which features remote access, group communications, file administration, on-line meetings that share desktops, and notification of uploaded information with direct live links. Gale International made the decision to house the LEED Advisory Committee data on their own system in order to maintain complete ownership. This system is under development and is not complete at the time of delivery of this paper.

The Korean design and construction teams use a sophisticated PMIS managed by Doalltech, which allows for a wide variety of organizational techniques based on a pre-planned documentation and dissemination structure. Attributes include a calendar with meeting invitation and acceptance capabilities, email, mail with pre-set forms, a quick-glance schedule, document upload, document approval processing functions, and project organizational structure that includes names, contact information, and photos of the individuals. PB met with Gale International Korea (GIK) and Doalltec to recommend the incorporation of LEED into the PMIS. A LEED tab was added to the core of the PMIS, which is consistently shown in all applications. The LEED tab hosts a LEED home page that will contain a pull down list of the LEED registered buildings, resource hotlinks to the USGBC, *Introduction to LEED* presentation, standards used by LEED, the LEED programs in English and in Korea, the CMMK research file, and templates for the contractors to streamline the requirements of the specifications.

CMMK. The CMMK team sends information to PB's LEED Project Director to include in the spreadsheet. It is currently housed within PB's server, but will be housed on the PMIS once LEED formatting is complete. All parties will be invited to provide updates to the spreadsheet as information is gathered. The results will be copied to the LEED Advisory Committee server for utilization.

LEED Implementation. For Tier 1 projects, there are two conditions for LEED implementation. One adds specifications for LEED implementation, and the other involves design changes and the additional specifications for LEED implementation.

For both conditions and for each project, the design team has submitted a draft LEED Checklist for Korean review. Specification Section 018113, Sustainable Design Requirements will be edited to reflect the LEED prerequisites and credits that are to be achieved and provided to the contractors as a PCO. For projects with design changes, the designers will also provide sketches and supplemental information for LEED compliance. For both conditions, the contractors will submit their comments. Under agreement, the contractor will then submit to Section 018113, Sustainable Design Requirements with the LEED Action Plan as a first step for Owner's review for acceptance. Once the LEED Action Plan is accepted, it will be updated as the LEED Progress Report in concurrence with the Interim Payment (IP). As the job progresses, LEED continuous metering product data, waste haul tickets, recycled content for products, regional materials product data, construction indoor-air-quality management plan, building air flush-out procedures, adhesives and sealants product data, carpet product data, paints and coatings product data, and composite wood or agrifiber products product data will be collected.

Conclusion

LEED implementation for New Songdo City is a full-time effort due to magnitude, the introduction of a new SB program in Korea, transfer of US design to Korean construction, and language and cultural challenges. It takes effort to bring obstacles to the attention of the team for quick resolution and to prepare the way for a smoother path for projects yet in design. This 1500 acre private development of 350 buildings is a master-planned new city of commercial, institutional, retail, and residential facilities. The introduction of LEED in Korea for this city, designed in the US and constructed by Korean contractors, provides an opportunity for the Korean team to enhance the global market for environmentally sensitive design, construction materials and methods, and building operation. LEED is internationally recognized and Korea is getting ready to be leaders in this global program.

Acknowledgements

A project of this size includes countless individuals and numerous organizations. Acknowledgement goes to the following organizations that are involved in the design and construction of New Songdo City: The JV, Gale International and Posco E&C, as well as Arup, Baum Architects Engineers and Consultants, Cook + Fox Architects, Cosentini, CS, Daewoo E&C, Gansam Partners Architects & Associates, Heerim Architects & Planners, HOK, Lehr Consultants International, LLP, Integrative Design Collaborative, KPF, Kunwon Architects, PB, Terrapin Bright Green, Whitman Strategy Group, and YRG Sustainability Consultants among others that may not be listed here.

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WHY MONITORING & VERIFICATION & BUILDING RATING ARE VITALLY IMPORTANT IN SUSTAINABLE BUILDING INDUSTRY

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Abstract

Designing new buildings or retrofitting existing buildings face challenging questions to how to evaluate building performance accurately at the design and after construction stages as well as how to compare building performance among each others. Developing and adopting effective Monitoring & Verification procedures and building performance rating system are critical in the success of the globally emerging sustainable building industry,particularly in the developing countries.

The paper will discuss the role of Monitoring & Verification Protocols and building performance rating in supporting the globally emerging sustainable building industry. Challenges and opportunities in establishing effective Monitoring & Verification and building rating in the developing countries will also be addressed. The pros and cons of using readily recognized Monitoring & Verification Protocols and Building Rating systems are highlighted.

A number of supporting examples will be provided for supporting the needs for effective Monitoring & Verification Protocol and building performance rating system in developing countries.

Keywords : Monitoring & Verification, Building Rating, Green Star, Sustainable Buildings, Developing Countries.

1. Introduction

Energy consumption in building sector represents substantial portion of the national energy balance particularly in the developing countries. For example, it is estimated that commercial and residential buildings consume about one-third of the energy consumed in the whole United States, and two-thirds of all electricity.

Further, buildings produce roughly a third of carbon dioxide emissions and other emissions that harm air quality and contribute to global warming.

Accordingly improving energy performance in buildings would have a significant impact on sustainable economic development and improve environment at country and global levels.

One of challenging issues facing the Energy Efficiency investment in new and retrofitted buildings is how to estimate accurately the improvement in building energy performance. This is critical for supporting investment in Energy Efficiency in buildings.

In addition, the ability of government, building owners and occupants to benchmark and rate reliably building energy performance and environmental impact are critical in the current growing sustainable building industry.

Accordingly, developing and using standardised approach for estimating and evaluating building energy performance and building rating are highly important for supporting the growth of sustainable building industry.

Internationally, there are a number of well established building energy Monitoring & Verification (M&V) and rating schemes. However, using any of existing energy M&V and building rating systems in a county requires adaptation to suite the country's existing energy efficiency and building industry status.

The following paragraphs shed lights on the role and development of Energy M&V and building performance rating systems highly need for supporting the globally emerging sustainable building industry, particularly in the developing countries.

2. Role & Benefits of energy M&V Protocol in Sustainable Building Industry

Estimating reliably and accurately the level of improvement in building's energy performance are essential in justifying investments in building energy efficiency.

Estimating the savings in energy consumptions resulted from using certain EE & RE technologies and techniques is one of challenging issues in the field of implementing EE & RE.

Accordingly, using well established energy Monitoring and Verification (M&V) Protocol for developing effective energy M&V plan plays a critical role in initiating and implementing Energy Efficiency (EE) and Renewable Energy (RE) projects including new and existing buildings. The M&V plan establishes at the outset of EE & RE project well defined methodology of energy and energy related data collections and process of calculating energy savings.

The effective M&V plan should strike a balance between the cost, desirable confidence and accuracy levels of M&V system.

It is essential that all parties involved in implementing EE & RE project to agree from start on the M&V plan to be used in to evaluate the energy savings and performance throughout the EE & RE project implementation.

2.1. Benefits of Using Well Recognised Energy Monitoring & Verification Protocol

Using an internationally recognised Energy Monitoring & Verification Protocol, such as the latest version of the International Performance Measurement & Verification Protocol (IPMVP) – EVO 10000 – 1.2007, enables the parties involved in implementing an effective M&V Plan which can provide the following benefits:

- **i.)** Financial Benefits.
- **ii.)** Legal Benefits.
- **iii.)** Engineering Benefits.

2.1.1. Financial Benefits

The financial benefits include:

- **i.)** **Lower cost of finance.** A good M&V Plan increases the transparency & credibility of reports on the outcome of energy efficiency investments. It also increases the credibility of projections for the outcome of efficiency investments. This would increase the confidence of investors in financing energy efficiency projects and lower interest rate.

ii.) **Document financial transactions.** This is important especially when the Energy Saving Measures to be implemented through EPC (Energy Performance Contract) by an ESCO (Energy Service Company) that requires performance report for payment approvals to ESCO.

iii.) **Lower transaction costs in an *energy performance contract.*** Adopting well recognised M&V protocol during EPC negotiation allows simplifying & reducing the cost of energy performance contract.

iv.) **Manage *energy* budgets.** Effective M&V plan allows accurately estimating energy budget and accounting for budget variances.

2.1.2. Legal Benefits

If the implementation of Energy Efficiency is materialized through an EPC by an ESCO, then there is a high risk potential of dispute between the ESCO and building owner associated with the level of achieved savings. This, quite often, can lead to take legal action by ESCO. Taking legal action is very costly and can affect the financial position and reputation of the ESCO.

Practice shows that using well developed and effective M&V Plan eliminates or lowers the risk of legal action associated with implementing EPCs.

2.1.3. Engineering Benefits

The main engineering benefits include:

i.) **Increase *energy savings.*** Accurate determination of energy savings gives facility managers valuable feedback on Energy Saving Measures (ESMs). This helps facility manager to adjust ESMs design or operations to improve savings.

ii.) **Improve engineering design.** Effective M&V Plan encourages comprehensive project design by including all M&V costs in the project's financial evaluation.

iii.) **Improve facility operations & maintenance.** Effective M&V plan helps managers to timely discover and reduce maintenance and operating problems resulting in maintaining the efficiency of their facilities.

iv.) **Enhance future engineering design.** Effective M&V Plan provides feedback for future project designs.

v.) **Increase public awareness of energy efficiency as a public policy.** Using well recognized M&V Protocol increases public acceptance of the related emission reduction leading to encourage investment in energy-efficiency projects or the emission credits they may create.

2.2. Criteria of Effective M&V Plan

Good and effective energy M&V plan must have the following criteria:

i.) **Accurate.** The **M&V** generated report should be as **accurate** as the M&V budget will allow. As rule-of-thumb, the M&V cost should not exceed **10%** of the total annual savings.

ii.) **Complete.** The reporting of Energy Savings should consider all effects of a project. In this case, M&V activities should use measurements to quantify the significant effects, while estimating all others.

iii.) **Conservative.** Where judgments are made about uncertain quantities, M&V procedures should be designed to under-estimate savings.

iv.) **Consistent.** The reporting of a project's energy savings should be consistent throughout the project regarding data collections; made assumptions; and data processing and simulations.

v.) **Relevant.** The determination of savings should measure the performance parameters of concern, or least well known, while other less critical or predictable parameters may be estimated.

vi.) **Transparent.** All M&V activities should be clearly and fully disclosed.

2.3. Designing Effective M&V Plan

There is no ready recipe for designing an effective energy M&V Plan, because M&V plan is a project specific and depends on the nature of Energy Efficiency Project; types of monitored parameters; measurement boundary; number and nature of the monitored parameters; frequency of measurements; length of monitoring period; and many others. Involving certified M&V expert is critical for designing an effective M&V Plan.

According to IPMVP – EVO 10000 – 1.2007, M&V Plan should address the following:

i.) Address the user's requirements from the planned M&V report in term of presenting saving savings.

ii.) Select the method of measurements of energy and other influencing independent parameters; method of evaluating the energy baseline and adjustment requirements; level of acceptable accuracy and M&V budget; and length of the baseline period and the reporting period.

iii.) Gather relevant energy and operating data from the baseline period and record them in a way that can be accessed in the future.

iv.) Prepare an M&V Plan containing the results of steps (i.) through (iii.) above.

v.) As part of the implemented ESMs, also the design, installation, calibration & commissioning any special measurement equipment that is needed under the M&V Plan should be included.

vi.) After installing the ESMs, inspect the installed & commissioned equipment to ensure that they conform to the design intent of the ESMs.

vii.) Gather energy and other related data from the reporting period, as defined in the M&V Plan.

viii.) Compute savings in energy and monetary units in accordance with the M&V Plan.

ix.) Report savings in accordance with the M&V Plan.

2.4. Example on Using IPMVP for Estimating Energy Saving

The example covers implementing a number of Energy Efficiency Measures in an office building in a tropical climate. The office building uses electricity as the only source of energy for running the building facilities. The energy saving estimation is based on measuring the whole building energy consumption and using building energy baseline to be established prior the implementation of the Energy Efficiency project. According to EVO 10000 – 1.2007 Protocol, the IPMVP Option "C" (see Paragraph 4.7, page 19, EVO 10000 – 1.2007 for more details) is be used for estimating energy savings in the building. The following M&V plan is used to estimate the project energy savings:

i.) Electric Utility monthly bills are considered as accurate measurements of the building energy consumptions (kWh/month).

ii.) Number of building occupants is regarded to be fairly constant. Accordingly, the office monthly operating hours and the outside air monthly average enthalpy (kJ/kg) at 3:00 p.m. are considered to be the main influencing parameters affecting the building energy consumptions.

iii.) Office operating hours are recorded on a daily basis and at the end of each month the office monthly operating hours are calculated.

iv.) Suitable metering equipment is used for measuring outdoor Relative Humidity (RH) and Dry Bulb temperature (DBT) at 3:00 p.m. on a daily basis. The recorded daily RH and DBT data are used to calculate the monthly average outdoor enthalpy (kJ/kg).

v.) Linear multiple regression modelling technique is used develop the correlation between building monthly energy consumptions (kWh/month) and office operating hours (hours/month) and outdoor air enthalpy (kJ/kg) at 3:00 p.m.

vi.) Using the office monthly energy consumption (dependent parameter), operating hours and outdoor air enthalpy (independent parameters) gathered over 12 month period prior to implementing the Energy Efficiency project, shown in Table 1, in MS Excel multiple linear regression function, enabled us to the establish the following equation which will be used for calculating the office building energy baseline before implementing the Energy Saving Measures:

Monthly kWh = 992.59 x No. of Monthly Operating Hours + 1,328.54 x Average Monthly Outdoor Air Enthalpy (kJ/kg) @ 3:00 p.m.

The model regression statistics analysis shown in Table 2 indicates that the above equation is statistically reliable in estimating the office monthly energy consumptions before implementing Energy Efficiency project.

Table 1, Building Historical Monthly Electricity Bills

No.	Month	Office Energy Consumptions, (kWh/month)	Office Operating Hours, (hours/month)	Outside Air Enthalpy @ 3:00 p.m., (kJ/kg)
1	Jan-06	346,742	225	87.22
2	Feb-06	339,563	220	90.54
3	Mar-06	338,231	220	91.51
4	Apr-06	370,276	250	95
5	May-06	341,032	220	95
6	Jun-06	340,000	220	91.06
7	Jul-06	382,312	265	88.65
8	Aug-06	342,765	230	86.76
9	Sep-06	346,143	240	87.23
10	Oct-06	351,235	235	89.62
11	Nov-06	339,763	220	88.22
12	Dec-06	348,653	230	86.77
13	**Jan-07**	**301,478**	**245**	**87.22**

Table 2, Regression Statistical Analysis

No.	Parameters	Regression Statistics	Significance Testing	Comments
1	R-Square	0.999863		This very high R-Square could be as a result of collinearity between independent parameters. This is excluded by having significant T-Test for these independent parameters.
2	Critical T-Test Value @ 95% Confidence level	1.833		
3	T-Statistic for monthly operating hours Parameter	12.1291	6.6171	> than 2*Critical T-Test Value, then the Parameter is statistically significant in explaining Monthly kWh
4	T-Statistic for outside air enthalpy Parameter	6.2961	3.4348	> than 2*Critical T-Test Value, then the Parameter is statistically significant in explaining Monthly kWh
5	Critical F-Test Value @ 95% Confidence level	4.26		
6	F Regression Value	36,362.1	8,535.7	>> than Critical F-Test Value, therefore the regression is statistically significant.

vii.) The energy saving achieved by implementing the Energy Efficiency project can be identified by subtracting the office monthly electricity bill after implementing the Energy Efficiency project (moth 13) from the calculated monthly electricity consumption baseline before project implementation. This can be calculated by substituting the office operating hours and outdoor air enthalpy identified for month 13 in above regression equation as shown in Table 3.

Table 3, Calculating Office Monthly Building Energy Savings

No.	Calculated Parameters	Values*	Units
1	Calculated building energy baseline (substitute operating hours and outside air enthalpy after implementing EE Project, month 13, in the Regression Equation)	358,381	kWh/month
2	Actual building energy consumption after implementing Energy Efficiency Project	301,478	kWh/month
3	Avoided Energy Consumptions	56,903	kWh/month
4	% savings	**15.9%**	%

** - Values shown are generated from MS Excel. Manual calculations using the above regression equation is expected to have slightly different results due to rounding errors.*

2.5. IPMVP Background

The International Performance Measurement and Verification Protocol (IPMVP) is sponsored by the Efficiency Valuation Organization (EVO), a non-profit private corporation. The first edition of IPMVP was published in March 1996 and at that time was entitled the North American Energy Measurement and Verification Protocol. Since then, IPMVP has been going through continuous development and the latest version is IPMVP – EVO 10000 – 1.2007.

IPMVP has been developed by a group of professional volunteers highly specialised in multidisciplinary Energy Efficiency related fields, including monitoring and statistics for the purpose of standardising the processes of estimating energy savings with a focus on level accuracy and confidence in estimated savings. The main objective is to facilitate and support the implementation of Energy Performance Contracts (EPCs) and other Energy Efficiency and Renewable Energy initiatives.

The use of IPMVP effectively requires in depth understanding the concept and process proposed by the protocol. To facilitate the implementation of IPMVP, EVO offers wide range of training on measurement and verification. EVO also has a Certified Measurement and Verification Professional (CVMP) program for professionals who pass a test demonstrating their knowledge of IPMVP and have appropriate knowledge, experience or training. CMVPs should be competent to develop M&V Plans and to manage M&V programs for straightforward applications. For more information on the CMVP program, and for the names of designated CMVPs, visit www.evo-world.org.

3. Role and Benefits of Building Rating in Sustainable Building Industry

As mentioned before, buildings consume substantial amount of countries' energy balance resulting in increasing the generation of carbon dioxide emissions. Further, building construction/retrofitting and operations are accompanied with emission of large amount of greenhouse gases and generation of wastes during construction and operations; can have poor indoor air quality, affecting worker health; and often don't consider the impact made on the community through increased transportation, sprawl, and cultural and historical impact. Accordingly improving energy performance in buildings would have a significant impact on sustainable economic development and improve environment at country and global levels.

An increasing number of studies support the idea that green building is good for business. Initial investments in environmentally preferable building technologies and materials often pay for themselves within a few years. In fact, investments in green buildings pay for themselves ten times over, according to a landmark study drawing on national data for 100 green buildings in the U.S. The report found that the financial benefits of green design are between US$538 and US$754 per square meter in a LEED (Leadership in Energy and Environmental Design) building, over ten times the additional cost associated with building green. The benefits include cost savings from reduced energy, water, and waste; lower operations and maintenance costs; and enhanced occupant productivity and health.

Building green rating allows us to measure and quantify building performance and benchmark buildings against best practice to determine their sustainability.

There is a growing international interest in the development of building environmental rating schemes and tools. The main objectives of green building rating scheme are:

i.) Stimulate the growth of sustainable building industry.

ii.) Setting minimum energy requirements of new buildings and major refurbishment

3.1. Global Sustainable Building Rating Systems

Globally, sustainable building rating systems have started about 10 years ago in the developed countries. Although most of existing building rating systems are voluntary, in some countries, such as Australia, it is mandatory requirements for minimum energy requirements of new buildings and major refurbishment. This allows eliminating bad energy performer buildings from the building industry. The following some of well established international sustainable building rating systems:

- LEED (USA).
- ABGR (Australia).
- Green-Star (Australia).
- BREEAM (UK).
- CASBEE (Japan).

The method of evaluating environmental building rating varies between various rating schemes. Table 4 shows the parameters used for evaluating building rating for the above building rating schemes.

Table 4, Evaluating Parameters of Some Well Established Sustainable Building Rating Systems

LEED (US)	ABGR (Australia)	Green-Star (Australia)	BREEAM (UK)	CASBEE (Japan)
i.) Sustainable sites **ii.)** Water efficiency. **iii.)** Energy & atmosphere. **iv.)** Materials & resources. **v.)** Indoor environment al quality **vi.)** Innovation & design process	**i.)** 12 months Energy use (electricity, gas, coal or oil). **ii.)** Hours of operations. **iii.)** Net lettable area. **iv.)** Number of people & computers.	**i.)** Management. **ii.)** Indoor environment quality. **iii.)** Energy. **iv.)** Transport. **v.)** Water. **vi.)** Materials. **vii.)** Land use & ecology. **viii.)** Pollution. **ix.)** Innovation.	**i.)** Management. **ii.)** Energy use. **iii.)** Health & well-being. **iv.)** Pollution. **v.)** Transport. **vi.)** Land use. **vii.)** Ecology, **viii.)** Materials. **ix.)** Water	**i.)** Energy efficiency. **ii.)** Resource efficiency **iii.)** Local environment. **iv.)** Indoor environment.

Further, each building rating system has different method of classifying buildings. For example, LEED uses four building rating categories:

i.) Basic LEED® Certification.

ii.) LEED® Certified Silver Level.

iii.) LEED® Certified Gold Level.

iv.) LEED® Certified Platinum Level.

3.2. Australian Building Sustainable Building Rating

In Australia, the Building Code of Australia (BCA) is used to set mandatory requirements for minimum energy requirements of new buildings and major refurbishment.

Further, there are two voluntary rating systems currently available in Australia for promoting sustainable building development. These are:

a.) Australian Building Greenhouse Rating (ABGR) Scheme.

b.) Green-Star Environmental Rating Scheme.

The **ABGR** is a greenhouse performance benchmark for existing office buildings that allows owners, managers and tenants to assess greenhouse performance on a valid, absolute scale. The underlying philosophy of **ABGR** is that it is performance based, i.e. it measures actual operational energy use rather than an assessment of design elements. This differentiates **ABGR** from **Green-Star**, as **Green-Star** is design based and provides no guarantee of, or commitment to, a specific level of performance. While **ABGR** focuses on performance in operation, **Green-Star** confines itself to the intent of the design and to some extent the provision of process to achieve that intent. The fundamental issue with all design-based assessment systems is that they create value in a design on the basis of design elements, which may or may not correlate with actual performance.

3.2.1. ABGR Scheme

The **ABGR** scheme is a '***world first initiative***' that is designed to help building owners and tenants across Australia to benchmark their building greenhouse performance. The scheme is administered nationally by the NSW Department of Energy, Utilities and Sustainability (**DEUS**) and it is promoted and managed locally by state governments throughout Australia. The **ABGR** scheme allows building owners, managers and tenants to understand the greenhouse impact of their commercial office buildings. This government and industry backed program aims to stimulate market recognition and demand for offices with improved greenhouse performance.

To determine the star rating and the amount of CO2 emissions per square metre in **ABGR** scheme, the rating uses 12 months of data that includes – energy (electricity, gas, coal or oil) use, hours of operation, net lettable area, number of people and computers. This means the rating reflects the way energy is managed as well as how efficiently the building is designed. The benchmark allows comparison with the greenhouse performance of other buildings within the state where the building is located. Figure 1 shows the ABGR rating categories.

Figure 1, ABGR Categories

3.2.2. Green-Star Environmental Rating Scheme

The **Green-Star** scheme is administered in Australia by the Green Building Council of Australia (GBCA) which is a Non-Profit Organisation.

Green-Star rating of projects is evaluated against eight environmental impact categories, plus innovation as shown in Figure 2. Within each category, points are awarded for initiatives that demonstrate that a project has met the overall objectives of **Green-Star** and the specific criteria of the relevant rating tool credits. Points are then weighted and an overall score is calculated, determining the project's **Green-Star** rating. Star ratings 1 through to 3 inclusive cannot be certified, ratings of 4 and above can be certified by GBCA.

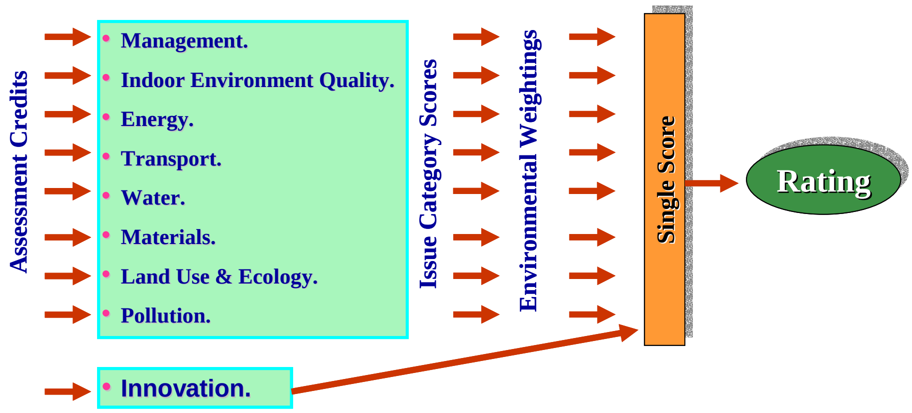

Figure 2, Green-Star Rating Process

Table 3 shows the Green-Star Rating eligibility criteria.

Table 3, Green-Star Environmental Rating Eligibility Criteria

No.	No. of Stars	No. of Points	Rating Eligibility	Comments
★	1-Star	10 - 19	No Rating	
★★	2-Star	20 - 29	No Rating	
★★★	3-Star	30 - 44	No Rating	
★★★★	4-Star	45 - 59	Certified	Best Practice
★★★★★	5-Star	60 - 74	Certified	Australian Excellence
★★★★★★	6-Star	75 - 100	Certified	World Leader

4. Developing M&V and Building Rating System in Developing Countries

Having well developed M&V Protocol and Sustainable Building Rating system plays significant role in stimulating and supporting the growth of Energy Efficiency and green building markets as well as sustainable economic development particularly in the developing countries.

4.1. Status of M&V Protocol and Green Building Rating Systems in Developing Countries

Existence of M&V Protocol and Sustainable Building Rating is strongly associated with the status and sophistication of Energy Efficiency market and sustainable economic development in countries. In general, the development of M&V Protocol and Green Building Rating is a response to the government enforcement and market needs for such systems.

Accordingly, it is no surprise that in most developing counties, where the Energy Efficiency and Green Building markets are not in existence or still at their infancy stage, the M&V Protocol and Green Building Rating do not exist or at its infancy stage.

Considering the amount of energy consumed by buildings to be one of the largest energy consuming economic activities, particularly in developing countries, the development of effective M&V Protocol and Green Building Rating system is vitally important for stimulating and nurturing the growth of Energy Efficiency market for.

The following are the most common challenges hindering the growth of M&V Protocol and Green Building Rating systems in most developing economies:

- **i.)** **Lack of Effective Energy Efficiency Regulations or Minimum Energy Performance Guidelines in New and Retrofitted Buildings**.

- **ii.)** **High energy subsidy.** The artificially low energy costs resulted from high energy subsidies in most developing countries hinder the financial investments in Energy Efficiency& Renewable Energy and Green Building Market Developments.

- **iii.)** **Absence or shortage of local energy efficiency building materials and equipment.** This leads to increase substantially the cost of energy efficiency building materials resulting in the difficult financial justification of Energy Efficient & Renewable Energy.

- **iv.)** **Lack of awareness of Energy Efficiency and Sustainable Building development among decision makers, building developers and professionals.** This obstructs the growth and development of energy efficient building industry.

Over coming the above obstacles would lead to stimulating the energy efficiency and green building markets leading to increasing demands on having M&V Protocol and Green Building Rating Systems in the developing countries.

4.2. Options for Developing M&V Protocol

In general, the Energy Efficiency projects involve using various techniques and technologies directed towards reducing the amount of energy input without affecting process outputs. Further, methods of calculating and estimating the Energy Efficiency savings resulted from implementing Energy Efficiency Measures are a function of:

- **i.)** The scale of Energy Efficiency project.
- **ii.)** Boundary of Energy Efficiency project.
- **iii.)** Monitoring system details used to collected energy and independent influencing parameters.
- **iv.)** Fluctuation and seasonality of energy demands.
- **v.)** Accuracy of monitoring equipment.
- **vi.)** Frequency of data collection.
- **vii.)** Mathematical and statistical techniques used in estimating Energy Baseline before and after implementing Energy Efficiency projects.

This shows that method of estimating Energy Savings is purely technical and there should not be any difficulties in using any of the internationally well developed M&V Protocols.

Considering the effort and resources required for developing comprehensive M&V Protocol by a developing country, it is highly recommended to adopt any of internationally well established M&V Protocol, such as IPMVP – EVO 10000 – 1.2007. This M&V Protocol has been going through continuous development and improvement and will continue to be reviewed and to accommodate the accumulated experience in the field of M&V of Energy Efficiency fields.

4.3. Options for Developing Green Building Rating Systems

In general, developing a Green Building Rating would involve:

- Identifying the key players driving the Green Building Rating Scheme in a country.
- Establishing the objectives of desired Green Building Rating scheme.
- Finalising the structure and process of calculating building rating.
- Establishing the administration driving Energy Efficiency market in the country.

Implementing above generic approach to developing a Green Building Rating Scheme would vary from country to country. The level of complexity and effectiveness of a rating scheme in a country is highly dependent on the level of government involvement in driving the Green Building Rating Scheme and Energy Efficiency market sophistication in that country.

The following approach can be considered as one of the possibility for developing a Green Building Rating Scheme:

i.) Assigning a organisation/authority for driving the development of Green Building Rating System.

ii.) Identifying the targeted building sector(s).

iii.) Identifying stake holders.

iv.) Establishing the structure of the Green Building Rating System including:

  a.) Rating classifications.

  b.) Data required for calculating the rating.

  c.) Calculation methodology.

v.) Carrying out a trial for the newly developed Green Building Rating.

vi.) Training qualified people on carrying out Green Building Rating.

vii.) Implementing full scale scheme across the targeted building sector.

The above approach is fairly complex to pursue particularly by the developing countries. Therefore, it would be sensible to review and adapt one or more of the current internationally well established Green Building Rating Systems that would suite the current Energy Efficiency market and aspiration of the building industry stakeholders.

5. Conclusions

i.) Using well developed and effective Monitoring and Verification (M&V) Protocol is essential for estimating reliably and accurately the level of improvement in building energy performance and justifying investments in building energy efficiency.

ii.) Having clear and well defined M&V Plan plays a critical role in financial justifications of investments in Energy Efficiency (EE) and Renewable Energy (RE) in new and existing buildings.

iii.) Using an internationally recognised Energy Monitoring & Verification Protocol, such as IPMVP – EVO 10000 – 1.2007, enables the parties involved in implementing Energy Efficiency project to reduce financial, legal and engineering failure risks.

iv.) There is a growing international interest in the development of Building Green Rating schemes and tools.

v.) The main benefits of having effective Building Green Rating scheme are to promote the development of sustainable building market and setting minimum energy requirements of new buildings and major refurbishment

vi.) It is recommended for developing countries to adapt one or more of the current internationally well established Green Building Rating Systems to suite their current Energy Efficiency market and aspiration of the building industry stakeholders.

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ESTABLISHING LOCAL WEIGHTING VALUES OF SBTOOL FOR APPLICATION IN MALAYSIA

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Abstract

Several sustainable assessment tools have emerged in recent years as a means to evaluate the performance of buildings across a broad range of sustainability considerations beyond environmental issues. SBTool is one such assessment tools with a comprehensive sustainable building assessment framework that has been developed over the past 9 years through the efforts of 21 participating nations. This study is the first initiative to customise SBTool for application in Malaysia.

SBTool framework is structured hierarchically in 3 levels, namely Performance Issues, Categories and Criteria. For regional customization, industry consensus on the weightings of Performance Issues and Categories are needed. The initial phase of the study investigates the current scenario of the Malaysian construction industry with regards to sustainability from available literature. The objective is to highlight the potential need and roles of sustainable building assessment tools in Malaysia. Subsequently, the study consists of a questionnaire survey among construction industry players to establish the weightings. The results are then used to formulate an approach for a Sustainable Building Rating System for the Malaysian construction industry based on the SBTool framework.

Keywords: SBTool, Weighting values, Sustainable Building Rating System, Malaysia

1 Introduction

Malaysia, experiencing severe environmental disasters during the past decade, was confronted with several crucial environmental problems and sustainability issues in a name of rapid economic and social development. The way forward for the construction industry is thus the implementation of sustainable development, which requires integration of social and environmental factors with economic factors.

To resolve these environmental problems, four categories of potential measures which ought to be taken by government and private sectors, namely i) regulations, ii) enabling mechanisms i.e. education & training programs, iii) financial incentive programs, and iv) measures to change market demand (Larsson 2000). Studies have shown that a national system of Sustainable Building Rating System (SBRS) is among the most effective measure to shift market demand (Larsson 2000; Cole 2005; Elisa Campbell Consulting 2006). In other words, the desired end state of building industry is to ensure that the market demands buildings that are high performance or sustainable. Through the design and implementation of suitable SBRS, professionals, contractors and building owners may be motivated to pursue set targets for achievements and recognitions, and by doing so it fulfils national and global objectives towards sustainable development.

SBRS has not yet been developed and introduced in Malaysia. Countries that have introduced such schemes in a non-mandatory base, as in European countries have already understood its need. The Green Building Challenge (GBC) was one of the early assessment frameworks to emerge, but it differed in significant ways from the few existing systems, such as BREEAM (UK), LEED (US), BEPAC (Canada) and etc. Unlike these existing systems, SBTool system, developed through the GBC process, offers regional customization of criteria and weights to reflect regional factors of building technologies, and even social and cultural factors.

This study is the first initiative to customize SBTool to suit the Malaysian context. To provide meaningful assessment results, all weighting values that are relevant to the specific region must be reevaluated to ensure applicability, and to avoid results that are meaningless and misleading. Therefore, this paper aims to present the results of appropriate weights of the Issues and Categories based on questionnaire survey among Malaysian construction industry players. The results can also provide useful guide to Malaysian policy makers in prioritizing the issues for sustainable development planning policy.

2 Review of Environmental Impacts of Buildings in Malaysia

For the past two decades, Malaysia has undergone a fast pace of urbanization largely attributed to the rapid economic growth and industrialization. However, rapid economic development, sometimes, comes with a price. Activities related to construction industry are one of the major causes of environmental problems in Malaysia. One of such activities is the uncontrolled opening of forestland for building construction purpose, which are not managed based on environmental concern. According to John and Othman (2007), Malaysian forests are still being logged excessively despite the fact that only 59.5% of Malaysian total land area remain under forest cover. Increasing pressure on natural forest areas by construction activities has led to the land erosions during heavy rains as well as sedimentation of rivers, which in turn causes flooding in low-lying areas and flash floods in urban areas (UNDP 2005). Another activity that creates negative impacts on river system is sand mining to cater for high demands for sand and gravel for Malaysian building industry. Statistically, less than half from a total of 146 rivers in Malaysia is categorized as clean, meanwhile 15 rivers in Malaysia are classified as critically polluted (Vijayan 2007).

In terms of energy, Malaysia is ranked 33rd in a list of global electricity consumption and 25th in the list of man-made carbon dioxide emissions (Mohd Yunus 2007). These are unfavourable positions for a small country of 26 million people. This phenomenon is somehow justified by Ang (2007) whose study reveals that there is a bi-directional causality between energy consumption and economic growth in Malaysia. Statistics show that Malaysian buildings account for about 12.85% of the total energy consumption and 47.5% of the country's electricity consumption (Dept. of Electricity and Gas Supply M'sia 2001). Of these, commercial buildings consume almost a third of the country's electricity consumption. Ahmad & Kasbani (2003) highlighted that 55-65% of electricity used in buildings is for cooling purposes while 25-35% is for lighting purposes. If energy consumption continues to increase at its current rate, domestic fossil reserve in Peninsular Malaysia is predicted to be depleted by 2014 and Sarawak by 2020 (EPU 2005).

Malaysian construction waste forms a significant portion of wastes that is finally disposed of in landfills. A study by Hassan, Yusoff et al. (1998) reveals that Malaysian construction sector has produced as much as 28.34% of wastes as a result to cope with the demands in implementing many development programs. Furthermore, waste reduction during the planning and design stage to minimize the generation of waste is rarely considered (Begum, Siwar et al. 2007).

These predicaments reflect the imbalance between the environmental and developmental demands; the benefits of development are negated by the costs of environmental damage. In other words, the current practices in the Malaysian construction and building industry can be deemed to be not sustainable.

3 Potential relevance of Sustainable Building Rating System (SBRS)

With alarming increase of environmental issues regarding the Malaysian built environment, the introduction of sustainable development that requires integration of social and environmental factors with economic factors seems rather crucial. It is encouraging that in Malaysia commitment to sustainable development has been initiated by the government. This is evidenced by its determination to implement the Project on Strategies for Sustainable Development and Agenda 21 (Selangor) (S'ngor State Government 2003). The principles of implementing Agenda 21 (Selangor) provide a useful guide for how sustainable development should be implemented. They are however too abstract to be easily applied to the building and construction sector. There is therefore a real need to translate these into a more practical guide, or set of objectives, for building and construction.

On the other hand, building environmental assessment methods have emerged as a means to evaluate building performance against an explicit set of criteria (Cole 2001). In addition, they are perceived as tools for promoting and contributing to sustainable building design and construction. Due to the fact that they reconcile mandatory (i.e. by reference to standards) and market-driven approaches to promote sustainable building construction practices, they are believed to be a potent agent of change in the specific context of the Malaysian construction sector. Cole (2005) posits that attaching a label of environmental performance for improved environmental qualities increases the real market value of buildings and motivates change in the construction industry and market transformation. The past 17 years have witnessed a rapid increase in the number of building environmental assessment methods in use worldwide, such as BREEAM (UK), LEED (US), HK-BEAM (Hong Kong), CASBEE (Japan) and etc. On the other hand, there is yet to be development of a comprehensive building assessment method in Malaysia. Since assessment tools are context specific, it is neither appropriate nor sufficient to directly adopt existing methods for evaluation of Malaysian buildings. Larsson and Cole claimed that they are not explicitly designed to handle regional-specific issues (1998).

GBTool (Green Building Tool) was one such assessment tools that has been developed over the past 9 years through the efforts of 21 participating nations under the Green Building Challenge (GBC). One of the early lessons learned during the development of GBTool was that green design is contextual – environmental, climatic, socio-cultural, economic, and energy-use factors affect what is considered environmentally prudent. Consequently, the system is adaptable to allow for these types of adjustments by the National Teams (Shymko 2003). Tianm Qin et al. (2005) also support the notion of remarkable adaptability and adjustability of GBTool. National teams are encouraged to make as many changes to GBTool as necessary to customize it to suit the environmental issues and priorities of the case-study building and context (Cole and Larsson 2002). They might find it most useful as a reference and basis for developing domestic assessment method (Todd, Crawley et al. 2001). The system is now known as SBTool (Sustainable Building Tool), reflecting the inclusion of a range of socio-economic considerations beyond green building issues.

4 Customization of SBTool

The assessment elements of SBTool are classified into three levels of factors: the high-level "Issues", the second-level "Categories" and the third-level "Criteria". The assessment scores are derived through the weighting of the scores at the lower levels. The overall building score is obtained through the weighted scores of issues. The weighting value, from the lower levels to the overall building, is a total of 100% (Cole and Larsson 2002).

Customization of SBTool undergoes four processes: i) Selecting Performance Issues, ii) Customizing of the Performance Scales, iii) Designation of Performance Criteria as non-applicable, iv) Customizing the relative Weightings of the Categories and Issues (Cole and Larsson 2002). These customizations had already been implemented in several countries including Hong Kong, Taiwan, Italy, UK, Japan, Brazil, and Sweden. The Italian "Protocollo Itaca", which is based on GBTool, is now the official reference assessment tool for all the public administration buildings of the Italian regions (Moro, Catalino et al. 2005). These remarkable efforts and results have inspired similar initiatives to be undertaken in Malaysia.

5 Research Methodology

The questionnaire was designed and structured into four sections. Section 1-2 aims to obtain respondents opinion on the relevance of SBRS in Malaysia and to assess their level of acceptance in introducing and implementing SBRS in Malaysia. Section 3 aims to attain an industry consensus for the customisation of weighting values for performance Issues and Categories. The questionnaire ended with questions related to respondent's details in Section 4.

The studies also took a departure from a standard SBTool list of performance Issues and Categories. The authors believe that there is a dichotomy between economic and social aspects in Malaysian construction scenario. This believe stem from the observation that Malaysian industry emphasized on building economic aspects at the expense of social responsibility. Therefore, we proposed the transfer of Social Aspects from Economic Aspects into "G. Cultural & Perceptual Aspects" (Table 1).

Table 1: Modification to SBTool standard structure

Standard SBTool		Customized SBTool for Malaysia	
Issues	Categories	Issues	Categories
F. Social & Economic Aspects	*F1. Social Aspects* *F2. Cost & Economic*	F. Economic Aspects	*F1. Cost & Economic*
G. Cultural & Perceptual Aspects	*G1. Cultural & Perceptual Aspects*	G. Social, Cultural & Perceptual Aspects	*G1. Social Aspects* *G2. Cultural & Perceptual Aspects*

This study relies more on quantitative research techniques and various statistical methods were used in analysing the data. Statistical analyses were done using SPSS Version 11.5 software. In questions related to weightings, respondents were required to rate the relative importance of each Issue and Category with a given statement on a 5-point Likert scale (1=Not Important to 5=Very Important). These scores were then totalled up for each group of questions. The percentage value was then worked out by dividing the individual score of each item over the total score of the question group.

To shed further light on establishing local weighting values of SBTool for application in Malaysian building industry, it is important to study the opinions of construction industry players from different fields on a common platform. Therefore, a survey was conducted involving six groups of professions: 1) Academics/ Researchers, 2) Private Professionals i.e. designer, project manager etc., 3) Public Professionals i.e. designer, policy maker, town planner etc., 4) Developers, 5) Facility/ Energy Managers, and 6) Contractors. The data was solicited by mail, visit to respondent's workplace or emailing the questionnaire to be returned by fax.

6 Data Analysis

Out of 120 questionnaires sent out, 56 respondents replied, which gives a response rate of 46.6%. This rate is good and provides a significant amount of data for the analysis. The distribution of the respondents among six groups is shown in Fig. 1. It can be seen that half of the respondents (51%) are Private Professionals. The second most represented group is Academics/Researchers (19%); and third is Government Officials (13%). Facility/Energy Managers, Developers, and Contractors make up the rest with a total of 7%, 6% and 4% respectively.

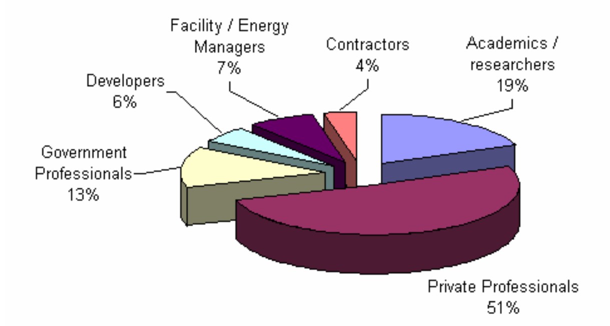

Fig. 1: Distribution of respondents

6.1 Relevance of SBRS

Respondents were asked on their opinion on the relevance of a SBRS for Malaysian construction industry. They were asked the following questions with a 'yes' (=1) and 'no' (=0) answer. The results are shown in Table 2**.** It is found that the majority of respondents agree that a SBRS is relevant to Malaysian construction industry. The highest percentage of agreement is found in the suggestion that the adoption of a SBRS should be rewarded with fiscal incentives (91%).

Table 2: Mean score of respondent's opinion of the relevance of SBRS

	Yes (%)	No (%)	Total (%)	Mean
Bldgs in M'sia should be rated based on their sustainability performance	49 (88)	7 (12)	56 (100)	.89
SBRS would lead to a more sustainable industry in Malaysia	49 (88)	7 (12)	56 (100)	.87
Bldgs awarded with a high sustainable performance rating would have a higher market value	46 (82)	10 (18)	56 (100)	.84
Adoption of SBRS in project devp should be rewarded with fiscal incentives	51 (91)	6 (9)	56 (100)	.93

6.2 Level of Acceptance in Implementing SBRS

Another series of question were related to the respondent's acceptance of SBRS to be implemented in Malaysia with a 'yes' (=1) and 'no' (=0) answers. The results are shown in Table 3. It has been found that even though overwhelming percentage agrees on the introduction of SBRS (93%), lesser majority thinks that it should be made mandatory (82%). Even a lesser majority thinks that the country is ready to implement a SBRS (62%).

Table 3: Mean score of acceptance level in implementing SBRS

	Yes (%)	No (%)	Total (%)	Mean
Agree for SBRS to be introduced	52 (93)	4 (7)	56 (100)	.95
Malaysia is ready to implement SBRS	35 (62)	21 (38)	56 (100)	.58
SBRS to be made mandatory	46 (82)	10 (18)	56 (100)	.79

6.3 Weighting Values of Performance Issues

In section 4 of the questionnaire, the respondents were simply asked to rate the relative importance of the Issues and Categories on a 5-point Likert scale to obtain an industry consensus local weighting values. The suggested weightings of Issue level are summarized in Fig. 2. The ranking position by Issue in descending order is as follows: 1) C. Environmental Loadings (0.148), 2) D. Indoor Environmental Quality (0.145), 3) A. Site Selection, Project Planning & Development (0.144), 4) G. Social, Cultural & Perceptual Aspects (0.143), 5) F. Economic Aspects (0.142), 6) B. Energy & Resource Consumption (0.140) and 7) E. Service Quality (0.138).

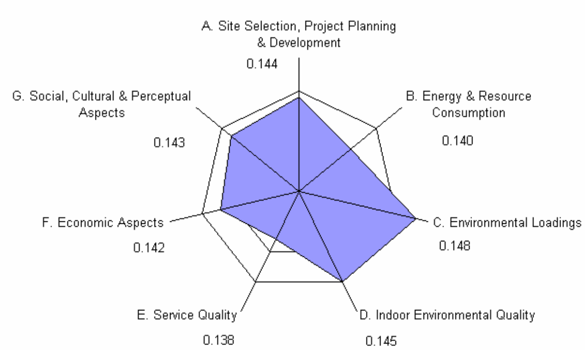

Fig. 2: The distribution of local weights of Issues

From the results, it is obvious that the difference between all of these weighting values is rather small; in other words, the respondents felt that all of these Issues carry the same weight in importance. This might be due to the fact that they have not had the experience with building environmental assessment thus unable to foresee the implications of the weightings assigned. With reference to SBTool, two of the three Issues deemed mandatory in building assessment namely, "C. Environmental Loadings" and "D. Indoor Environmental Quality" were rated as the top two most important issues. However, another issue of "B. Energy & Resource Consumption" received the second lowest ranking.

6.4 Weighting Values of Performance Categories

With respect to the Categories level, their local weights were derived from the Likert scale value in the questionnaire by converting them into a weighted percentage. The Global Weight for each Category was then calculated by multiplying the local weight of the respective Category (a) and the local weight of its parent Issue (b). The results are shown in Table 4.

Table 4: Local & global weights for all categories

	Issues (i)	Local weights (wi)	Categories (c)	Local weights (wc)
A	Site Selection, Project Planning & Development	0.144	A1. Site Selection	0.328
			A2. Project Planning	0.344
			A3. Urban Design & Site Development	0.328
B	Energy & Resource Consumption	0.140	B1. Total Life Cycle Non-RE	0.198
			B2. Elect. Peak Demand for Facility Oprn	0.199
			B3. Renewable Energy	0.204
			B4. Materials	0.193
			B5. Potable Water	0.206
C	Environmental Loadings	0.148	C1. Greenhouse Gas Emissions	0.175
			C2. Other Atmospheric Emissions	0.160
			C3. Solid Wastes	0.160
			C4. Wastewater, Stormwater & Rainwater	0.173
			C5. Impacts on Site	0.160
			C6. Other Local & Regional Impacts	0.172
D	Indoor Environmental Quality	0.145	D1. Indoor Air Quality	0.199
			D2. Ventilation	0.205
			D3. Air Temperature & Relative Humidity	0.205
			D4. Daylighting & Illuminance	0.207
			D5. Noise & Acoustics	0.183
E	Service Quality	0.138	E1. Safety & Security During Operations	0.168
			E2. Functionality & Efficiency	0.173
			E3. Controllability	0.160
			E4. Flexibility & Adaptability	0.157
			E5. Commissioning of Facility Systems	0.159
			E6. Maintenance of Oprtg. Performance	0.180
F	Economic Aspects	0.142	F1. Cost & Economic	1.000
G	Social, Cultural & Perceptual Aspects	0.143	G1. Social Aspects	0.530
			G2. Cultural & Perceptual Aspects	0.470

To make a practical ranking of all the Categories, the Global Mean of each category was used. This value is derived by multiplying mean score Category and the mean score of it's parent Issue. The result is then expressed as a fraction of maximum 25 score value (score of 5 for Category x score of 5 for Issue) as shown in Table 5. It is noted that the top one-third of the list is dominated by Issue "C: Environmental Loading" (i.e. C1, C6, C4, C2, C5), followed by Issue "G: Social, Cultural & Perceptual Aspects" (i.e. G1, G2). Whereas, the bottom one-third is dominated by Issue "B: Energy & Resource Consumption" (i.e. B5, B3, B2, B1, B4), followed by Issue "E: Service Quality" (i.e. E3, E5, E4).

Table 5: Raking position of assessment categories

Rank		(a) Mean C	(b) Mean I	(axb) Global w	Mean G (axb)/25
1	C1. Greenhouse Gas Emissions	4.51	4.47	20.16	0.806
2	C6. Other Local & Regional Impacts	4.45	4.47	19.91	0.796
3	C4. Wastewater, Stormwater & Rainwater	4.40	4.47	19.66	0.786
4	E6. Maintenance of Operating Performance	4.51	4.30	19.40	0.776
5	C2. Other Atmospheric Emissions	4.33	4.47	19.35	0.774
6	G1. Social Aspects	4.42	4.38	19.33	0.773
7	A2. Project Planning	4.38	4.36	19.08	0.763
7	G2. Cultural & Perceptual Aspects	4.36	4.38	19.08	0.763
9	C5. Impacts on Site	4.25	4.47	18.98	0.759
10	D2. Ventilation	4.38	4.33	18.94	0.758
10	D4. Daylighting & Illuminance	4.38	4.33	18.94	0.758
12	C3. Solid Wastes	4.23	4.47	18.92	0.757
13	E2. Functionality & Efficiency	4.38	4.30	18.83	0.753
14	D3. Air Temperature & Relative Humidity	4.34	4.33	18.78	0.751
14	D1. Indoor Air Quality	4.34	4.33	18.78	0.751
16	E1. Safety & Security During Operations	4.36	4.30	18.75	0.750
17	A1. Site Selection	4.26	4.36	18.59	0.744
18	F1. Cost & Economic	4.25	4.34	18.42	0.737
19	A3. Urban Design & Site Development	4.21	4.36	18.34	0.734
20	E3. Controllability	4.23	4.30	18.18	0.727
21	E5. Commissioning of Facility Systems	4.19	4.30	18.02	0.721
22	B5. Potable Water	4.30	4.17	17.94	0.718
23	B3. Renewable Energy	4.26	4.17	17.78	0.711
24	B2. Electrical Peak Demand for Facility Operation	4.25	4.17	17.72	0.709
24	D5. Noise & Acoustics	4.09	4.33	17.72	0.709
26	E4. Flexibility & Adaptability	4.11	4.30	17.69	0.708
27	B1. Total Life Cycle Non-Renewable Energy	4.17	4.17	17.39	0.696
28	B4. Materials	4.09	4.17	17.07	0.683

6.5 Difference of weighting pattern between different professions

On top of this, another different weighting pattern can be expected between different professions in the industry as their vested interest lies in different areas of sustainability (refer Table 6). The highest (darker shade) and lowest (lighter shade) weightings derived from each group of respondents are highlighted in the table. It is noted that Issue “A. Site Selection, Project Planning & Development” has been weighted highest by Academics/Researchers and lowest by Contractors, whilst Issue “B. Resource Consumption” has been weighted highest by Contractors and lowest by Developers. Developers have considered Issue “C. Environmental Loadings” as the most important Issue whilst the Academics/Researchers rated Issue “D. Indoor Environmental Quality” the highest. Issues “E. Service Quality” and “F. Economic Aspect” have been weighted highest by Contractors and lowest by Developers and Academics/Researchers respectively. Lastly, Issue “G. Social, Cultural Aspects” has been weighted highest by Private Professionals only and lowest by Facility/Energy Managers and Contractors. However, an ANOVA analysis was conducted and it is found that the differences are not statistically significant for any of the groups. Nevertheless, these subtle differences have given an early insight into the current disparity of understanding and concern for sustainability issues of the construction industry players in Malaysia.

Table 6: Comparison between nature of employment and weightings of Issues (%)

Issues/ Nature of employment	A. Site Selection, PPlanning & Devp	B. Resource Consumption	C. Env. Loadings	D. IEQ	E. Service Quality	F. Economic Aspects	G. Social, Cultural & Perceptual Aspects
Academics/Researchers	14.867	14.333	14.733	15.533	13.633	13.278	13.578
Private Professionals	14.248	13.922	14.739	14.278	13.865	14.000	14.878
Government Professionals	14.860	13.540	14.140	14.860	13.540	14.860	14.140
Developers	14.600	11.150	16.600	14.900	13.150	14.900	14.600
Facility/Energy Manager	13.550	15.600	15.500	13.600	13.600	15.500	12.700
Contractor	12.900	16.100	12.900	12.900	16.100	16.100	12.900
Total	14.366	14.039	14.782	14.536	13.775	14.175	14.273

7 Summary & Conclusion

This paper presents the results of a questionnaire survey to evaluate the perceptions of Malaysian construction industry players on SBRS, and to assess the appropriate weights of the Issues and Categories for SBTool. It is found that the majority of the respondents agreed that SBRS is relevant to the Malaysian construction industry, and a surprising majority (83%) feels it should be made mandatory. It has also been found that Malaysian construction industry is ready (93%) for the introduction of SBRS, although a much smaller percentage (62%) feels that the industry is ready for the actual implementation.

From a general observation of overall weighting values obtained from the survey, it is obvious that there is no significant emphasis on certain performance Issues and Categories. Nevertheless, the subtle differences do indicate the current state of understanding and concern for sustainability issues where "C. Environmental Loading" seems to lead in terms of the overall concern, followed by "D. Indoor Environmental Quality". "E. Service Quality" and "B. Energy & Resource Consumption" have been placed to the last bottom two. Having no experience with building environmental assessment, it is possible that the respondents could not prioritise the various issues as well as anticipate the implications of the weightings assigned. It is anticipated that a second round of weighting exercise be done once the industry had gone through several assessment exercises. The customisation could then be made with the contribution of those who had participated in the earlier assessments, and thus could better judge the relative importance of various parameters.

Sustainable building assessment, rating and labelling system is a tool that merges mandatory and market-driven approaches to promote sustainability in construction industry. It has the potential to be introduced in Malaysia if the local industry players can complement the government's initial efforts by establishing voluntary initiatives such has been done in Hong Kong. It is hoped that the results of this study will spur other similar initiatives that will assist to form a useful guide to all Malaysian regulators and policy makers in prioritising sustainability issues for environmental development planning policy as a step towards a sustainable construction industry in Malaysia.

Acknowledgements

The authors would like to acknowledge Ministry of Science, Technology and Innovation (MOSTI) for granting the EScience Fund (Project no: 04-01-04-SF 0274). The support and guidance from Nils Larsson (iiSBE) in clarifying certain issues relating to SBTool is also acknowledged.

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OVERVIEW OF BUILDING INTEGRATED PHOTOVOLTAIC INSTALLATION IN HONG KONG GOVERNMENT BUILDING

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Abstract

Architectural Services Department is the works agent for facilities development of The Government of Hong Kong Special Administrative Region. We continue to promote sustainable development in Hong Kong construction industry by adopting of energy efficient devices and including of renewable energy technologies in our building design. This paper will briefly describe various types of building integrated photovoltaic system (BIPV). Our experience in applying building integrated photovoltaic system in two projects: a government office building and a primary school building will also be shared. Moreover, some of the design considerations and factors affecting the output of the photovoltaic panel will be discussed. Throughout different applications of building integrated photovoltaic system and its operation data, the feasibility of different types of BIPV systems in Hong Kong situation will be generally reviewed.

Keywords: Sustainable development, Renewable energy, Building integrated photovoltaic system

1. Introduction

According to the World Commission on Environment and Development, sustainable development is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs. "Recently, with the rapid growth of global economics, energy consumption has also increased significantly. Demand for energy continues to grow but sources of the combustible fuels such as coal, oil and natural gas are limited. In addition, the increased burning of fossil fuels raises concerns over global warming and air pollution. The rapid depletion of fossil fuels and the emission of carbon dioxide from the conventional power generation plants have drawn worldwide attention to the conservation of energy and to look for alternative energy sources. In the ways to increase prosperity and improve the quality of life while reducing overall pollution and waste, the Council for Sustainable Development has set the sustainable development strategy for Hong Kong. Whereas, the promotion and development of renewable energy is one of its major policies. It has also set the target of having 1-2% of Hong Kong's total electricity supply met by renewable energy by 2012.

Solar energy is clean, unlimited and can be replenished naturally. Environmentally, solar energy has the significant advantages of producing no pollutant emissions in use, and by replacing the use of the fossil-fuel for generating electricity, solar electric system spares environment from tons of harmful emissions, such as carbon dioxide, nitrogen dioxide and sulphur oxides, which are the major contributors to smog, acid rain and global warming.

2. Photovoltaic Panel

The term "photovoltaic", commonly referred to as PV, is derived from a combination of "photo", the Greek word for light, and "Volta", the name of the Italian physicist, Alessandro Volta, who invented the chemical battery in 1800. The photovoltaic effect is the direct conversion of solar energy into electricity. PV power systems do not have any moving parts. They are reliable, require little maintenance and generate no noise or pollutants. PV systems are modular-building blocks (modules) and come in a wide range of power capabilities, from a fraction of a watt (e.g. solar watches and pocket calculators) to more than 300W.

PV cells are normally fabricated using special semiconductor materials that allow electrons, which are energized when the material is exposed to sunlight, to be freed from their atoms. Once freed, they can move through the material and carry an electric current. The current flows in one direction (like a battery), and thus the electricity generated is termed direct current (DC). The DC output from the PV modules can be converted to AC power by an inverter, and then may be connected into the building's service panel/main switchboard or local utility grid. The energy generated by PV modules can be used immediately or stored in batteries for later use. Normally, the excess energy generated in autonomous PV systems during sunny periods is stored in batteries. The batteries then provide electricity at night or when there is not enough solar radiation.

There are three basic types of PV cell technologies. Common PVs available are monocrystalline silicon/polycrystalline silicon, amorphous silicon and thin film technology of copper indium diselenide (CIS). The monocrystalline silicon cell is sliced from single-crystal ingot silicon and it has the highest conversion efficiency among all technologies as over 15%. The polycrystalline silicon cell is sliced from blocks of cast silicon and its has less efficient and expansive than monocrystalline silicon cell. It has the conversion efficiency of about 10-15%. The amorphous silicon has the lowest conversion efficiency among the other technologies as about 4-7%. The thin film technology of copper indium diselenide cell has the conversion efficiency about 9-12%.

3. Building Integrated Photovoltaics System

PV system being integrated into building envelope is called "building-integrated photovoltaics" (BIPV) and this accounts for a significant and rapidly growing number of applications. Building-integrated photovoltaics not only produces electricity from natural sunlight but also forms part of the building envelope, where the PV elements actually become an integral part of the building, often serving as the exterior skin. For example, the PV arrays take over the normal function of the roof (i.e. keeps out the weather) and is not just placed on top of the roof. PV specialists and innovative architects are now beginning to explore creative ways of incorporating solar electricity into their designs.

The economics of BIPV is improved by allowing some costs of the PV system to be shared by roof, building facade or overhang of the building. BIPV may be installed on roof or a vertical exterior wall panel facing the direction with most sun, i.e. replacing basic construction materials, such as roofing and glass walls with photovoltaics through BIPV. Thus the cost of the PV wall or roof can be offset against the cost of the building element it replaces.

There are three basic ways of integrating PVs in buildings: roof-based systems; facade systems / curtain walling system; and sunshades and sun-screens.

The roof-based systems are often free from over-shadowing. The roof slope can be selected for high performance. It may be easier to integrate PVs aesthetically and functionally into a roof than a wall.

Facades have significant development potential. PV cladding can be considered to be panes of glass to which PV cells are applied and so massive glazed facades can be built upon. The mullion/transome stick system is the most commonly adopted for curtain walling system. PV modules can be fabricated and incorporated easily as factory-assembled double-glazed units, the outer pane being laminated glass-PV-resin-glass and the inner pane, glass with a sealed air gap between.

The sunshade systems normally consist of panels set slightly off from the building to allow for drainage and ventilation. As such they are very suitable for PV integration. The ventilation gap (e.g. 100mm or more) has the beneficial effect of reducing temperatures, thus enhancing performance. It also provides space for cable routes. It can also provide shading for the direct sunlight, penetrating into the indoor and hence reduce the burden for air conditioning plant.

The use of PVs should be part of the total energy approach for the building and the application of BIPV should be carefully considered as the required PV area and the construction cost can vary enormously according to the desired goal.

PVs are worth considering if the following key factors are right: The solar radiation at the site is the most important factor and good access to the site. Besides, the project should have an electrical requirement that much of the output from the PVs installation can be used on site. And, the availability of adequate surface area for installation of PV is also a critical factor. The design team should carry out the initial assessment of PV feasibility by studying the following factors: location and direction of space available for installation of PV panels, building form and aesthetics of the building, PV cell type and its combination, tint angle of PV panels, its operating temperature and cost.

In brief, the more solar radiation and the more uniform the radiation is on the array, the better the PV output is. The topography of the site should be studied carefully. In urban areas self-shading by the building itself and overshadowing by other buildings is very common in the situation of Hong Kong. It is desirable to have a site with as little shading by hills and other geographical features as possible since this will reduce the electrical output. Overshadowing by nearby buildings and self-shading due to the architectural form should be avoided wherever feasible. Where shading is unavoidable, careful selection of components and configuration of the array can help minimize losses. Computer programmes are available to assist in analyzing the loss of PV output due to shading effect.

Orientation of PV array is important but there is some flexibility for improvement to deal with this constraint. It is desirable to locate the building on the site so that PV array is approximately with 22° tilted and facing south. This will permit collection of more solar irradiance to the solar panels.

The potentially high temperatures associated with building elements specifically designed to capture the solar radiation should be carefully considered. The more solar radiation it receives, the higher temperature the solar panel is. In order to keep the operating temperatures as low as possible to maintain good performance of PV module, it is desirable to ventilate the back of the PV modules to improve the efficiency of the solar arrays. In general, as long as the heat from PV modules does not build up and is removed by ventilation there should not be a major problem. Hence, the local wind regime should be considered as part of the PV application for ventilating the solar arrays.

4. EMSD HQs

The EMSD Headquarters is located at the ex-airport near Kowloon Bay. Although it is located in the urban area, the district is not densely built and without ultra high rise building nearby. This is suitable for the adoption of photovoltaic technology.

Fig. 1 PV panels & its surrounding environment

The EMSD Headquarters is, currently, equipped with the Hong Kong's largest photovoltaic panel system comprising over 2,300 photovoltaic panels including BIPV (Fig. 1). The peak electricity generation rate can be up to 350kW. Monocrystalline PV cells are used in the photovoltaic system so as to achieve the highest conversion efficiency. It is almost the same as the electricity consumption of a large chiller plant.

Fig. 2 BIPV in Viewing Gallery

All the panels are faced south and inclined at 22° to the ground to receive most of the available solar radiation. The tinted panels can also provide the self-cleaning effect when it rains. The BIPV panels are integrated at the roof glass structure of the Viewing Gallery (Fig. 2). With carefully planned location of the PV cells, the daylight at the Viewing Gallery is not compromised while solar energy can be captured. Besides, the spacing between rows of PV panels is enlarged with due consideration of the shadowing effect and daylighting effect. This could generate electricity from the solar irradiation and also reduce the electric lighting power by the shaded sunlight. The PV system is grid-connected to the electrical distribution system of the local electricity company. This could enhance the reliability of the system. While considering the basic electricity demand of the building, the power generated by the PV system could be completely utilized within the building without any influx to the supply network.

The estimated electricity generation is around 300,000 kWh to 400,000 kWh annually which represents 3 to 4 percent of the building's electricity consumption or equals to the total annual electricity consumption of 90 families in Hong Kong. Besides this, using the PV panels to generate electricity also reduces the power stations' carbon dioxide emissions by about 280 tonnes every year.

Fig. 3 PV panels & BIPV

5. Ma Wan Primary School

As this project is the first purpose built school with solar-energy design, it serves as a model and research tool for the future school design of sustainable development. Architectural Services Department and Education Bureau (formally Education and Manpower Bureau) advocate to demonstrate how smart energy strategy can be implemented for contemporary academic approach while lowering its operating cost simultaneously.

The school is located in an outlying island, Ma Wan. The school is orientated to the southwest for daylighting and free of overshadowing from the adjacent residential towers. Moreover, there is plenty of natural wind for ventilation and lower the operating temperature of the solar panel. This is eminently suitable for PVs.

There are three different PV technologies applied in this school project and their details are listed in Table 1 and the photographs.

Table 1 Detail of BIPV in Ma Wan Primary School

Type of BIPV	Thin-film copper indium diselenide sunshades	Polycrystalline silicon skylight	Amorphous silicon sunshades
Peak	28.8	4	7.2
PV Panel Area (m2)	432	50	216
PV cells type	Thin film copper indium diselenide	Polycrystalline silicon	Amorphous silicon
Characteristics	Installed in roof top as electricity generating device ; provide extra insulation and protection from solar heat gain to indoor	Incorporate as part of the glass modules to suit the curved design of the roof-skylight over the lobby stair; electricity generating device; shading of sunlight and weather protection	Installed in roof top as electricity generating device; provide extra insulation and protection from solar heat gain to indoor
Energy output (kWh)	26000	3300	7200
Final yield (kWh/kW$_p$/year)	940	829	1009
Performance Ratio	0.65	1.11	0.93
Photos			

$$\text{Final Yield} = \text{Total energy output (kWh)/ Rated power of the PV arrays } (kW_p) \quad \text{Eq 1}$$

$$\text{Performance Ratio} = \text{Final Yield (hours)/ Reference Yield (hours)} \quad \text{Eq 2}$$

The Final Yield (kWh/kW_p) is the total net energy output of the PV array normalised to the rated power of the PV array. It is used to compare the different PV power systems regardless the size of the systems. The performance ratio is the ratio of the final yield to the reference yield. It is also widely used to indicate the overall effect of losses on the PV array's rated output due to array temperature, incomplete utilisation of the irradiation, system components/ wirings inefficiencies or system failure. By comparing with overseas and local experience, similar operating data is obtained for the overall performance.

6. Conclusions

To promote energy efficiency, adoption of renewable energy technologies like solar PV technology wind turbine technology as integral parts of the energy progamme become a global trend for sustainable development. By comparing with the experience of the other country and the local PV system, similar operating data is obtained for the overall performance.

Acknowledgements

The BIPV system of Ma Wan Primary School is technically supported by Department of Architecture, Hong Kong University. The BIPV system is jointed funded by the HK Government, Innovation and Technology Commission, CLP Research Institute (HK) which is a research institute of utility company and Department of Architecture, University of Hong Kong.

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INSTALLATION EFFECT OF FUEL CELL CO-GENERATION SYSTEM IN HOUSING

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Abstract

The shift from the fossil energy to renewable energy is needed from the view point of the resource depletion, and also the prevention of global warming. But from a practical standpoint, it is very difficult to secure enough renewable energy to keep current living standard. In the long term, it is needed to shift to renewable energy, but in the medium term, it is unavoidable to strengthen nuclear power. In this case, the problem is surplus electricity. Current nuclear power is driven to operate with thermal power generation because of the difficulty of the output adjustment. The way of solving this problem is to develop a large scale storage system for electricity. From the viewpoint of it, hydrogen obtained by electroanalyzing water is a kind of electricity storage system, and it is why we have large expectation for hydrogen.

The purpose of this study is to examine the effects of installing PEFC-CGS and SOFC-CGS in Japanese housing through numerical simulation. PEFC and SOFC are both fuel cell system using hydrogen, but at the current moment, the system obtains hydrogen from the natural gas. We built a model-based numerical simulation program to calculate the effects of the installation of these units. The reduction rate of primary energy is highest when SOFC-CGS is driven in rated operation all day. The reduction rate is 45.9%. In this case, the effects of utility cost reduction is highest.

Keywords: Energy system in housing, Fuel Cell, Co-Generation, Energy saving, CO_2 reduction.

1. Introduction

Reduction of energy consumptions in houses is strongly required in view of the Kyoto Protocol came into effect in February, 2005. Many countermeasures have been taken, such as improvements of device efficiencies by using top runner approach and strengthening thermal insulation at housings. But, because CO_2 emission is steadily increased in recent several years as that from homes is increased by 31.5 %[1] in 2004 compared with that in 1990, drastic measures are required. On the other hand, electric power supply in Japan is based on nuclear electric power generation and hydraulic power generation in spite of difficult output control. And, peak power is supported by thermal power generation. Efficiency of providing power by thermal power generation is currently stays at around 40 %(HHV) and efficiency of power generation is estimated at around 53 %(HHV) even after MACC type[2] is widely used. Therefore, even in the future, large amount of exhaust heat will be released in the air or in the water without making good use of it. At the time of reducing energy consumption in homes, ineffectiveness of energy providing system itself should be considered.

Currently, as home distributed power and heat source system, gas engine micro co-generation system (CGS) or fuel cell CGS is being installed or developed into Japanese Houses. They are power and heat source system with the ability to generate power and provide hot water at an installation site. And, around 80% of efficiency is said to be achieved. And PEFC-CGS (Polymer Electrolyte Fuel Cell CGS) and SOFC-CGS (Solid Oxide Fuel Cell CGS) are being developed as a distributed power and heat source system.

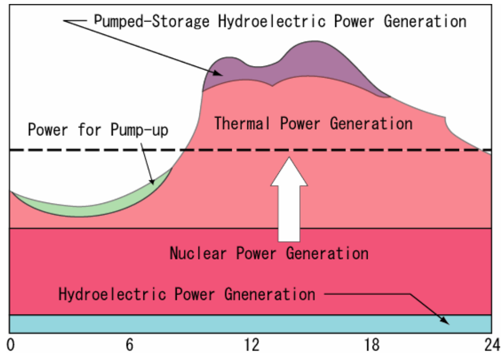


Fig.1 Difference of the electric power supply day and night [3]

These systems which are supposed to use hydrogen as a fuel in the future, are a kind of electric storage. When the price of the fossil fuel elevates, we could not avoid to up the share of nuclear power generation in the medium run. When the difference of the electric power demand day and night is big, huge amounts of electricity will remain at nighttime, and how the electric power is used becomes a problem. So the Fuel Cell Systems are expected as a part of devices which store the electricity at nighttime by electroanalysis of water

Under these circumstances, we have created model-based numerical simulation program to calculate energy saving effect, CO_2 reduction effect, and utility costs reduction effect for Fuel Cell CGS and have provided further insights into its introduction effect at homes.
In this paper, we would like to introduce the comparison of the effects of PEFC-CGS, SOFC-CGS and the conventional system based on this simulation program.

2. Outlines of PEFC-CGS and SOFC-CGS

Table 1 shows the specifications of PEFC-CGS and SOFC-CGS[4]. Because of the operating temperature of PEFC-CGS is comparatively lower than other fuel cell, PEFC-CGS has already been put to practical use in. Meanwhile, the important features of SOFC-CGS are the higher generating efficiency and operating temperature. Therefore the thermoelectric ratio of SOFC-CGS is smaller than PEFC-CGS. So the expectation toward the SOFC-CGS is getting higher as a source of heat and power under the situation that the hot water demand is almost satisfied and the electricity demand are increasing.

Table 1 Specifications of PEFC-CGS and SOFC-CGS

	PEFC-CGS	SOFC-CGS
Rated Power Output	1kW	1kW
Rated Exhaust Heat Output	1.66kW	0.69kW
Electric Power Generation Efficiency (LHV)	35%	49%
Exhaust Heat Recovery Efficiency (LHV)	58%	34%
Temperature of Hot Water Output	60℃	70℃
Hot Water Tank Capacity	200L	200L
Operating Temperature	90℃	750℃
Fuel	Manufactured Gas13A	Manufactured Gas13A

On the other hand, because of the high operating temperature of SOFC-CGS, new technologies development, such as a prevention of heat deterioration and hot gas seal. Now the operation temperature has come down from 1,000℃ to 750℃, and the generating efficiency has come up 49% (LHV).

3. Outline of the Simulation Program

3.1 Modeling the simulation program

The simulation program is written in FORTRAN. INPUT data are electric-demand, hot water demand and the temperature of supply water per minute. OUTPUT data are purchased power, reverse power, power generation, natural gas consumption for CGS and sub-gas boiler, heat quantity in hot water tank and the temperature of hot water in tank. In the last analyses, the simulation program provides the integrated value for seasons, primary energy consumption, CO_2 emissions and utility costs. Detail of this program was reported in previous works by the authors (Kuroki, H. et.al,. 2006)[5].

SOFC-CGS for housing is now under development, so it is quite difficult to obtain detailed performance of it. Thus the performance under partial load is based on PEFC-CGS which we have tested for two years. And we set the case which we buy the electricity from the power company and use the gas boiler (heat efficiency : 80%) for hot water demand as a conventional system.

3.2 Operating method

Each CGS should have most suitable operation method and activation control. PEFC-CGS takes Daily Start & Stop (DSS) operation which activates the CGS once or twice a day. Because of its high operating temperature, long time and big energy consumption for activation, it is difficult for SOFC-CGS to start and stop every day. So we set the 24h continuous operation method for SOFC-CGS. In DSS operation, PEFC-CGS will stop when the hot water tank (200L) is filled. But in 24h continuous operation, SOFC-CGS will use a cooling fan for surplus heat.

In Japan, the government and the power company do not consider the fuel cell CGS as green energy, because it uses a natural gas as a fuel. So at this moment, the power company does not buy the surplus electricity from the CGS. So generally CGS takes the following electric power load operation. In this paper, as a future perspective, we checked the rated operation that considers a reverse power flow. SOFC-CGS that takes the 24h continuous operation, will be operated also at night and the surplus electricity will be produced at night. So we also checked the case that SOFC-CGS takes the 24h continuous operation from 8 to 22 o'clock, and takes the following electric power load operation other time. We calls this case "rated operation (following electric power load at night)".

3.3 Input load data

To calculate the installation effect of each CGS for housing, we use the automatic life schedule production program called "Schedule Ver.2.0[6]" and thermal load calculation program called "TrP[7]to set the model house's input load data. The plan of model house is based on the AIJ standard house[8]. Family composition is father, mother and two children. Location is Fukuoka City in Japan. Input load data is one minute interval. Fig.1 shows the electric power and hot water supply load a month, and thermal electric ratio.

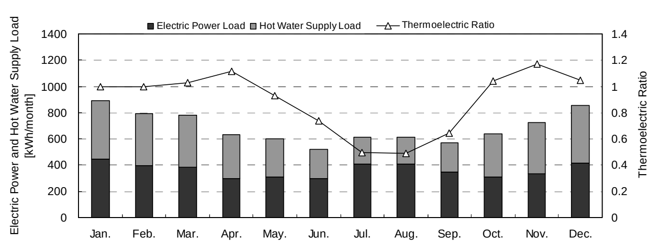


Fig. 1 Electric Power and Hot Water Supply Load

4. Results of the Simulation and Discussions

4.1 Effect of Energy Saving

The annual primary energy reduction rate (Fig.2) of PEFC-CGS of DSS following electric power load operation is 8.3% of DSS rated operation is 9.6%. The average of operation time is 8 hours a day for DSS following electric power load operation, and 5 hours a day for DSS rated operation (Fig.3). So the contribution rate of the electric power supply is low (Fig. 4). But because of the heat output is larger than the electricity comparatively, the contribution rate of the hot water supply is high. Particularly the annual contribution rate of hot water supply is 99% in DSS rated operation (Fig. 5 & 6). The exhaust heat use substance efficiency is 50% irrespective of operation. The power generation substance efficiency is low in summer because of the low hot water demand and short operation time. Therefore the proportion of activation energy is higher than in winter. The total of the power generation substance efficiency and the exhaust heat use substance efficiency is 73.6% in DSS following electric power load operation, 75.3% in DSS rated operation annually.

The annual primary energy reduction rate of SOFC-CGS is 22.9% in 24h following electric power load operation, 45.9% in 24h rated power operation, and 40.0% in 24h rated operation (following electric power load at night). Because of the 24h operation, all operation methods effect over 90% of the annual contribution rate of electric power supply. The contribution rate of hot water supply is 100% in summer when the hot water demand is low, but in winter the rate becomes lower than summer. So the annual contribution rate of hot water supply is about 80%.

Meanwhile, the rated operation which has a large heat output effect about 100% of the annual contribution rate of hot water supply. But under this operation, even in winter, the cooling fan is driven all the time. So 43.5% of heat in 24h rated operation, 27.3% of heat in 24h rated operation (following electric power load at

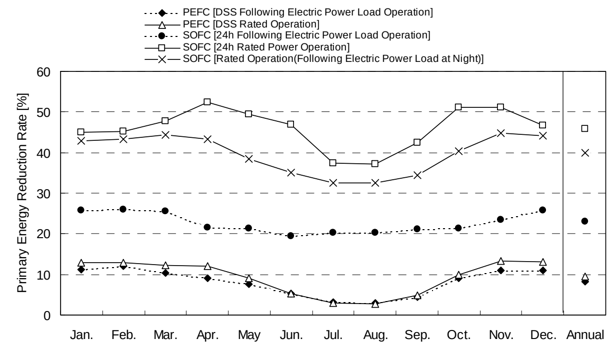


Fig. 2 Primary Energy Reduction Rate

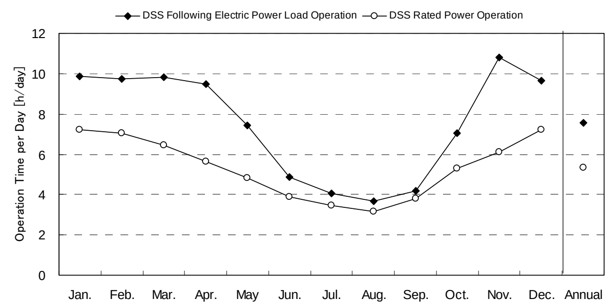
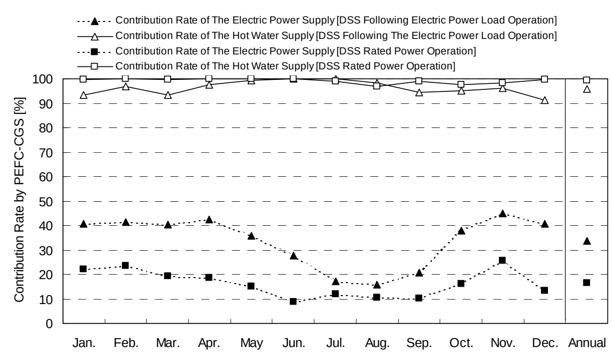
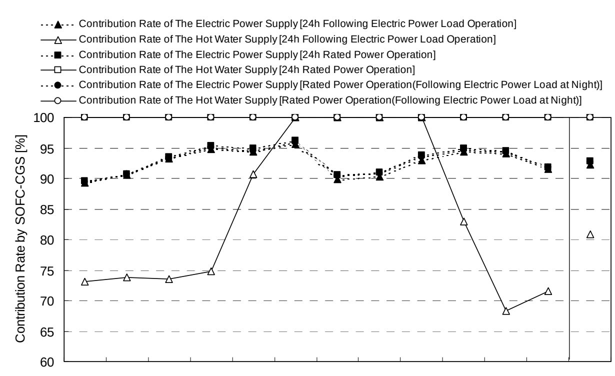


Fig. 3 Operation Time of PEFC-CGS



(a) Contribution Rate by PEFC-CGS



(b) Contribution Rate by SOFC-CGS

Fig. 4 Contribution Rate

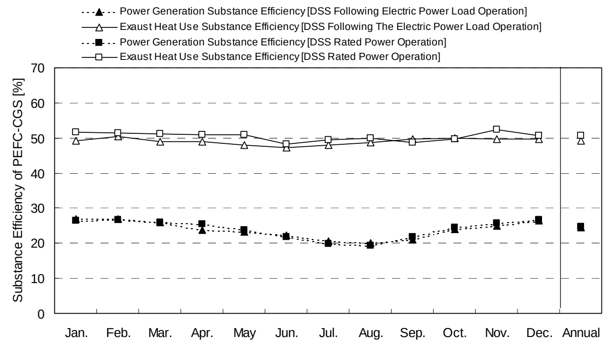
night) is not used. As a result, the annual exhaust heat use substance efficiency is 26.6% in 24h following electric power load operation, 17.3% in 24h rated power operation, and 21.6% in 24h rated operation (following electric power load at night). These come under influence of heat release. The total substance efficiency is highest in 24h following electric power load operation marks 69.6%, followed by 24h rated operation (following electric power load at night) marks 69.0% and 24h rated power operation marks 66.1%. This means that the primary energy reduction rate is highest but the total substance efficiency is lowest in 24h rated operation. This phenomenon comes from the things those the generating efficiency of SOFC-CGS is higher than the power company, and the heat release is large.

4.2 Effect of Utility Costs

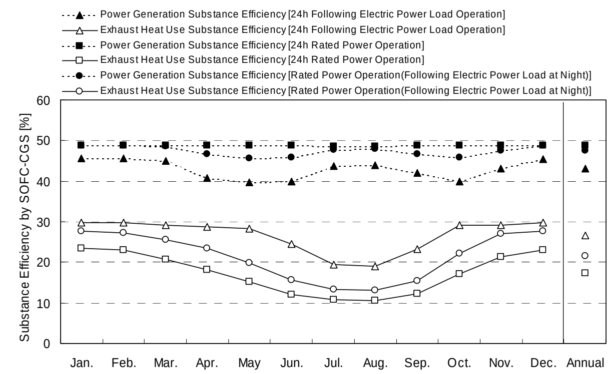
Table 2 shows the annual effect of utility costs by installation of PEFC-CGS and SOFC-CGS. To calculate the utility costs, the price table of local power company and gas company were used. This local gas company has a special price table for CGS. In case of the reverse power flow is considered, we set the power company has to buy the surplus electricity in the price of "Renewable Portfolio Standard (RPS)". And also we check the case of the regular price.

By installation of PEFC-CGS, the DSS following power load operation saves 46,000 yen ($383), the rated operation in RPS saves 44,000 yen ($367), the rated operation in non-RPS saves 34,000 yen ($283) annually.
The operating time of DSS rated operation is short comparatively shorter than DSS following power load operation. Therefore contribution rate of electric power supply is low. Then the purchase electricity is large and reduction figure of utility cost is low.

By installation of SOFC-CGS, the 24h following electric power load operation saves 65,000 yen ($541), the 24h rated operation in RPS saves 100,000 yen ($833), the 24h rated operation in non-RPS saves 27,000 yen ($225). The 24h rated operation (following electric power load at night) in RPS saves 85,000 yen ($708), the 24h rated operation

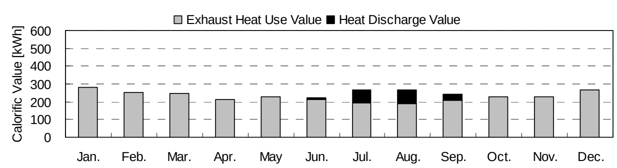


(a) Substance Efficiency of PEFC-CGS

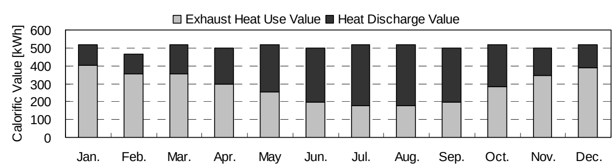


(b) Substance Efficiency of SOFC-CGS

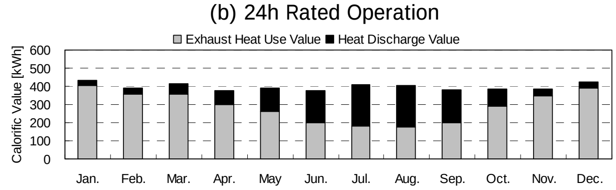
Fig. 5 Substance Efficiency



(a) 24h Following Electric Load Operation



(b) 24h Rated Operation



(c) Rated Operation (Following at Night)

Fig. 6 Exhaust Heat Use and Heat Discharge

Table 2 Utility Costs Reduction (yen)

			Conventional System	PEFC-CGS		SOFC-CGS		
				DSS Follow	DSS Rated	24h Follow	24h Rated	Rated(Follow at Night)
Electricity [yen]	Buy		98,285	68,296	83,400	22,223	21,892	22,017
	Sell	RPS	-	-	12,026	-	87,435	48,152
		non-RPS			2,438		14,692	8,658
Gas [yen]			103,260	87,017	86,334	113,971	167,048	142,749
Total [yen]	RPS		201,545	155,313	157,708	136,194	101,505	116,615
	non-RPS				167,296		174,248	156,108
Reduction of Utility Cost [yen]	RPS		-	46,232	43,837	65,351	100,039	84,930
	non-RPS				34,249		27,297	45,436

following electric power load at night) in non-RPS saves 45,000 yen ($375).

5. Conclusions

The most effective CGS operation is SOFC-CGS 24h rated operation from the viewpoint of primary energy reduction.

These effectiveness relate to the efficiency of power company. If the distributed power and heat source system could reduce the peak of electric supply from the power company, the efficiency of the power company would be improved. There is a correlation between these parameters.

Also, from the viewpoint of the cost, the practicality of RPS is still questionable. Even if the RPS is applicable, it is not marketable yet.

These system will be put to practical use in ten years. However, further examination is needed in order to get the most effective system by considering factors such as power company, distributed power and heat source system and their relationship with nuclear power.

Acknowledgements

This work was supported by a 21st Century COE Program Grant of "Architecture of Habitat System for Sustainable development" (Representative: Prof. Kawase, Kyushu University) and Grant-in-Aid for Scientific Research(c) "Life Style for Energy Saving and the improvement of the usability of distributed power and heat source system for housing "(Representative: Prof. Watanabe, Kyushu University) from Ministry of Education, Culture, Sports, Science and Technology. And we would like to thank Hiroshi Kuroki and the Saibu Gas Corporation.

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Appendix

The contribution rate is an index that shows how much the CGS could provide the electricity and heat of demand. This rate is represented by the next formula.

$$\text{Annual contribution rate} = \frac{\text{Power generation or used heat from CGS}}{\text{Annual demand of electricity or heat}}$$

The substance efficiency contains the efficiency of partial load, heat loss from the hot water tank, energy for activation and auxiliaries. And when we considered the reverse power flow, we considered the surplus electricity as utilizable energy. And the exhaust heat use means the heat for hot water actually used, and the heat discharge means the heat release by cooling fan.

SUSTAINABLE BUILDING DEVELOPMENT—THEORY & PRACTICES

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Abstract

Energy consumptions in buildings represents substantial amount of the total country's energy balance, particularly in the developing countries. Further, building energy consumption plays essential role in sustainability of building design and operations.

The paper addresses the main factors affecting the sustainable building development during the design, construction, operations, maintenance and retrofitting stages. It also presents common challenges facing the emerging energy efficiency building industry in developing countries hindering the achievement the full potential of the industry to reduce the alarming increasing demands on fossil fuel and generation of Green House Gases globally.

Keywords: Sustainable buildings, Integrated design, Passive design, Building Commissioning, Developing countries

1. Introduction

The essential purpose of buildings is to provide a protected environment in which to live, work, or accommodate assets. The degree of protection offered by a building can be rudimentary (e.g. a garden shed), or highly controlled (e.g. clean rooms in pharmaceutical industries or operations theatres in hospitals). Generally, the more comprehensive the environmental control, the more energy required to maintain that environment against the external forces of nature.

Building energy consumptions represent significant part of the country's total energy demands, particularly in the developing countries. Therefore, improving the energy efficiency in buildings can have substantial impact on the country's energy demands.

Practice shows that energy inefficient buildings characterised with low indoor level of comfort by being too hot or cold and it is often by improving the building's energy efficiency would lead to improving the indoor level of comfort.

In general, energy is the single largest operating expense for a commercial office building (in order of **30%** of its operating expenses). Accordingly, Energy Efficient building industry is increasingly attracting the attentions of decision makers, business communities and building occupants.

Currently, the humanity at the crossroads of the most significant crisis of modern times regarding the global warming and rapid depleting our limited fossil fuels and it is a mater of survival for us and our future generations to make significant change in our way of using energy. Accordingly, energy efficiency in buildings has the potential to reduce depleting the fossil fuel and cut the current Green House Gases generation.

The growth of sustainable building industry in the last decade and so has experienced and still is experiencing strong growth in the developed countries. By contrast, the energy efficiency building industry is still at its infancy stagy in the developing countries and there are a number challenges that abstract its development and growth.

The following paragraphs shed lights on various stages of energy efficient building life cycle and highlight the challenges facing the development of energy efficiency building industry in the developing countries.

2. What Makes Building Energy Efficient

Designing, constructing and operating energy efficient building is a complex process requiring people involved in all building development stages to be aware of the factors affecting building energy consumptions and how to keep the level of building energy efficiency at its maximum.

The follow are the main factors that can lead to design, build and operate energy efficient buildings:

i.) Adopting integrated energy efficient building design.

ii.) Constructing and commissioning building with energy efficiency in mind to insure that the building satisfies the intended design objectives.

iii.) Operating and maintaining buildings at their highest possible energy efficiency level.

iv.) Carrying out building modification, retrofitting and renovation with energy efficiency in mind.

3. Integrated Energy Efficient Building Design Concept

Integrated Energy Efficient building design involves adopting ***Passive Building Design*** approach that minimises building envelope heat loads and using ***Energy Efficient Equipment and Utilities Systems*** that lead to a substantial reduction in the building energy consumptions as well as creating a high quality indoor air quality.

From the energy efficiency perspective and to avoid undesirable conflicts accompanying building passive design, the following strategies should be addressed early during the conceptual design stage and followed through the detail design, construction, commissioning and operation & maintenance, to ensure an integrated and well-balanced environment in any commercial building with the least life cycle cost:

i.) Thermal Comfort Strategy.

ii.) Use of Daylight and Visual Comfort Strategy.

iii.) Use of Natural Ventilation Strategy.

iv.) Indoor Air Quality Strategy.

v.) Specific Indoor Environment Requirement.

All the above strategies will finally affect specific design alternatives which includes the following:

a.) Building orientation and shape.

b.) Building envelope materials.

c.) Building construction and commissioning.

d.) Interior space planning and zoning.

e.) HVAC and its control strategy.

***Quote 1:* The most important strategy for low energy design of buildings is to design and build according to the climate where the building is located. Geographically, the climatic conditions are diverse and hence the designer is required to describe and interpret climate in ways that are relevant to building design. – Comfortable Low Energy Architecture, London Metropolitan University.**

f.) Lighting and its control strategy.

g.) Building management and control system.

h.) Building Operations & Maintenance.

***Quote 2*: At the beginning of conceptual / schematic design stage, it is important to have a meeting between the architect, mechanical engineer, electrical engineer, lighting designer, building planner, owner/tenants and other consultants to discuss design strategies for energy efficiency. The list of design issues such as thermal comfort, visual comfort, specific indoor criteria requirement could serve as a framework. The meeting should result in a list of potential strategies with alternatives of design criteria to meet the design goals – Hawaii Commercial Building Guidelines for Energy Efficiency**

Practice shows that the incremental costs of designing and constructing energy efficiency building is in order of 3% to 5% of the conventional building design and the payback period is expect to be less than 10 years. The level of reduction in energy consumptions of energy efficient buildings is in order of 50% compared with conventional building design.

3.1. Passive Energy Efficiency design

Perhaps passive Energy Efficiency design are the most critical design criteria that has to be taken into account early during the conceptual design stage by all designers, especially the architects.

Passive Energy Efficiency design includes adopting design measures, such as building orientation and shape, selection of building envelope wall and roof materials with low thermal mass conductivity, building shading design, window type and design, type of glazing, daylight harvesting strategy, using natural ventilation, etc. Adopting these types of measures with incremental premium costs that can be recovered within 5 to 10 years are considered very attractive, because of the benefits they provide to reduce the HVAC heat load leading to lowering the sizes of HVAC. This results in reducing HVAC capital cost and building energy costs throughout the long life of the building. Most importantly, the building with effective passive design enjoys pleasant and appealing indoor environment created by daylighting and other features.

The passive building design also includes provision of building features that reduces building HVAC load, improves natural ventilated building thermal comfort and optimises use of daylight in the building perimeters. This includes:

3.1.1 Building Orientation and Shape

Selecting the most optimal building orientation is one of the critical design decisions that could have impact on the building energy performance. The geographic location and weather conditions dictate the desirable features of building façade and strategy to optimise harvesting sun radiations. Although the ability of selecting the building orientation is constrained by available land boundaries, the architect skill and creativity can play an important role in coming up with an optimal orientation that suits the available land.

The building designer should endeavour to limit the amount of windows and walls facing the east and west and increase the sizes of the walls facing south and north as shown in Figure 1. This would limit the excessive brightness (glare) from direct sunlight from the east and west in the morning and afternoon. Further, the sun positions during the day make the shading of the south facing windows (in northern hemisphere) or north facing windows (in the southern hemisphere) relatively easy.

Figure 1, Building Orientation with Major Façades Facing South & North

A computer modelling of a number of government health clinic buildings in Malaysia showed that by rotating one of the buildings shown in Figure 2 by 250° clockwise during the design stage would allow reducing the total building energy consumption by 4.2%.

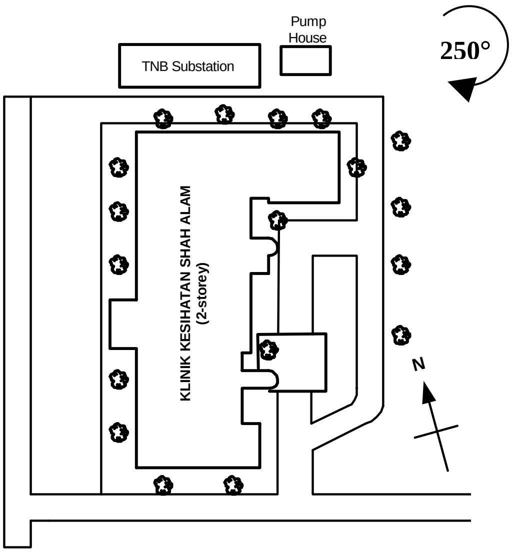


Figure 2, Existing Building Orientation for a Government Clinic (Shah Alam, Malaysia)

3.1.2 External Walls and Roofs

The external walls and roofs represent the exterior structural materials and finishes that enclose a space and separate inside space from outside.

In hot and cold climates selecting low heat conductivity construction materials in building walls and roofs leads to reducing the building heat load and consequently allowing smaller HVAC system resulting in reducing the building energy operating costs. Using such construction materials in non air-conditioned area would improve the building occupant's comfort level.

Optimal use of low heat conductivity, such as Aerated Light Concrete (ALC) blocks and insulation (Figure 3 and Figure 4) help reducing building heat gains and use heavy mass materials in building structure that absorb the transmitted heat into the building helps shifting considerable amount of peak heat load to the off peak time, when there is no cooling required in buildings.

Figure 3, ALC Block

Figure 4, Sample of roof insulation

3.1.3 External Windows and Doors

Windows and external doors play significant role in building façade. They bring into building envelope desirable daylight and create conducive indoor environment.

Using solar radiation can provide unique opportunities for the designer to harvest the daylight as substitute for artificial lighting in buildings consequently improving the building energy efficiency as well as creating pleasant and good quality lighting. However, sun electromagnetic radiation spectrum consists of a wide range of wave lengths and the daylight wavelengths detectable by the human eye cover 400 to 700 nm wave lengths as shown in Figure 5. Below 400 nm wave length represents ultraviolet (UV) band and above 700 nm wave length represent infrared (IR) band. Both UV and IR bands carry sun energy that is not desirable in hot weather. In passive building design the design needs to strike a balance between exploiting desirable daylight and managing other sun radiation, i.e. UV and IR, for the benefit of improving the building energy performance through specialised glazing.

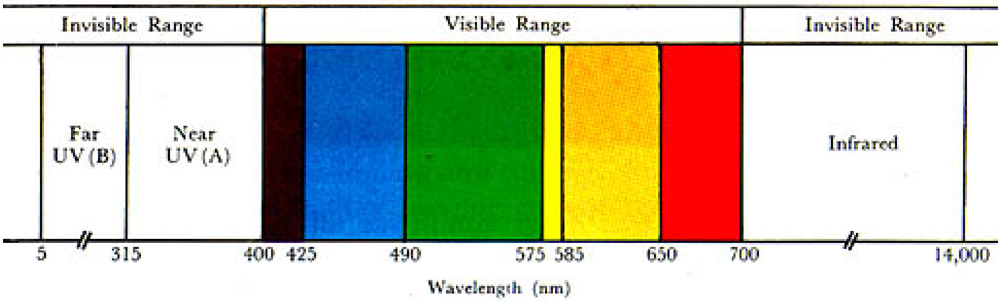


Figure 5, Solar Radiation Spectrum Showing Different Radiation Bands & their Wavelength Ranges.

Daylighting is highly favourable in many buildings as they are associated with improved productivity, improved education quality, aid in healing process and also improved in sales. Another important feature of daylight is its natural colour rendering which is useful in few applications such as dental procedure rooms, shopping complexes (colours for fabrics), photo gallery, etc.

In addition, right selection of window type and daylight harvesting devices, such as the use of light-shelves and glazing materials with low shading coefficient provides better opportunities for increasing the using daylighting and consequently reducing the building artificial lighting and reducing undesirable sunlight glare into the building as shown in Figure 6.

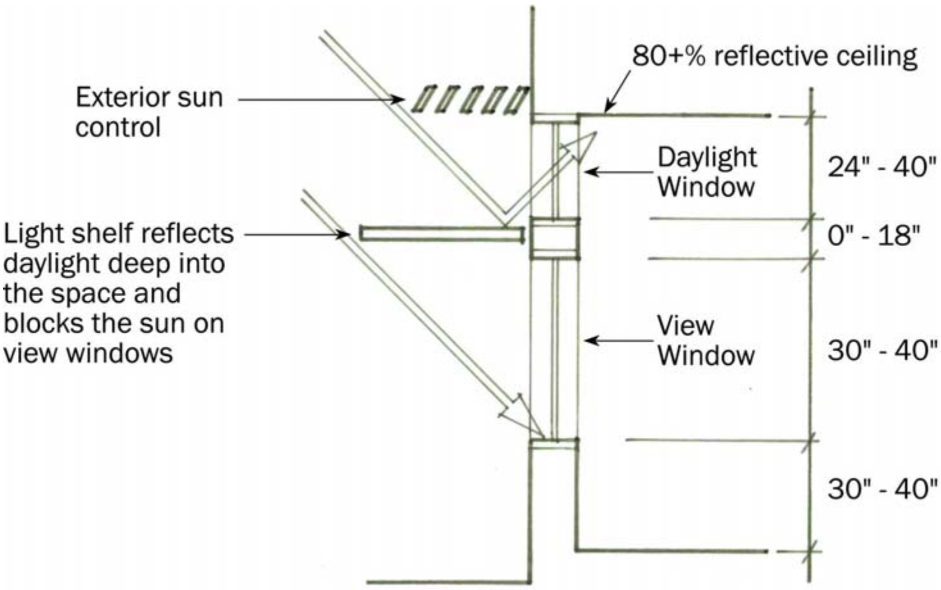
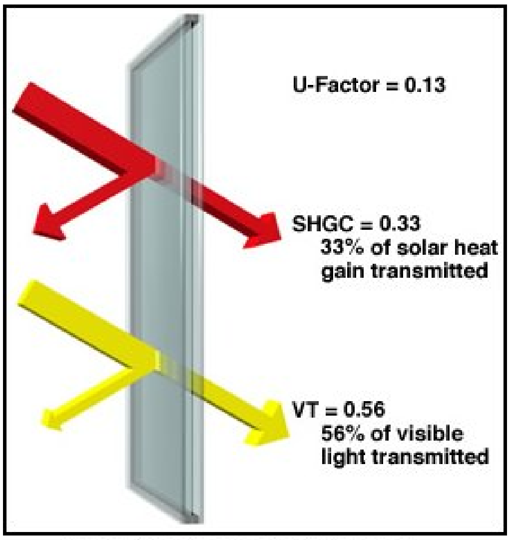


Figure 6, Daylight Harvesting by Using Exterior and Interior Daylight Shelves

Solar heat gain through external windows and doors can account for the major part of the building envelope heat load in hot climate and consequently the building HVAC load. In general, reduction of such heat gain can be achieved through:

i.) **Using suitable window and door sizing and materials.** Excessive window to wall ratio increases the level of building heat load. Therefore, sensible selection of window sizes, numbers and materials will have positive impact on the building heat load.

ii.) **Using High Performance Glazing.** Using windows with high performance glazing, such as Low Emissivity Glass (Low-E-Glass) or double glazing with Low-E-Glass and spectrally selective film allows maximising daylight admission and control heat penetration into the building (See Figure 7).



Credit: Efficient Windows Collaborative

U- Heat Transmission coefficient (W/m2 ^{o}K).

SHGC - Solar Heat Gain Coefficient.

VT - Visible Light Transmittance.

Figure 7, High Performance Double Glazing Window

iii.) **Using window frames with low heat transmittance.** The commonly used aluminium window frames allow substantial heat to leak into the building envelope. Using aluminium window frames with thermal break can reduce heat leak into the building. Refer to Figure 8 for the Schematic Diagram of Thermal Break in the window frame.

iv.) **Using suitable window shading.** The most effective method of controlling solar radiation is to prevent its direct entry into the building through using external shading, such as overhang, side reveals or external louvers as shown in Figure 9 for various window shading applications.

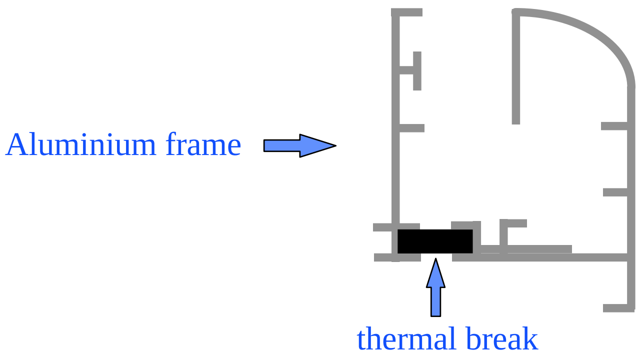


Figure 8, Thermal Break in the Window Frame

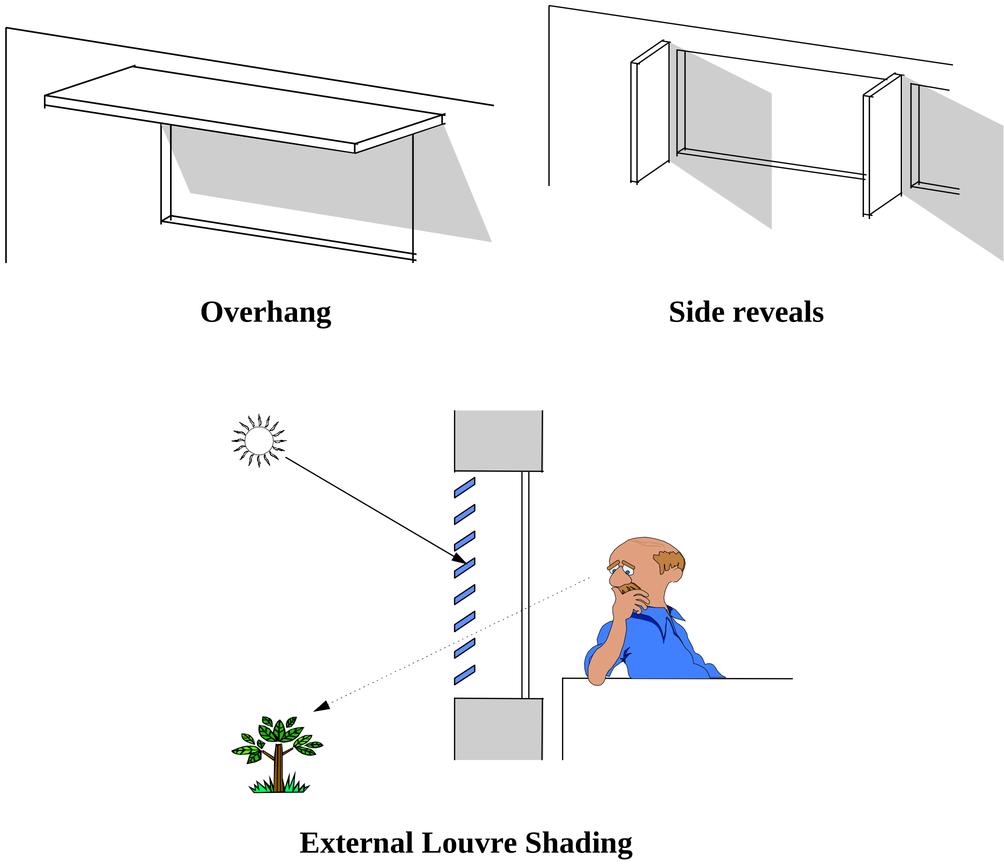


Figure 9, Window External Shading Devices

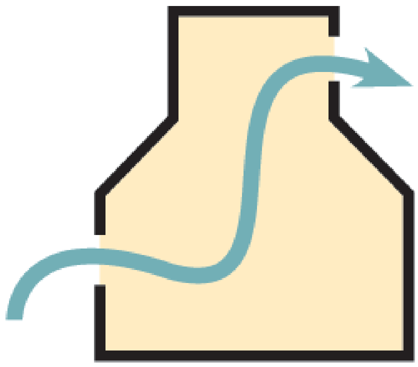
3.1.4 Natural Ventilation Strategy

Natural ventilation, unlike fan-forced ventilation, uses the natural forces of wind and buoyancy to deliver fresh air into buildings. Fresh air is required in buildings to alleviate odours, to provide oxygen for respiration, and to increase thermal comfort. At interior air velocities of 160 feet per minute (0.81 m/s), the perceived interior temperature can be reduced by as much as 5°F (2.8^{o}C). However, unlike mechanical air-conditioning, natural ventilation is ineffective at reducing the humidity of incoming air. This places a limit on the application of natural ventilation in humid climates.

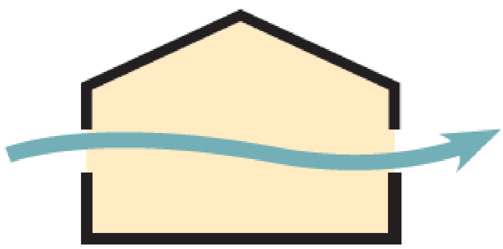
When ventilating a building using natural ventilation, two distinct design strategies must be considered - one for the winter and one for the summer. During winter only small air flows are needed (usually 5-8 l/s per person), but there is the risk of cold air drafts. During the summer, the main challenge is providing enough air flow to give effective cooling. Some designs use mechanical systems to provide outdoor air for occupants but use natural ventilation to provide cooling.

The design of natural ventilation utilises the stack effect and wind pressures to supply outdoor air to building interiors for ventilation and/or space cooling purposes (see Figure 10). The aim is to have an airtight building envelope while controlling outdoor air supply to provide the required ventilation. Features of naturally ventilated buildings include operable windows, exhaust vents located high in the building with intakes located low in the building, and open building plans to facilitate air movement. Designs can incorporate atria, internal stairwells, ventilation chimneys and small fans to move ventilation air.

Natural ventilation reduces energy consumption for fans and mechanical cooling and in most cases gives occupants control over their office space. Further benefits include no fan noise and in some cases elimination of the mechanical cooling system.



STACK VENTILATION: height separation of inlets and outlets promotes airflow.



CROSS VENTILATION: locate new inlets upwind; outlets downwind.

Figure 10, Stack and Cross Natural Ventilation

3.2 Active Energy Efficiency Building Design

Active Energy Efficiency Design refers to selecting energy efficiency equipment, utilities systems, control system and strategy that result in direct reduction in the building energy running costs. This includes using high efficiency HVAC system, such as using Variable Air Volume (VAV) or chilled beam air conditioning technologies; using high efficiency motors, pumps and fans, Variable Speed Drives (VSDs) with motors driving pumps and fans with variable loads; use of high efficient lighting system and occupancy sensor; and use of effective control system and others. Adopting these design criteria at the conceptual design stage will have minimum payback period (minimum additional cost) compared to replacing currently running equipment in existing occupied building.

Further, reduction in building total heat load resulted from adopting effective passive and active building design leads to substantial reduction in size of air conditioning system. The savings achieved from the small size HVAC system which would offset part of incremental costs of using specialised building materials.

The following paragraphs discuss various energy efficiency measures which can be used in commercial building:

3.2.1 Energy Efficient HVAC Systems

HVAC systems are intended to provide adequate cooling/heating comfort, dehumidification, and ventilation to occupied spaces at reasonable costs.

The following paragraphs highlight recommendations for designing and operating Energy Efficient HVAC systems in commercial buildings:

i.) Minimise outside air infiltration and exfiltration.

Excessive infiltration/exfiltration results in increasing the HVAC heat load. Eliminating such undesirable outside air infiltration/exfiltration can be achieved through having airtight building envelope. Practically, it is impossible to build fully airtight building. However, maintaining building under positive pressure under 12.5 Pa would result in minimising the level of infiltration/exfiltration provided the building envelope is adequately sealed.

ii.) Proper zoning of areas service by the HVAC.

If building areas or zones that have similar occupancy schedules and orientations are serviced by dedicated Air Handling Units (AHUs) or air conditioning equipment, then the operations of the HVAC system becomes more flexibility and energy efficient.

iii.) Use of Effective HVAC Control System

Using effective HVAC control system allows optimising HVAC loading; maintaining indoor temperature and humidity at required levels; and limiting operation hours according to building occupancy schedules. This can lead to substantial reduction of the energy consumptions of HVAC and its auxiliaries.

iv.) Use of Heat Recovery Wheels

Using Heat Recovery Wheels for recovering the reject heat through the building exhausted air for pr-treating outside air introduced in the building for ventilation purposes can be very effective in reducing the HVAC energy consumptions. The effectiveness of this measure dependents on having HVAC with ducted return air and airtight building envelope.

3.2.2 High Efficient Lighting Equipment

Building artificial lighting load is one of the main building energy end-uses. Using energy efficient light system can offer substantial reduction in lighting load, especially if the use of artificial lighting is coordinated with daylighting by using photo-sensor controls.

Energy efficient lighting system includes using T5 fluorescent lamps and other energy efficiency lamps; electronic ballasts; high performance luminaries; and utilising occupancy sensors for intermittently occupied areas.

3.2.3 Use of Energy Efficient Office and General Equipment

Further, selecting Energy Efficient office equipment and other utilities equipment leads to reducing the building energy consumptions resulting in reducing building cooling load in hot climate.

Office equipment includes computers, printers, faxes, copying machines and other equipment. Energy consumptions of such equipment can represent large portion of the building energy consumption. Using readily available energy efficient and reasonably priced office equipment, such as computers with power management functions, laptop, liquid crystal displays (LCDs) monitors, multifunction office equipment and others can offer substantial reduction in office equipment energy consumptions.

3.2.4 Building Monitoring, Control, Operating, Energy Management & Reporting System

Having an effective building monitoring, control, operation energy management and reporting system can play a critical role in operating and maintaining Energy Efficient building.

4 Building Energy Efficient Construction and Commissioning

Energy efficient building construction and commissioning are carried out with an aim to achieve the planned energy efficiency specified at the design stage.

4.1 Energy Efficiency Building Construction

Real life shows that most the time building construction does not go smoothly and quite often the final building details would be different from the original design. This leads to affecting the building energy performance with varying degrees. The reasons for that could be one or more of the following:

i.) Contractor or subcontractor tends to cut corners for saving material and labour costs.

ii.) Building design drawings and documentations are not clear enough to help the contractor or subcontractors to construct the building as the building designer is originally planned.

iii.) Unplanned amendments or alterations to the original design that have negative impact on the building energy performance.

iv.) Poor workmanship quality leading to negatively affecting the building energy performance.

To overcome the above difficulties, it is essential that building designers are involved in the construction stage and building commissioning is planned and started at the early stage of building design and during the construction.

4.2 Energy Efficiency Building Commissioning

In general, the purpose of building commissioning is to ensure that the building and its utilities systems perform their intended functions and the design "Energy Efficiency Promises" are achieved.

In practice, the commissioning is usually carried out over a short period of time before full occupancy of the building with a focus on operation rather on performance. Realising that building utilities systems performance particularly the HVAC will be changed when the building is fully occupied and after the equipment being operational for some time, the building commissioning needs to be structured into two phases. The first phase is the "***Acceptance Commissioning"*** and the second phase is the "***Final Commissioning"*** after the building being fully occupied.

To commission and set up a building utilities system to not only provide the desired internal conditions, but also do this in the most energy efficient way possible. This requires new approach to building commissioning guidelines.

Commission requires the designer to have a good understanding of the main building heat load contributors and utilities systems and how these systems should be tuned in the ***Acceptance Commissioning*** phase. Further, it is necessary that during the guarantee period these systems as the building is occupied and the seasons go through their annual cycle before carrying out the ***Final Commissioning***. Building and utilities systems energy efficiency indicators at commissioning stage need to be derived from the design and energy model by the designer. These should answer the question, "***How to Test Building Design to Ensure it is Energy Efficient***". The designers must be involved in the building construction and commissioning. Their involvement will improve their understanding of how the installed designs operate and are maintained and how they actually consume energy.

Change is continual in modern buildings. Therefore, it is important that the essential design information that underpins the energy efficiency of the original systems is recorded and available to future designers who are required to modify the systems without compromising the intended efficiency. Design information is not usually passed on from the designer and is not usually recorded in a form that is readily passed on. Both these things need to change if design energy efficiencies are to be maintained over time.

Due to the continuous change in building structure and operations as well as the tendency of BAS transducers to drifting, it is essential to recommission the building and its air conditioning systems periodically to ensure that the building will operate efficiently all the time. These will allow to:

i.) Document any changes.

ii.) Tune and readjust the system to accommodate any changes in the building structure and operations.

iii.) Establish baseline performance.

iv.) Collect and evaluate performance data continuously.

5. Building Energy Efficient Operations and Maintenance

It is important to realise that sustaining the building energy efficiency after completing the building construction and commissioning stages is highly dependent on how the building is being operated and maintained.

Building energy performance is highly affected by how building occupants operate the building utilities and various energy end uses and their interaction with the building controls.

Energy efficient operations and maintenance differ from normal maintenance that strives to maintain the asset availability and asset value by aiming at maintaining the energy efficiency at its optimum through understanding of how building and its utilities systems consume energy and where the risks to energy efficiency lie.

For example, a relatively small deviation in AHU damper settings or three-way valve control from the optimum may not result in any noticeable problems with the systems ability to maintain conditions, however it may have a very significant affect on energy consumption over the year. With these systems it is often not noticed until the settings are far enough out of calibration as to affect the HVAC plants ability to cope with temperature extremes that the problem is noticed and rectified.

A lot of energy efficient maintenance practices are dependent on information about the design, with settings confirmed at commissioning and the tracking of this information over time against these commissioning benchmarks. This process should be thought through by the designer and set out at design stage with clearly documented procedures for energy efficient maintenance specified for the particular design.

In addition, maintaining the asset of a building under a normal maintenance contract has a lot of interaction with energy efficiency implementation and maintenance. Therefore, it is recommended to integrate both the asset maintenance and energy efficiency contracts or combine them under one contract. Otherwise, there will be unclear accountability for achieving the energy efficiency programme objectives.

6. Building Energy Efficient Retrofitting

Building retrofitting is a part of building life cycle and the reasons for its occurrence can be one or more of the following:

i.) Building renovation.

ii.) Fixing problems with the building facilities.

iii.) Building expansions.

iv.) Facilities aging.

Building energy efficient retrofitting is very challenging tasks requiring thorough understanding the current building facilities and future anticipated changes.

Real life shows that carrying out building Energy Efficient retrofitting is far more complex than new energy efficiency building design. It is common that most of old building drawings are outdated and most of major equipment manuals and specifications are missing.

In general, building functions and internal layouts usually change over time, but the facilities and in particular the HVAC do not follow these changes.

The main rule of building energy efficient retrofitting is to review the whole building function and facilities and try to adopt the changes that can achieve the most energy efficient solution with the least life cost cycle.

The follow are an approach which can bring the best outcomes from building energy efficient retrofitting:

i.) Selection of experienced engineer who will take the responsibility for conducting the retrofitting.

ii.) Collecting existing building information including drawings and equipment manuals.

iii.) Interview building operators and maintenance staff to understand the nature of building facilities.

iv.) Obtain history logbooks.

v.) Monitor and evaluate the current building energy performance and indoor air quality and level of comfort.

vi.) Establish building retrofit alternatives and conduct technical and financial evaluations of these alternatives.

vii.) Select the most effective energy efficient building retrofit.

viii.) Carry out building retrofit design.

ix.) Construct building retrofit.

x.) Commissioning to ensure that the retrofitted building operates as planned.

xi.) Document the building retrofit.

xii.) Train building operators on the new retrofitted facilities.

7. Building Energy Efficiency – Theory and Practice

The designer of an energy efficient building needs to take into account a long term approach to selection, operation and expansion of the system. It is essential for the designer to consider the ability of building utilities system to facilitate the ongoing energy efficiency through the design, construction, commissioning, operations and maintenance.

Often most of the energy wastes and the majority of the unfulfilled building "promises" in existing buildings can be traced back to the dilution over time of the original design principles and perhaps more significantly the drift of building controls.

As soon as a building is completed the building change process usually starts. Tenants are keen to further customize the space to ensure it is productive. This will leads to affect the original design and affect the building and its facilities performance.

In real life, it is extremely difficult to realise and maintain exactly what the best efficient design and computer modelling can anticipate. This situation is exaggerated when the designer rely heavily on complexity of control, which would be difficult to maintain and prevent occupants from tampering, especially when the building structure start to change with the time. Unfortunately, this is the nature of building life cycle and the key question is how to keep the departure of real life from the original design as little as possible.

The best practice is to keep things simple by reducing complexity where possible and this will go a long way to ensuring that building utilities and in particular HVAC systems will be installed, commissioned and maintained for ongoing energy efficiency.

7.1 Building Control and Energy Efficiency

Designers of modern buildings tend to rely heavily on using high tech controls. It is necessary to recognise that the selected technology to be used in building should be appropriate to the need. The more complex the technology the more difficult it will be to set up and maintain appropriately. This can lead to significant energy wastage and high cost to rectify because of the systems complexity.

It is also important for designers to recognise that all controls technology will drift and require checking and re-calibration over time. Real life shows consistently how the most sophisticated hi-tech building can be run in most inefficient way. It is not unusual to find that transducers used by a Building Automation Systems (BAS) bear little or no resemblance to what's happening in the real life. BASs are complex and they are totally dependent on the quality inputs, regular checking and calibrations of transducers are essential for efficient operations of building facilities including HVAC systems.

Considering the above, designers should give some thought as to how theses systems can be made to be self checking, even in the simplest sense. Call for the incorporation of self-checking "reports by exception" to raise alarms. Parameters and trend logs can be set intelligently to do this. The controls suppliers will not normally do this type of reporting without it being specified. There is the opportunity to establish checking indicators based on commissioning data to warn of drift over time, e.g. supply air requirements can be tracked to check drift over time on VAV boxes and other field controls that can typically manifest themselves as steadily increasing gross supply air requirements.

Therefore, BAS, Direct Digital Control (DDC), differential pressure and temperature transducers calibration and checking should be an annual exercise. Features that facilitate system checking and calibration should be incorporated in the design and the requirement to regularly check and calibrate controls clearly specified.

7.2 Human Factor and Building Energy Efficiency

Continuous building energy performance surveys are being conducted by the USA Department of Energy (DOE) since late seventies. Recent DOE survey findings shown in Table 1 indicate that the average energy consumption of surveyed buildings is over 200% of energy efficient buildings. Further, Table 2 shows that the level of Energy Efficiency technologies used in buildings doesn't warrant improvement in building efficiency. On the contrary, level of energy efficiency technologies in the buildings that fall in the bottom 25% performers is more than double of that the top 25% performers. This shows that the Energy Efficiency technologies become energy wasters if not tuned and maintained properly.

Table 1, Energy Indices of USA Commercial Buildings

Building Categories	Energy use (kWh/m2.yr)
Energy Star (2000)	154.2
Average Buildings (1995 CBECS)[iii.]	337.6
Efficient Buildings (Top 25% 1995 CBECS)	162.0

Table 2, Level of Energy Efficiency Technology Use in USA Commercial Buildings

EE Technologies	Energy Star	1995 CBECS	1995 CBECS

	2000	(Top 25%)	(Bottom 25%)
Economisers	70%	30%	75%
Variable Speed Drives	55%	20%	45%
VAV	70%	35%	65%
Energy Management Systems	80%	25%	55%
Motion sensors	60%	10%	20%

8. Energy Efficient Building Industry in The developing Countries

Energy Efficient building industry in the developing countries is still at its infancy stage. The total amount of energy consumed by buildings represents one of the largest energy consuming economic activities in these countries. Therefore, improving energy efficiency in buildings would reduce substantially the alarming increase of energy demands in these countries and cut the generation of Greenhouse Gases. Accordingly, the development and growth of Energy Efficient building industry is expected to have a significant impact on sustainability of economic developing in the developing countries.

The current energy efficient building industry in the developing countries has a number of challenges hindering the achievement of its full potential. These challenges vary from one country to another to reflect the socioeconomic differences between various countries.

The following are the most common challenges to energy efficient building industry in most developing economies:

- **i.)** **Lack of Effective Energy Efficiency Regulations or Guidelines that specify the minimum expected energy performance in new buildings.** Presence of such regulations and guidelines is essential in particular in the developing countries where government buildings account for a very high portion of the total country's commercial building stock.

- **ii.)** **High energy subsidy.** The artificially low energy cost resulted from high energy subsidies in the developing countries makes the financial justification of investment in energy efficient building very difficult.

- **iii.)** **Absence or shortage of local energy efficiency building materials and equipment.** This leads to increase substantially the cost of energy efficiency building materials resulting in the difficult financial justification of energy efficient building industry.

- **iv.)** **Lack of awareness of energy efficient building among decision makers, building developers and professionals.** This obstructs the growth and development of energy efficient building industry.

Over coming the above obstacles would lead to stimulating the energy efficient building industry in the developing countries.

9. Conclusions

- **i.)** Designing, constructing and operating energy efficient building is a complex process requiring all people involved in building development to be aware of factors affecting building energy consumptions and how to keep the level of building energy efficiency at its maximum.

- **ii.)** Adopting integrated energy efficient building design concept that incorporates the passive aspects of the building's thermal performance and use of high efficiency building utilities systems is essential in achieving energy efficient buildings.

- **iii.)** Commissioning, operating, maintaining and retrofitting buildings with energy efficiency in mind are critical for achieving and maintaining the building at its intended Energy Efficiency.

iv.) Control systems play a critical role in Energy Efficient buildings. However, all control systems inherently drift with time and need tuning from time to time. Otherwise, these systems if not continuously calibrated and tuned they lead to increase the building energy wastes.

v.) Energy Efficient building industry in the developing countries is still at its infancy stage and faces a number of challenges that hinder its growth. Addressing these challenges is essential for achieving the full potential of substantial reduction in energy consumptions.

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IMPACT OF BUILT ENVIRONMENT ON OUTDOOR THERMAL CONDITIONS IN THE HOT HUMID CITY OF CHENNAI

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Abstract

The outdoor environment is deteriorating in many cities due to rapid urbanization. This leads to a series of environmental problems and affects the outdoor activities. Outdoor comfort conditions affect the indoor climate to a large extent and leads to increased energy usage. It is therefore important to improve the microclimatic conditions around buildings in urban environments. This paper aims to study the impact of built environment on the outdoor thermal comfort conditions in the hot humid city of Chennai, India. Different street designs are evaluated from a thermal comfort perspective. Microclimates in a residential environment are analyzed through field measurements in different street geometries and orientations. The comfort conditions are estimated by calculating the Physiological Equivalent Temperature (PET) using Rayman 1.2. The study indicates that a shallow urban canyon is warmer than a deeper one. A deeper urban canyon experiences tolerable comfort levels, mainly due to the shading effects of buildings, reduction in solar penetration and reduced sky view factor. The streets with N_S orientation provides better thermal comfort than E-W orientation. The study confirms that it is very difficult to achieve thermal comfort in the hot humid city of Chennai but considerable amount of improvement is possible with better street geometry and orientation. Presence of vegetation in street geometry also increases the comfort conditions and enhances the usage of outdoor spaces considerably.

Keywords: Street geometry, outdoor thermal comfort conditions, aspect ratio, PET, Urban design guidelines.

1. Introduction

Urbanization tremendously changes the landscape of an urban area and results in distinguished climatic conditions termed the "Urban climate". Luke Howard (1833) carried out the first scientific study of urban climate modifications (Landsberg 1981). He compared the temperature of a city weather station with that of a rural station and found that the city station was warmer. The warmth of cities in contrast to their rural surroundings is termed as "Urban Heat Island" (UHI), a term according to Landsberg (1981) coined by Gordon Manley (1958). Research on UHI phenomenon was done by Chandler.T.J, 1976, Oke 1988, Akbari et al 1992 and Jauregui, 1997. This has revealed a series of causal relationship between urban factors and climate. Urban geometry and thermal properties of urban surfaces have been found to be the two main factors influencing urban climate (Oke 1987, Arnfield 2003). Urban geometry affects the most at neighbourhood and smaller scales (Todhunter 1990, Arnfield 1990). The urban geometry of a city is characterized by the "urban canyon" which is defined as the three-dimensional space bounded by a street and the buildings that abut the street. The Urban canyon layer (UCL) is the layer of atmosphere where most life occurs: from ground up to the mean height of roofs. Urban canyons restrict the sky view and free movement of air. It also causes multiple reflection of solar radiation. Urban canyon geometry is specified by the height of building to the width of street (H:W) ratio, known as aspect ratio. Terjung and Louie (1974) were among the first to suggest that the urban/rural daytime temperature anomaly is largely attributable to the aspect ratio. In the hot humid environment of Dhaka, Bangladesh, Ahmed (1994) found that on an average the daily maximum temperatures decreased, by 4.5 degree Celsius when the H/W ratio increased from 0.3 to 2.8. Studies indicate that the street-level thermal comfort depends largely on the aspect ratio in the hot humid climate. The comfort condition outdoors also dictates the usage of outdoor spaces in an urban environment (Nikolopoulou et al., 2001). However, urban climate and outdoor thermal comfort are generally given little importance in the planning and design processes. (Evans 1996, Eliasson 2000).

The aim of this paper is to study the impact of built environment on the outdoor thermal comfort conditions in the hot humid city of Chennai, India. This is done by comparing different street geometries and orientations in the residential area of Methanagar, Chennai, India. The study is based on field measurements of air temperatures, wind speed and relative humidity. Thermal comfort is assessed by calculating the Tmrt (Mean radiant temperature) and Physiological equivalent temperature (PET) using Rayman 1.2 model (Bauer et al 2000, Matzarakis 2000, 2003).

2. Area of Study

Chennai-Madras, one of the four metropolitans of India, is the capital of the southeastern state of TamilNadu. It lies between 12.9° and 13.9° N and between 80.9° and 80.19° E. The maximum temperatures in summer is around 40-44 °C and the minimum temperatures in winter is around 20-22 °C. Varying microclimates exists within the city due to changes in built environment. A typical residential area in Methanagar was chosen for the study to assess the impact of built environment on the outdoor thermal comfort conditions. The residential area has a dispersed urban form with two to three storey buildings and having setbacks on all sides of the plot.

3. Methodology

3.1 Site Selection

Based on street geometry and orientations eight locations were identified at Methanagar. Four locations A, B, C and D having aspect ratios of 0.75, 0.75, 0.67 and 0.33 respectively in the East – West orientations (Fig. 1) were considered for the study. Similarly four other locations E, F, G and H with aspect ratios 1.8, 1.2, 0.75 and 0.5 respectively were identified in the North – South orientations (Fig. 2). The geometric characteristics of the measurement locations are given in Table 1.

Table 1. Geometric characteristics of the measurement locations in Methanagar

Location	Building height (m)	Street width (m)	H/W ratio	Orientation
A	6	8	0.75	E-W
B	9	12	0.75	E-W
C	6	9	0.67	E-W
D	3	9	0.33	E-W
E	9	5	1.8	N-S
F	6	5	1.2	N-S
G	9	12	0.75	N-S
H	6	12	0.5	N-S

Fig. 1 East – West Oriented Streets

G

Fig. 2 North – South Oriented Streets

3.2 Field measurements

Air temperatures, relative humidity and wind speed were recorded four times during 7.10 am, 10.45 am, 4.00 pm and 6.15 pm in all eight locations on a typical summer day. The measurements were taken at a height of 1.2m above ground level.

3.3 Assessment of thermal comfort

The air temperature, relative humidity and wind speed recorded were used to assess the thermal comfort conditions at all eight locations by calculating PET (Physiological equivalent temperature) and Tmrt (Mean radiant temperature) expressed in °C using Rayman 1.2 model. The thermo-physiology of the human body (age, sex, height, weight, clothing insulation 0.9 clo, physical activity 80 W) has been considered for the study.

4. Results and Discussion

4.1 Microclimate at street level

4.1.1 Air Temperature. The E-W oriented streets experienced higher air temperatures for most part of the day when compared to N-S oriented streets. The air temperature of E-W street canyons increased as the day progressed and reduced in the evening, whereas in N-S street canyons the air temperature gradually reduced from morning 7.10 am to 10.45am and then increased marginally during late afternoon and reduced in the evening. During daytime N-S oriented streets were comfortable when compared to E-W streets. Shallow canyons with aspect ratio of 0.33 and 0.67 in the E-W direction and 0.5 and 0.75 in the N-S direction experienced higher temperatures than the deeper canyons. The air temperatures (Ta) of E-W and N-S orientated streets are presented in Fig 3.

4.1.2 Humidity and Wind speed. The relative humidity in E-W and N-S canyons is presented in Fig 4. The RH increased gradually in N-S canyons and reached the maximum during evenings. In the E-W canyons the variations were minimal. Lesser aspect ratios experienced higher humidity in E-W and N-S canyons. In the deeper canyons the relative humidity was comparatively less. The wind speeds were higher in E-W orientations when compared to N-S orientations. Location A of E-W orientation experienced the maximum wind speeds through out the day. The close proximity of playground to location A plays a major role in increasing the wind speeds. Higher velocities in hot humid region accelerate the evaporation processes thereby creating comfortable outdoor spaces.

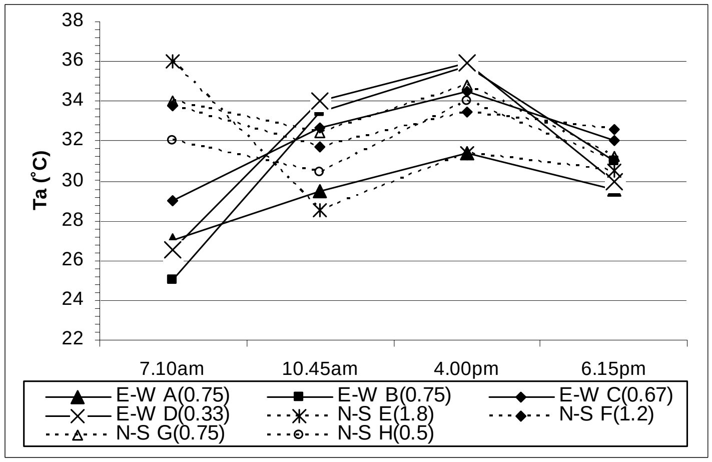

Fig. 3 Ta (air temperature) at 1.2m above ground in the street canyons on a typical summer day

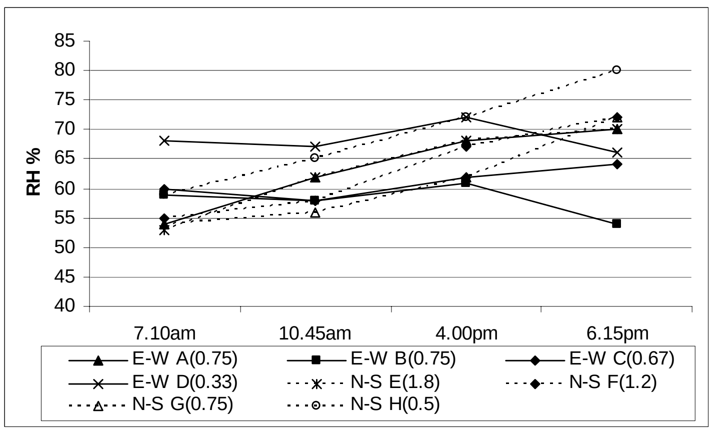

Fig: 4 RH (Relative Humidity) at 1.2m above ground in the street canyons on a typical summer day

4.1.3 Mean Radiant Temperature and Physiological Equivalent Temperature. The E-W orientation experienced higher T_{mrt} during day time and reduces during the mornings and evenings. The N-S oriented streets experienced similar T_{mrt} through out the day without much variation. The PET in all urban streets for E-W and N-S orientation is presented in Fig 3. The PET values increased considerably in the E-W canyons during day and reduces in the evenings. In the N-S canyons the variations were minimal.

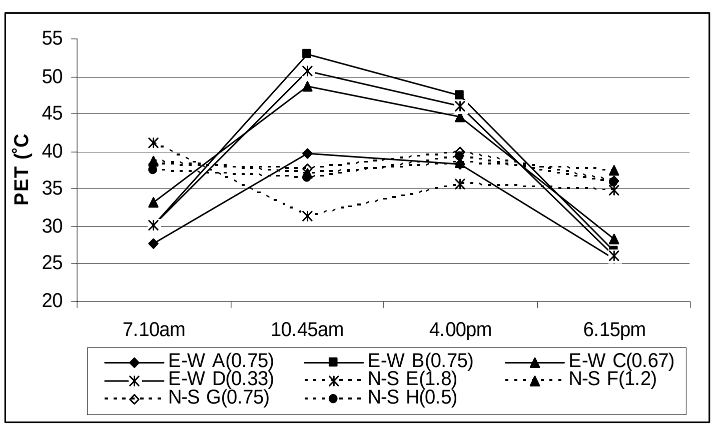

Fig: 3 PET calculated using Rayman 1.2 Model for the street canyons on a summer day

4.2 Thermal Comfort Analysis

4.2.1 Impact of Canyon geometry. Deeper canyons with higher aspect ratio were better when compared to shallow canyons in terms of comfort. However during early mornings deeper canyons act as heat traps due to multiple reflections. The comfort analysis was done based on the PET values. The thermal sensation in tropical climate and the grade of physiological stress was arrived using PET values (Hoppe, 1999) using Rayman 1.2 model (Matzarakis 2002).

4.2.2 Impact of orientations. East-West oriented Streets - The E-W streets experienced strong heat stress in the afternoons with PET values higher than 30 °C. In the mornings and evenings moderate heat stress were experienced with PET values between 26 °C to 30 °C. All locations experienced similar physiological stress irrespective of the street geometry through out the day. The thermal sensation was better with higher aspect ratio. North-south oriented Streets - The N-S streets experienced better thermal sensations with increased aspect ratios. At 7.30 am location E experienced very hot thermal sensation while other locations were hot. But during 10.45 am, 4.00 pm and 6.15 pm location E experienced slightly warm and warm thermal sensation and other locations experienced hot thermal sensation. Through out the day strong heat stress was experienced in all locations.

5. Recommendations

Thermal comfort is very difficult to achieve in hot humid climates but considerable amount of improvement is possible with better street geometry and orientation. Based on the findings of the study, it is clear that N-S orientations are better than E-W orientation. Deeper canyons provide better outdoor thermal comfort than shallow canyons. Presence of vegetation in street geometry also increases the comfort conditions and enhances the usage of outdoor spaces considerably.

Conclusions

The study confirms the dependence of thermal comfort on canyon geometry and orientations. Both aspect ratio and orientation were found to have a considerable influence on the street thermal environment and the thermal sensation of people. Further study on diurnal and nocturnal situations in street geometry and thermal storage of materials can lead to better street designs and improved urban environment.

Acknowledgements

The Author is grateful to Sudha, Anu.T.Chungath and Sukirtha for data collection and data processing.

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EFFECT OF VENTILATION ON INDOOR TEMPERATURE IN MALAYSIA

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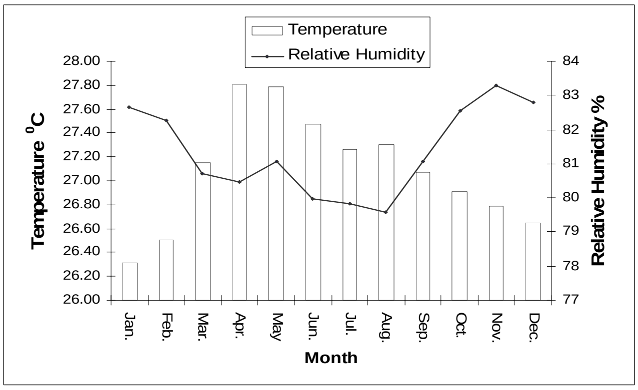
ABSTRACT

Housing design for thermal comfort with passive means in the hot humid climate is the most difficult to achieve and requires careful analysis and evaluation. Night ventilation is considered the best strategy for improving the indoor thermal condition under hot humid climate, whereas the effect of daytime ventilation on building thermal performance and indoor thermal comfort is not clear and less understood. A typical residential housing was selected to clarify the effect of daytime ventilation with different orientation of the openings and location of spaces on thermal comfort. The indoor and outdoor temperatures were recorded continuously in different spaces with closed and opened windows during day and night. The impact of ventilation and the effect of orientation of windows on indoor temperature were discussed. Several recommendations for improving the indoor thermal comfort in Malaysia were suggested.

Keywords: Hot Humid Climate, Ventilation, Passive Design, Thermal Comfort.

1. Introduction

Kota Kinabalu city (the capital of the Sabah state of Malaysia) experiences a typical equatorial humid climate with heavy rainfall usually in the afternoon time, where the temperatures are uniformly high and extremely invariable thought the year (Harimi et.al., 2005). Figure 1 shows the mean average monthly temperature and relative humidity in Kota Kinabalu from 1968 to 2006 (38 years). The recorded data were collected from Jabatan Meteorologi Malaysia.



Temperature & Relative humidity variation in Kota Kinabalu

The mean average yearly relative humidity in Kota Kinabalu is above 80% with a mean minimum monthly average value of 79.82 % recorded in July and the mean maximum average monthly relative humidity is about 83.30% recorded in November. The mean average yearly temperature is 27.09 ^{0}C. The mean minimum monthly average value is 26.32 ^{0}C recorded on January and the mean maximum average monthly value is 27.81 ^{0}C recorded on April. A Summary of Climatic Impact on Building thermal design analyzed with Mahoney Tables under Kota Kinabalu climate is given in Table 1 (Harimi, 2005)

Table 1 Mahoney table recommendations

Building Element	Mahoney table recommendations
Orientation	- The building should be oriented north and south with long axis (East-West)
Geometry	- Open spacing for breeze penetration and to reduce the unwanted radiation and rooms should be single banked
Walls	- Low thermal capacity with short time-lag
Windows	- Permanent air movement should be considered. The openings should be 40-80% of the wall area at body height and well protected from direct sunlight

The application of light surface color under tropical humid climate is considered efficient and an economical means to reduce indoor temperature in hot-humid climate. Cheng, et al., 2005 from their experimental study reported that the maximum air temperature inside an unventilated and no-window room could be more than ten degrees higher when it was in dark than in white colour (Cheng et.al., 2005). However, the dirt accumulation can reduce the effectiveness of this strategy. Further, the Malaysian buildings are very colorful which may restrict the adoption of such approach in Sabah, although it is highly recommended to implement this low cost strategy whenever it is possible. It is necessary to highlight that such strategy is applied in the south part of Algeria in a very famous location named Garadia and known for its architecture adopted climate, and the weather in this area is generally hot and dry. It was also observed that the extreme building elongation (2.5:1 ratio) creates a narrow building with a large wind-exposed face for ease of ventilation and therefore recommended to be applied under severe hot-humid climate (FEC, 1986). The Climate plays a major role in naturally cooled buildings. The amount of heat removed is a function of the ambient temperature, outdoor temperature and airflow rate (Sharag-Eldin, 1998). Wind-induced airflow is a result of a pressure difference. This pressure gradient may be caused either by the difference in interior-exterior temperature (thermal forces) or by external wind flow (wind forces) (Sharag-Eldin, 1998).

Plotting the average temperatures of Kota Kinabalu in Givoni's bioclimatic chart for developing countries yielded ventilation as the only strategy to provide comfort conditions. Air movement also can improve the rate of convective and evaporative heat loss from the skin to the environment which could enhance considerably the thermal comfort sensation (Michael et.al., 2002). Generally**,** ventilation cools interior spaces by exchanging the hot inside air with cooler outside air. However, it was reported that when the air temperature and relative humidity are generally high, the effectiveness of natural ventilation is always questionable (Tantasavasdi et.al., 2001). The wind force is the only kind of ventilation that needs further elucidation under tropical climate. Even though, the ventilation under tropical climate is highly recommended for thermal comfort but the impact of cross ventilation on building thermal performance is not clear which could affect the indoor thermal comfort. This paper explores the potential of wind forces through the use of natural ventilation in building thermal design and in human thermal comfort.

2. Description of Building System

A typical building of 5 stories high was chosen for this study. It is of linear type and medium cost apartment. The apartment is located in Inanam with a total built area of almost 64 m^2. This residence is positioned in the second floor. The building was selected owning to its corner location. It was reported that strong wind generally occurs at building corners as the air flows from the high pressure zone on a building's windward side to the low pressure zone on the leeward side (FEC, 1986). Strong wind is the vital parameter for such study. Fig. 2 shows the floor plan with the indication of the building orientation. The house is built with bricks plastered both sides of about 12 mm. The external and internal walls are beige. The layout of the house as shown in Fig. 2 is consisting of one living and dinning room, 3 bedrooms and kitchen. Two facades are exposed to the outdoor temperatures and built with large windows except for kitchen. The windows areas represent around 12.89 % of the total surface building envelope and about 28.85 % of the exposed exterior façades. These openings are covered with single plane glazing 5mm. The windows are of jalousie type with an effective open area of about 75%. The windows in room 1, 2, and 3 are protected with a narrow overhang of 0.65m giving little protection to the glassing, whereas the windows kitchen are not protected by shading device and the direct sun radiation can not penetrate into it. The kitchen is almost dark and artificial lighting is required during daytime. The direct sun radiation reaches the interior of dining room and room 1 in the early morning and penetrate into room 1, 2 and 3 in the afternoon. These spaces are bright and therefore glare is the main problem.

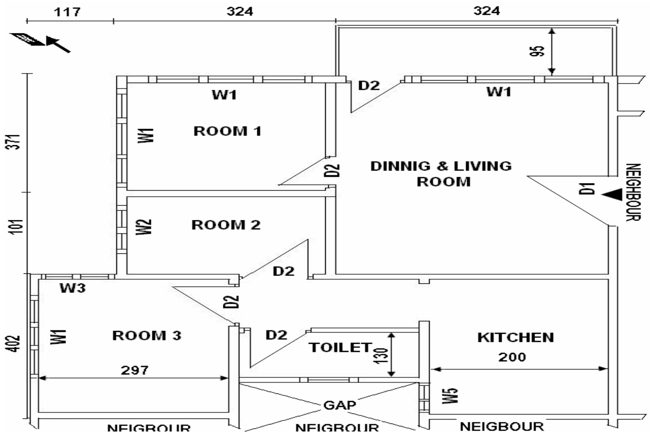


Fig. 2 Plan View of the house

Temperatures data were first monitored in the middle of the house from 7 January 2007 to 21 February 2007 over 46 days. As a second step the hourly indoor temperatures and relative humidity were monitored from 28 February 2007 to 8 March 2007. The hourly indoor and outdoor temperatures were also recorded in the centre of Dinning room, kitchen, room 1 and room 3 at 1.70m from floor level with closed doors and windows on 24 February 2007, next the temperatures were recorded with opened doors and windows during daytime on 25 February 2007, and after that with opened doors and windows during night time on 27 February 2007. One data-logger was fixed outside the house to monitor the outdoor temperature during the whole experimental study. The data-loggers were well protected from wind currents and solar radiation. The loggers were programmed to register air temperature and outdoor temperatures every one hour over a 24-hour. The Data were downloaded into a computer and average figures were determined and analyzed.

3. Thermal Performance of Building

Fig. 3 shows the temperature patterns in the selected house with closed windows. The outdoor temperatures recorded during this period varied from 22.86 ^{0}C to 34.06 ^{0}C with an average value of 27.8 ^{0}C and the indoor temperatures varied from 25.17 ^{0}C to 30.31 ^{0}C with an average value of 27.94 ^{0}C. The average maxima outdoor temperature was lowered below the average maxima outdoor temperature by about 3.7 ^{0}C, whereas the average minima indoor temperature was above the average minima outdoor temperature by about 2.37 ^{0}C. This is due to the effect of the thermal mass of this building which absorbs the heat during daytime and releases it during night. It is interesting to highlight that although lightweight building are always recommended under tropical humid conditions, the thermal mass of the building has also its advantage in Malaysia when the outdoor temperature is high and the construction is only used during daytime such modern offices and banks which are usually actively controlled. This observation is also reported by Cheng et al. (Cheng et.al., 2005). This alternative strategy could be the most appropriate solution under specific conditions, although it is not the ideal solution.

The selection of the suitable microclimate is primordial. Learning from mother Nature may help future designers to create a suitable modern building adapted to climatic conditions by not centering their attention on housing design for human thermal comfort only but extending it to the surrounding microclimate. and nature.

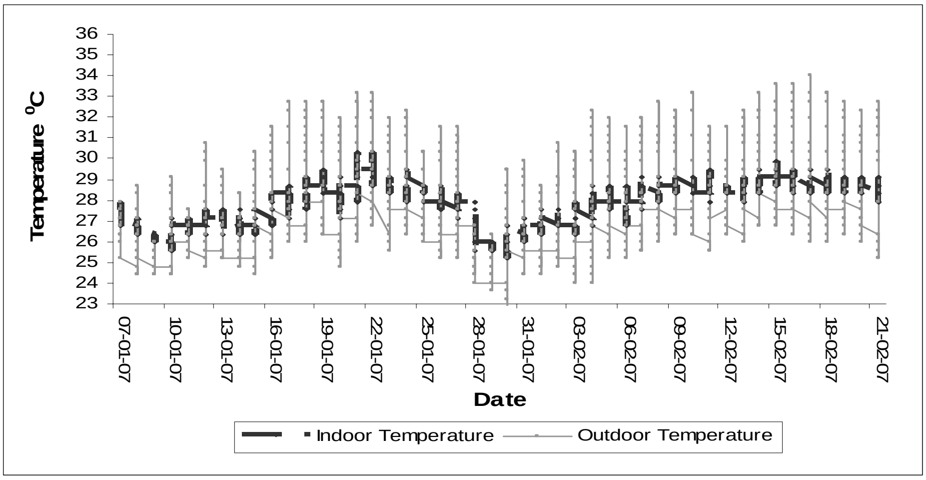


Fig. 3 Temperature Patterns in the selected house

The relative humidity and indoor temperature was recorded from 28 February 2007 to 8 March 2007. From the recorded data, it was noticed that the maximum indoor temperature almost coincided with the minimum indoor relative humidity, which is not always the case with the minimum outdoor temperature and maximum indoor relative humidity. This could be explained by the fact the temperature and relative humidity variation in some days are quite small and thus this comparison has its limitation. Although it is clear from the Fig. 3 that the increase in the relative humidity is followed by the decrease in the indoor temperature and vice versa. The maximum recorded relative humidity is about 77.9 % and the minimum is about 58.5 % and the average estimated value of about 71.82%. The correlation between the indoor hourly temperature and relative humidity was found weak with a coefficient of determination of 0.2076 for a linear regression.

4. Ventilation for building cooling versus human thermal comfort

To assess the impact of ventilation on building cooling, the indoor temperatures were recorded in several spaces of the house from 22 February 2007 to 5 March 2007. The first step was with closed doors and windows. The recorded Average daily maximum, minimum and mean temperatures were estimated and plotted in Fig. 4. From this figure, it can be seen that the outdoor temperature was always higher than the indoor temperature, whereas the situation is completely reversed during night time. Room 1 recorded the highest indoor temperature compared to kitchen, room 2 and dinning room. This is due to the large building envelope area in room 1 exposed to the outside and also due to the large windows area compared with other rooms. However this situation is reversed at night. It appears that room 1 is more convenient to be used for night activities such bedrooms, whereas the Dinning and living room are more convenient for daytime activities. From Fig. 3, it can be seen that the kitchen recorded the lowest maximum temperature. This is because the kitchen has only a very small window and no façade is exposed directly to the outside. However, artificial lighting is required in the kitchen during daytime. The average daylight factor was estimated from Equation 1. (Pritchard, 1999) In solving any design problems, the interaction between human and nature must not be ignored. Passive and long term solutions should be considered.

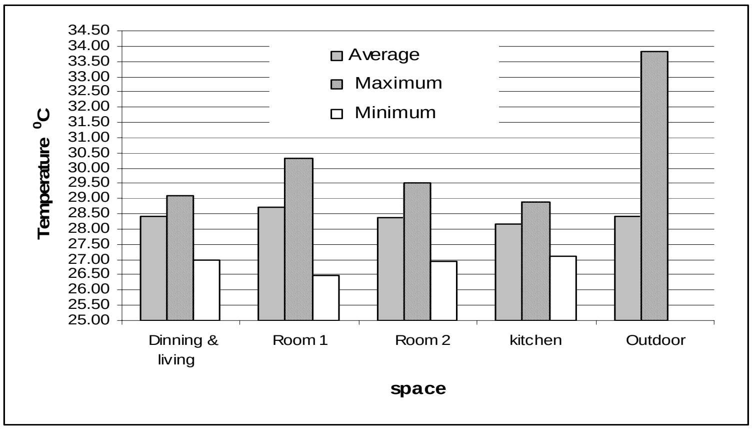


Fig. 4 Temperature variations in different spaces
Closed Doors and Windows

$$DF_{avg} = \frac{\sum (W\,T\,\phi\,M)}{A\,(1 - R^2)} \quad \% \qquad \text{Eq.1}$$

Where

W = The area of each window (m²),
T = Transmittance of each glazing material
Ø = Vertical angle of the sky as seen from the centre of each window
M = Maintenance factor based on angle of glazing and the cleanliness of its environment
A = Total internal surface area of the space, including walls, floors, ceilings and windows (m²),
R = Area weighted average reflectance of all surfaces

The following values were inserted in the formula: W=1.0528 m2, ***T=*** 0.8, Ø**=** 5.39, M**=** 0.9, A**=** 272.4, R**=**0.5. The estimated average daylight factor with the above values is about 0.0629 which is unacceptable for an indoor space. For an average daylight factor of about 2% and using the same kitchen windows area, the required minimum distance from the kitchen windows to the outside gap was calculated. The minimum distance from the kitchen window in the vertical plane normal to the window was found 15 m.

To assess the impact of ventilation on indoor temperature, the hourly outdoor and indoor temperature for one representative day were plotted in Figs. 5, 6, 7 which represent respectively the temperature variation with closed windows and doors during day and night, with opened doors and windows during daytime and the third one with opened windows during night time. The maximum, minimum and average values for every case were calculated and reported in Tables 2, 3, 4.

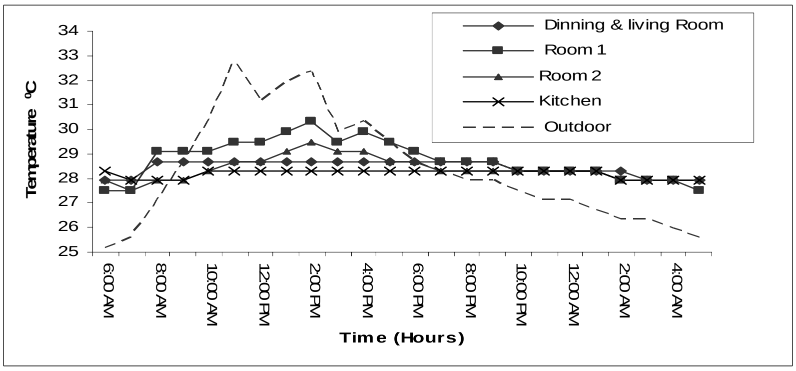


Fig. 5 Hourly Temperature variations in different spaces
Closed Doors and Windows

Table 2 Indoor Temperature with closed doors and windows

Space / Temperature $^{\theta}$C	Dinning Room	Room 1	Room 2	Kitchen	Outdoor
Maximum Temperature	28.70	30.31	29.50	28.31	32.76
Minimum Temperature	27.91	27.52	27.52	27.91	25.17
Average temperature	28.45	28.76	28.37	28.19	28.34

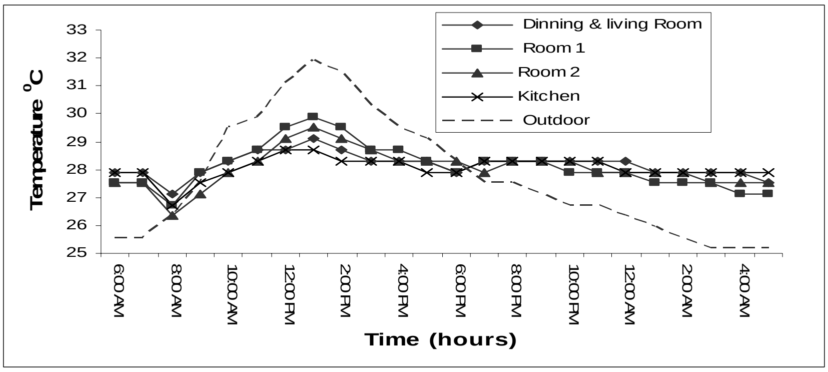


Fig. 6 Hourly Temperature variations in different spaces
Opened Doors and Windows during daytime

Table 3 Indoor Temperature with opened doors and windows during daytime

Space / Temperature $^{\theta}$C	Dinning & Room	Room 1	Room 2	Kitchen	Outdoor
Maximum Temperature	29.10	29.90	29.50	28.70	31.93
Minimum Temperature	27.12	26.73	26.34	26.73	25.17
Average temperature	28.18	28.11	28.05	28.06	27.71

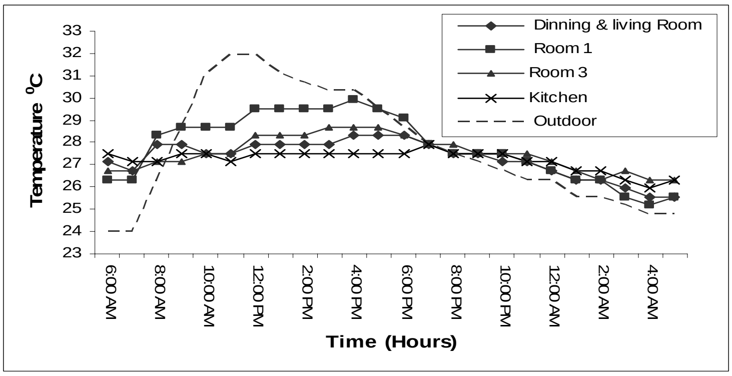


Fig. 7 Hourly Temperature variations in different spaces
Opened Doors and Windows during Nightime

Table 4 Indoor Temperature with opened doors and windows during nightime

Space / Temperature ^{0}C	Dinning Room	Room 1	Room 2	Kitchen	Outdoor
Maximum Temperature	28.31	29.90	28.70	27.91	31.93
Minimum Temperature	25.56	25.17	26.34	25.95	24.01
Average temperature	27.29	27.79	27.50	27.22	27.77

From the plotted graphs and Tables 2, 3 and 4, it appears that the indoor temperature in all rooms and in the kitchen increase when windows and doors are opened during daytime in comparison with closed doors and windows during daytime; however during nighttime it was observed a slight decrease in the indoor temperatures although the windows were closed. The decrease of the indoor temperature was more noticed when doors and windows were opened during night. The indoor wind velocity could well reduce the thermal sensation of the temperature. Whereas, it may increase the indoor temperature which could directly affect the occupant. The question that may arise is: what is the required wind velocity in Kota Kinabalu to reduce the indoor temperature to the comfortable level if doors and windows are opened during daytime? .To answer this question, the neutral temperature was estimated for the February month using Humphreys formula:

$$T_n = 0.534\,T_m + 11.9 \qquad \text{Eq. 2}$$

Where, T_n is the neutral temperature, T_m is the mean monthly outdoor temperature (^{0}C). Using climatic data of Kota Kinabalu, T_m=26.51, therefore T_n=26.06 ^{0}C. The established neutral temperature with adaptive approach using equation 2 is applicable with air velocity assumed to be equal or less than 0.1m/s. The result of air movement to achieve a cooling effect can be estimated using equation 3 (Zain et.al., 2003).

$$V = (ExcessTemperature / 3.67) + 0.2 m/s \qquad \text{Eq. 3}$$

The excess temperature in the monitored rooms where calculated with the monitored data on 25 February 2007 when windows and doors were opened during daytime with the estimated neutral temperature of 26.51 ^{0}C. The estimated values are given in Table 5 for the recorded data from 10am to 4pm only due to the limited paper numbers in the publication.

Table 5 Excess temperature in the monitored rooms on 25 February 2007

Time	Dinning Room	Room 1	Room 2	Kitchen
10:00 AM	2.25	2.25	1.85	1.85
11:00 AM	2.64	2.64	2.25	2.25
12:00 PM	3.44	3.44	3.04	2.64
1:00 PM	3.84	3.84	3.44	2.64
2:00 PM	3.44	3.44	3.04	2.25
3:00 PM	2.64	2.64	2.64	2.25
4:00 PM	2.64	2.64	2.25	2.25
5:00 PM	2.25	2.25	2.25	1.85
Required air velocity for the maximum indoor temperature	1.25m/s	1.25m/s	1.14m/s	0.92m/s

It was reported that the upper limit of air movement for an indoor space is 1 m/s, at which the wind starts to pick up light objects, such as loose paper (Tantasavasdi et.al., 2001). The prevailing wind in Kota Kinabalu is from the east which varies from 0.3 to 3.3m/s. Taking into account the reduction factors as mentioned by Moore (Moore, 1993), the predicted wind velocity around the house was estimated. For windows jalousie type, the required reduction factor is about 0.75%, whereas for a suburban location, the reduction factor is 0.65m/s and the reduction factor for windspeed ratio is 0.35. Hence, the maximum expected wind velocity for housing design in Kota Kinabalu can be V_{expt} = 3.3*0.75*0.65*0.35 = 0.56 m/s. As a result the wind velocity in Kota Kinabalu can reduce the excess temperature by only 1.32^0C using Equation 3. Studies revealed that house with doors and windows opened during daytime is hot and uncomfortable for the most part of the day.

5. Conclusions

From this study, it can be concluded that in sunny hot days when the house is occupied the whole day, opening windows during daytime is not the recommended strategy for improving the indoor temperature and therefore should be avoided. This may not be the case in the rainy days, whereas opening windows during nighttime is highly recommended for building thermal performance and also for human thermal comfort. It was observed that thermal mass has its advantage under tropical humid conditions when the building is only occupied during daytime and actively controlled such the case of the banks.

Acknowledgements

The authors acknowledge the help of Jabatan Meteorologi Malaysia for providing us relevant climatic data used in this study

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TAKING STEPS TOWARDS SUSTAINABLE HOSPITAL BUILDINGS

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Abstract

Maintenance of building services has been the Cinderella of the construction industry for too long. It is now emerging as area that requires more attention in the design of a building. Failure to maintain a building and its building services could definitely affect building performance. On the other hand, improved maintenance will bring long-term benefit to our buildings. One of the key attributes of a well-designed, cost-effective, maintainable green building is a sustainable and integrated design. It is, obvious, that maintenance issue can no longer be treated in isolation, and must be right on the drawing board at the first time of starting a design.

The aim of this paper is to provide a commentary on inadequate design for maintenance of services in an existing hospital building being investigated by the author. The author discusses and elaborates the missing linkages between the vital design, installation and maintenance of this highly serviced health care project in conjunction with the requisite issues of sustainability. These linkages are often missing in construction debate – the relationship between the right quality of building design and the important green issues. The author gives his comments on how to achieve best management of design and maintenance and also suggests some pragmatic ways which can be used to improve building care and sustainability. This paper summaries the author's vision of sustainable construction as a result of enlightened building design that embraces fully integrated design, innovative construction and effective operation in a seamless process. Most significantly, all construction professionals should treat maintenance aspects as a significant part of any sustainable building design.

Keywords: Sustainable hospitals, Building care, Design and maintenance.

1. Introduction

Putting maintenance at the centre of the continuing post – Egan reform process is long overdue. A common design problem is lack of design for maintenance for building and building services. Many buildings are not completely maintainable. These buildings cannot be adequately maintained because the quality of design inhibits maintenance. Many professionals have not yet concentrated on good planning of maintainability for all building elements. Though considered important by many, the aspect of maintenance is seldom fully taken into account during the building process. The outcome: low quality of building and its M&E services with poor maintainability. This often leads to poor building and ultimately dissatisfied clients. Directly and indirectly, the quality of such buildings can have a significant impact on building sustainability. Case studies do indicate that design strategies can have a significant effect on operation and maintenance, user satisfaction, client business, profitability and the sustainability of building and services. It is, therefore, necessary to have a critical appraisal of building services design together with the commonly neglected maintenance issue during the conceptual stage of a green building design to optimize the whole life aspects of building and its building services installations.

In recent years, much information has been put forth about the impact of the built environment on the natural environment, the concept of sustainability or green building issues and better design for our buildings. Vast amount of useful information is available for designing and constructing greener or better buildings. Nonetheless, study on maintenance of building and its building services in conjunction with sustainable building care (i.e. use of building and the continuing maintenance) appears to be scarce. Apparently, the industry tends to focus too much on glamorous new construction and energy issues, but still leaving maintenance aspect as a Cinderella of the design and construction process. Design for maintainability is little discussed and often neglected by many in industry. So it is difficult to produce real green buildings, it is no wonder why many of these buildings still do not run efficiently, and very often, extra maintenance works are necessary in order to maintain the use of these facilities. Hence, many buildings are still not completely sustainable.

2. Towards More Sustainable Buildings

To begin with, a mutual understanding of sustainability must be established. There may be never be a consensus view on its exact meaning. However, one way of looking at sustainability is the ways in which built assets are procured and erected, used and operated, maintained and repaired, modernized and rehabilitated and reused or demolished and recycled. So sustainability constitutes the complete life of building construction activities. Given this long definition it is vital that sustainable issues are given due consideration as early as possible during the procurement process. As seen from this definition, sustainability is not a building fashion, but a concept of good building design incorporating the best environmental management for the building, its people, the indoor and outdoor environment. Sustainable building is sustainable development. At its basic, it is the three tiers of environmental, social and economic contexts. It is not rocket science. It is far more complicated and important than rocket science. As its heart is the simple idea of ensuring a better quality of life with the design, construction and operation of a building for everyone now and for generations to come. Better designed buildings and their building services can improve the quality of life. It has already been demonstrated that sensible sustainable development reduces operating cost while providing better buildings that enjoy greater occupant satisfaction. Obviously, all designers (i.e. Specialisms of design and operation) have a crucial role to play in developing appropriate sustainability.

3. Drivers for Sustainable Building Care

Building care is a part of sustainability issue. Building care is customer focused, and encompasses the management and maintenance of premises and its building services. The quality of maintenance or building care will definitely have a significant impact on the delivery of appropriate sustainability performance of a building. Obviously, to attain the highest building care and the best sustainability, the most effective way is to design maintenance out in conjunction with the development of a green building during the outset of a project. It will take both practical and innovative as well as synergistic designs that cut across design disciplines to achieve true success. This will result in better sustainable building that achieves high performance, over the full life-cycle, in the following areas:

- Lean design with appropriate technologies
- Design attuned to use of building
- Higher sustainability in terms of energy air/water pollution and use of resources (i.e. energy and water efficient building with less waste and pollution)
- Higher building performance that provides greater satisfaction, wellbeing and value to customers and users.
- Low (or little) maintenance but higher reliability, durability, adaptability, reuseability, availability and longer useful working life
- Low obsolescence and high reusability

The maximum value of sustainable building care is obtained by considering the areas stated above at all stages of a project. Sustainability needs to be considered in design and construction and in use. Therefore, spending time in researching and considering different solutions at the design stage has the greatest impact on achieving a sustainable building. Time well spent in preparation and design will enhance the effectiveness and efficiency of a sustainable project. Designing better building; more efficient construction techniques; better building services; improved maintenance and operation of the existing building stock can bring economic, social and environmental benefits.

4. Maintainable Building

A sustainable building (and its services) and sustainable maintenance are possible; indeed, the one presupposes and requires the other. In theory, while zero maintenance may be striven for, it is ultimately unachievable in practice. Some maintenance will be necessary and, in deed, desirable if one wants to ensure the highest performance and reliability of the mechanical and engineering (M&E) building systems in a building. In good design, a minimum maintenance model is to be pursued, in which the design of maintenance based on good engineering principles (e.g. simple design, functional analysis, reliability centred maintenance, fault analysis and risk identification, and a combination of all planned maintenance techniques and systems) is carried out that will sustain the building and its building services in the best working conditions for a reasonably long period. If a green building is to be achieved, it is essential that the building and its M&E services are capable of being maintained to continue in the green performance conditions. Suffice it to say that any shortcomings in design and maintenance will not achieve a satisfactory green building as issues such as selection of materials, processes, systems, effective and efficient plant operation, maintainability, standardization, durability, health and safety – all these are (in addition to energy efficiency environment issues, waste reduction etc) significant components of the sustainability debate. They are whole life issues that need to be in the right context at the design stage.

Some designers jump on the energy and environmental band wagon without giving due consideration to equal or more important but less fashionable issues such as optimizing operation and maintenance, reducing design margins, minimizing redundancy, simplification of complex designs, improving standardization etc. these can all have a far more greater and long term impact on sustainability (over 50 to 60 years, the average life of a building) due to knock-on effects such as extra energy consumption and waste all with extra maintenance costs and problems. Hence, the building services engineer has considerable influence on the environmental performance of buildings through involvement in design and operation.

Having outlined the basic concept of getting a better sustainable building care, it would be helpful if the readers can see the missing linkages between the design, installation, construction and maintenance and the effects in a real life situation. A special case study is useful in this respect.

5. A Case with Difficult Maintenance

This case study is based on the $4 billion (≅ 0.56 USD) rebuilding one of the largest teaching hospitals in Hong Kong, and the author's views on better design for maintenance together with green design sustainability. Its aim is to highlight some key issues that should be considered during the beginning of a project in order to improve the quality of a sustainable hospital building (as well as other buildings).

The Hospital Authority (HA) in Hong Kong released details of the plan of rebuilding a large teaching hospital which is only 20 years old, but it should have a long working life of 50 years or more. The plan was under fire, critics wanted to know why this 1400 beds healthcare facility could not simply be refurbished, and why it had to be torn down, especially when the HA would normally have an excellent repair and maintenance programme for its buildings in place. The HA argued that rebuilding the hospital was more economical than refurbishing it. The HA also declined to comment on whether the redevelopment plan was triggered by faulty design or substandard construction, but some of following comments had been given from different sources:

- Inadequate site area for future hospital expansion
- Dilapidated state and accelerated deterioration of building finishes and other installations
- Serious water leakage problems due to building construction and building services installations
- Water damage to power facilities in basements/sub-basement as a result of flooding and the high moisture content within this sub-structure (it was a swamp)
- Never-ending maintenance activities/renovations
- Heavy usage of hospital and inflexible building layout
- Undesirable effect/inconvenience to users/patients
- Considerable age and insufficient capacity for future medical technology to be carried out
- Inadequate spaces for proper services installations and subsequent maintenance

The HA defended the plan saying that the rebuilding plan would take less time to complete than renovation and refurbishment of this facility. The maintenance cost ($37 million or US4.74 m for a five-year programme) would also be reduced after the completion of the redevelopment.

This case clearly illustrates that maintenance was not probably strongly enough addressed by all project participants in any great detail at the design stage, otherwise, normal maintenance problems can be tackled easily, and the building can be used at least for another 25 years. Hence, the quality of this hospital design would have a considerable impact on:

- Reliability and durability of building and its building services systems (low in this case)
- Energy efficiency of the building services systems (less efficient as a result of difficult maintenance in this case)
- Use of resources, materials and generation of wastes will be more due to more repairs, replacements or renovation of building and building services in this case
- Sustainability and longevity of building and its building services (comparatively low and short in this case)
- Users and client's satisfaction (will be less satisfactory in this particular case and less value for money throughout the lifetime of the building)
- Use of funding (expensive maintenance cost is a big problem in this case)
- Building care (below expected quality as viewed by the HA)

If the building is to be torn down, the building will definitely produce more waste, emissions and pollution and environmental impact. Furthermore, the community will not have proper medical care for a few years time. The problems stated above are definitely related to the quality of design, construction and maintenance. As design is an exercise comprising a multiplicity of decision, maintenance should be a function of design and an important decision. Care at the design stage will give a care-free sustainable building. Unacceptable deterioration and breakdown are analysed, anticipated and corrected before they occur, thus avoiding many common maintenance problems. Maintenance problems can be designed out in many cases with both conventional and un-conventional design features, with resulting low cost of repairs, maintenance and better use of building. But how can this be done? There are numerous contributors to reliability, efficiency and maintainability: the original designer of the system, the manufacturer, the person who made the selection and installed the equipment and component, the users who use the facility and the persons who look after the building and its building services. However, the services designer can help reduce the maintenance problems by offering better design and maintenance together with the remainder of the design team in the design process. In short, the following paradigm for achieving a sustainable building is useful:

- No separation of design and maintenance
- Design for today and tomorrow (but must learn about the problems of yesterday maintenance) if feasible
- Provision of the right building and its building services by all professionals
- Use of common sense, wisdom, design feedback information as well as proven technologies that can improve maintainability and durability

This paradigm should lead to sustainable development.

6. Designing Maintenance for Sustainable Building Services

The combination of the escalating of building services installations and the increased rate of use of modern technology has resulted in the modern hospitals (same as in other buildings) being the most complex of present day building types. It is important, therefore, that the subject of maintenance needs to be addressed much sooner in the design stage to ensure that the design of proper maintenance is fully integrated into a building design. The implications of building services installations on hospital design are many and varied with their inter-relationships complex. These implications not only influence the planning process of design but in many instances actually dictate the planning (not just two-dimensional, but three-dimensional considerations for the accommodation of services, etc.). The implications of building services permeate throughout every aspect of hospital design so that the resulting whole becomes an integrated matrix of building fabric and building services with elements interdependent on each other for function, support, protection, operation and maintenance.

The effect of the building services design not only encompasses the consideration of simply containing the various services, but also the parallel effects of the construction method, accommodation of services and the future maintenance needs. All in all, hospital designs and building services are one which cannot be separated or considered in individual categories, without team effort, it is impossible to produce a useful, flexible and sustainable hospital.

It is crystal clear that in hospital engineering services terms the most important role is that of the designer. He has a range of equipment from which to select, he can dictate how it will be installed and how the components will be brought together to form the various systems to produce a functioning building. A multi-disciplined design team has professional responsibility to design out maintenance and/or make suitable provisions for maintenance. The building services designer should have a higher professional responsibility to influence the remainder of the team in the decision making process in relation to the neglected maintenance of services after their physical installation. Clearly, the design process can have the single largest impact on sustainable development. Cutting back on the time and resources required for a good design is a receipt for delivering poor quality outcomes.

It is appreciated that the maintenance of the equipment and the systems is only one of many considerations that the building services designer must consider when trying to satisfy a client's brief and working to produce an integrated building design with all the other professionals involved. However, it is, one facet that may not have received the degree of importance that it deserves, and, therefore, buildings are still not wholly sustainable.

7. Important Consideration for Good Maintenance

Problems of maintenance will result in high cost penalties in terms of loss of service, high cost of repairs and, sometimes, unnecessary building damage. It is important, therefore, to consider the maintenance operational policy at an early stage in the design process to ensure that a maintainable building is possible.

Factors determining the approaches are:

- Capital costs
- Complexity of building design and intensity of engineering services in the building
- Use of simple technology, avoiding the use of special system, labour and material
- Level of reliability, durability and availability
- Future flexibility of layout and flexibility for changing client needs
- Consequence of failure or disruption of services and cost of failure
- Frequency of maintenance operations in conjunction with maintainability
- Health and safety aspects
- The acceptance of new design ideas with greater integration of building and its building services
- Maintenance with adequate access
- Obsolesce and quality of system/equipment to facilitate good use of building
- Impact on the environment
- A care-free sustainable building

The above-mentioned factors can greatly influence the future maintainability of the engineering services. We have to reengineer our practice (e.g. value analysis, risk evaluation and analysis, functional analysis and the process of continuous improvement such as design and maintenance audits) and give better designs to improve the requisite sustainability. With the increasing complexity of modern services, it is more than ever essential that the engineering and architectural aspects of a project are developed simultaneously from their inception. Most importantly, the types of services installation to be used should be identified before the overall architectural design is finalized and the necessary plant spaces determined.

Better design solutions can be used to enhance the maintainability of the lifeline of a building with or without necessarily increasing costs; where increased first cost cannot be avoided the increases can be demonstrated to have potential in more efficient operation and maintenance (O&M) and longevity of the services systems. In turn, this contributes to a more sustainable building care.

8. Designing Better Operation & Maintenance

The engineering services needed to support the functions within a modern hospital (same as in any modern and highly serviced buildings) are vastly more complex and more sophisticated than they were ten years ago. With the increasing complexity and importance of the engineering content of hospital schemes, Services must be properly considered, coordinated, designed and analysed to ensure efficient operation and maintenance.

This is something easier said than done because design for O&M is more of an awareness than a technical issue. It is important for the design team to have a vision of the life cycle of the building, rather than considering it simply a new building to hand over. All members in the project team should have:

- A clear policy that the design is to meet the O&M requirements during the life cycle of the building
- A position statement to elaborate the essential issues to meet such requirements
- An action plan to execute all possible procedures for meeting the O&M requirements.

During the design stage, there are, nevertheless, grey areas where it is not clear who has the responsibility. It is then advisable for the project manager to:

- Assign such responsibility to designated person
- Have a schedule to constantly receive progress reports to avoid confusion and shirking of responsibility.

9. Designing Maintenance Out Is the Only Answer

In the process of planning sustainable buildings, the project team should also implement the integration of services with the building envelope and structure through coordination meetings. It should also include maintenance engineer in the project team. All designers should consider the following needs when planning a sustainable building.

- All possible design solutions that can cut down energy consumption and give an environmentally friendly building
- Design is fully integrated and coordinated and each services system can be installed and maintained with ease
- Simple design solutions which can give better reliability and durability. At the same time, reliability centred maintenance should be used for services design and planning of maintenance.
- Early design audit in conjunction with T&C requirements and the important design of maintenance
- Ensuring that replacement or refurbishment is possible with adequate space and access and, without breaking the structure or building enclosure housing the services (this will save resources and also reduce waste)
- Checking whether any plant and equipment provided may become obsolescent before the end of design life. Also investigate the removal and replacement of this plant with the provision of suitable means of access for that work.
- Adequate attention is given to health and safety issue during the operation and maintenance

10. Barrier to Designing Maintenance

From experience, it is known that an ideal design is very rarely attained and that bureaucratic procedures, inflexible decision making, in-cooperative culture in the industry and the unbalance of power amongst building designs as well as hard cash normally accounts for a large part of the difference between what we would have liked to have had and what we in fact get. The failings of inflexible building design, poor maintenance, etc. are mistakes which anyone of us might well have made and, for obvious reasons they are a general record of what has been found in a number of hospital buildings rather than the limited experience of any particular one.

The time is past when architects can refine a client brief without the help of engineers and other experts. The greener the buildings, the more important it is for all project participants to start working together from day one.

11. Reconciliations of Discussions

In today's building the engineering services may account for as much as 50% of the total cost and the engineer must be a full partner with the architect in any part of the design which affects the efficiency of all services. Maintenance should be considered as an integral part of the project during all phases of the design and, preferably, during the preparation of the brief. The larger the buildings, the more important early consideration of services design and maintenance becomes. Engineering services are a major cause of aggravation and tend to affect everyone in a building. They must be specified, designed, installed and commissioned correctly. Most importantly, the design should be sustainable and have sufficient flexibility and good maintainability.

Maintenance problems (e.g. cramped services which are difficult to maintain) are mostly attributed to the failure of design co-ordination between architect, engineer and client. It is fair to say that the services maintenance problem is only one of the aspects of building design (even more important in a hospital) in which all project participants still have much to learn. If they can prevent the mistakes re-appearing they will have served their customers with better building care.

It cannot be emphasized too much that a highly serviced building (e.g. hospital) is one of the most complicated buildings calling for a team approach to design and the engineering member of the team must make sure that the services he is briefed to provide are permitted to do the job which is required. If not, the engineer must insist that he be given sufficient space to accommodate the services. The engineering profession can play a more positive part in green building design than in the past. Architectural and engineering design must go hand in hand and architectural features which create impossible problems for the engineering services to overcome must be firmly restrained, otherwise, we still have poorly maintained services and un-green buildings.

12. Concluding Remarks

Modern buildings are designed to meet more complicated needs than those of previous time; improved space standards, higher environmental standards and new pattern of use of building can effect their design and construction. The natural result of these changes is higher building standards and more complicated buildings. This means that (1) increasing reliance is being placed on M&E services to provide the environment and the facilities needed, (2) there is a growing need to ensure services are available when required, operated at an expected level of efficiency, and (3) the design influence on the maintenance of a sustainable building is greater than ever before.

Maintenance of building services has been the Cinderella of the construction industry for too long. We have learned some lesions of poor maintainability. So it is now emerging as an area that requires more attention in the design of a sustainable building. Failure to maintain building services could definitely affect building performance. On the other hand, improved maintenance will bring long-term benefit to our buildings. One of the key attributes of a well-designed, cost-effective, maintainable green building is that it is designed in a "integrated approach" and maintenance should no longer be treated in isolation.

To get the best green building, all designers have to adopt a rational approach to the management of services design, installation and maintenance. The design process is the first crucial element when procuring a sustainable building. Once designed, the building must be constructed commissioned, and operated in a way that supports the sustainability concept. If it is not designed with the intent to make it sustainable the desired results will never be achieved. Care at the design stage will be repaid many times over, saving expense and anxiety. A maintenance-free building is an extreme possibility. Maintenance is unavoidable but design can give a maintainable building.

In conclusion, a building will not be adequately maintained because the quality of design inhibits maintenance. Designers can greatly influence the future maintainability of our sustainable buildings. Hence, designers should improve whole life performance through either simple or innovative design solutions. The consideration, during the procurement of built assets, of the influences of the factors discussed in this paper is a necessity. It is hoped that this short paper will draw all project participants' attention to the importance of design for better building care.

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SUSTAINABLE HOSPITALS WITH GROWTH AND CHANGE

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Abstract

Rational discussion of hospital design is complicated by the fact that hospitals are connected with matters that affect life and death. Once these absolutes are mentioned the provision of a flexible hospital building that can be used for many years becomes a difficult task. A hospital which has considered possible growth and change in the outset of its design is a good design. This building should have good sustainability, i.e. a building which is able to cope with present and future needs within a period of 15-25 years after its completion. Ungreen hospitals tend to limit expansion and changes. Future growth and changes are the result of changes in medical technologies and practices together with increase in population. Research findings do show that ungreen buildings do not give value for money and many have to be redesigned and rebuilt. This is not a sustainable construction.

Same as the maintenance issue, many designers do not give serious consideration to growth and change, many hospital designers tend towards a finite notion of a hospital building, for implicit in them is the assumption that the operational policies and the balance of the various types of accommodation will continue relatively unchanged during the life of the structure. This is not right at all. Because of the inevitability of growth and change, a hospital building does need changes. A hospital is never likely to be complete. The building will inevitably require alterations and additions during its working life. Such needs will have a direct impact on sustainability and all designers should therefore give more attentions to a green/good design.

This paper attempts to address the growth and change issues based on some case studies. Besides, some useful suggestions are given to hospital designers so that better and sustainable hospitals can be developed for the benefit of the society. This should also improve our sustainable building developments. To achieve great success, all project participants must give more efforts to the front end of a hospital design as it is difficult to develop a sustainable design after the initial design stage.

Keywords: Sustainability, Growth and change, Flexible design.

1. Introduction

The ways in which built assets are procured, used, operated and maintained, modernized, rehabilitated and reused constitute the complete life of sustainable construction activity. Surely, a good building that is useful for many years is a true sustainable building. Hence, a green/good building must be designed for present and future needs with the constraint of economy. Sustainability has a much wider scope (not just on energy, waste and environment), it also means better quality of life, customer satisfaction, and better use of building over the life of its occupation.

New and innovative technologies (communication technologies, biotechnology, bionics, mechanical and electrical components in human body, computerized systems, etc.) are being developed on a daily basis to improve the patient's quality of life and longevity. Healthcare in every country is therefore undergoing enormous and continuing change, be it an increase in medical technology application, or evolving healthcare service and clinical innovation. All new technologies are beginning to influence more and more the medical practice patterns and the design of a proper healthcare building layout and size.

New hospital infrastructure is being designed and built with a 30-60 year life, and this will need to be flexible to accommodate the aforesaid changes, otherwise, the healthcare facility will become functionally obsolete even when its physical life is not yet exhausted. So, how can we ensure that the facility planning carried out this year or the next will produce a right hospital building that is responsive to the needs of patients/users and payers in the year 2010, 2020 and beyond?

2. Healthcare Building Design

It is axiomatic that healthcare facilities exist to accommodate the delivery of good healthcare services. Because there will be clinical innovations in terms of new care models and the use of better medical technologies for better health service. Re-engineering processes is unavoidable and in deed essential. It follows that good healthcare facilities should be designed, located and provided to meet future service requirements within a continuum of change.

The need for healthcare buildings to be able to respond to change is essential and the scope of flexibility required needs to be identified for each project during the early stage of a project. This flexibility will also be tailored to specific functions as required.

If best value hospital buildings are to be pursued. Requirements such as functionally suitable for current and future services needed to be developed in the design brief. This will inevitably reflect that the success of a hospital project is the quality of the original building design which will have a direct bearing on the use of a particular building by all users.

Although healthcare investment is primarily in people and technology, the building design and its site can have a major positive or negative contribution to the clinical outcomes, the efficient use of technology, the efficiency of staff and energy consumption. Costs for running a hospital will also be improved by the flexible and intelligent design of its building too.

All in all, innovation in facility design and construction is a very important factor that can shape the performance of a healthcare facility. Unquestionably, the selection of a good site that can provide sufficient spaces for the present hospital and the availability of space into which the growth and change can occur is paramount importance, but it is easier said than done for both technical and capital constraints.

3. Sustainable Hospital Design Master Planning

In general, a building site must be large enough for all planned functional requirements to be met and for any possible expansion envisioned within the coming 20 to 25 years or more.

The author's research also confirms that a sufficient allocation of site for future development is a basis for sustainable effectiveness in master planning. Designers should consider how to make best sue of the land and make strategic decisions about, environmental, building and engineering designs that minimize restrictions for future development. At the same time, they should make the best use of the site topography, boundaries, landscape, etc. to enhance the quality of the patient and staff needs. Most importantly, planners should try to avoid sterilizing parts of the site now that could be used in future.

For a sustainable hospital building, a realistic analysis of growth and change in hospital needs should form an important part of the client's brief. It is important that the growth issue should be thought through and this should not be implemented afterwards from the constraints of a building design that has been conceived in ignorance of the unavoidable change. In a nut shell, one should think about flexibility in building use, building size, building layout and the planned lifecycle of buildings according to service need. This should represent the future model for delivering hospital building in the 21st century.

4. Reconciliation of Growth and Change

As the inevitability of growth and change has come to be recognized, views have been expressed in the last two decades which maintain that, whenever it is situated, a hospital is never likely to be complete. Hospitals that have been used for 20 years or more are outdated and fail to comply with new health standards. An old building will inevitably require alternations and additions during its working life.

Provision for growth is often not treated carefully in some hospital designs. In many cases, provision for growth is an afterthought. Technically, this growth should form part of the initial planning and design process, and especially during the preparation of the master plan for a hospital. Imaginative foresight should be used to identify all possible areas in which there will be fast growth or contraction. Growth is inevitable and, as discussed earlier, is mainly generated by:

- Growth of the community (especially in new towns)
- Special requirements (e.g. outbreak of a new disease)
- Changing statutory requirements
- Changing methods in medicine and healthcare service level
- Obsolescence and deterioration
- Improvement in building performance
- Social and political reasons

For a good analysis, sufficient data such as possible growth in population (young and old); development of the city/region/district; transport system within the region and other regions; topography; utilities available; natural features; town planning limitations; building shape; environment issues and changing methods in medicine must be evaluated by all concerned in a hospital project. To be successful, database system for space management should be employed whenever possible, but complete database system is not readily available before commencing a project.

5. Observations from Some Un-green Existing Hospital

The author has carried out some studies on hospital design in Hong Kong and other parts of the world. The studies show that many hospital sites can allow future growth (if these sites have 50-60% more site area) but some do not have enough room for efficient/effective expansion or redevelopment for the following reasons:

- Limited land space is the biggest problem
- Visual and environmental impact on surrounding is the second main reason
- Selection of less optimum site (e.g. shape and arrangement of existing hospital blocks) is the third main problem
- Inadequate allowance for future spaces in design
- Difficulty in converting some old hospital buildings with constraints such as limitations in spaces surrounding the building; capacity of M&E services, and structural loading. To certain extent, the

rigidity of the existing building also impinges ideal expansion. In many cases changes can only be accomplished with disruption.

- By virtue of its height and complex design, high-rise hospitals are difficult to change or expand unless some future floors (shells and core only) have been incorporated in the building first.

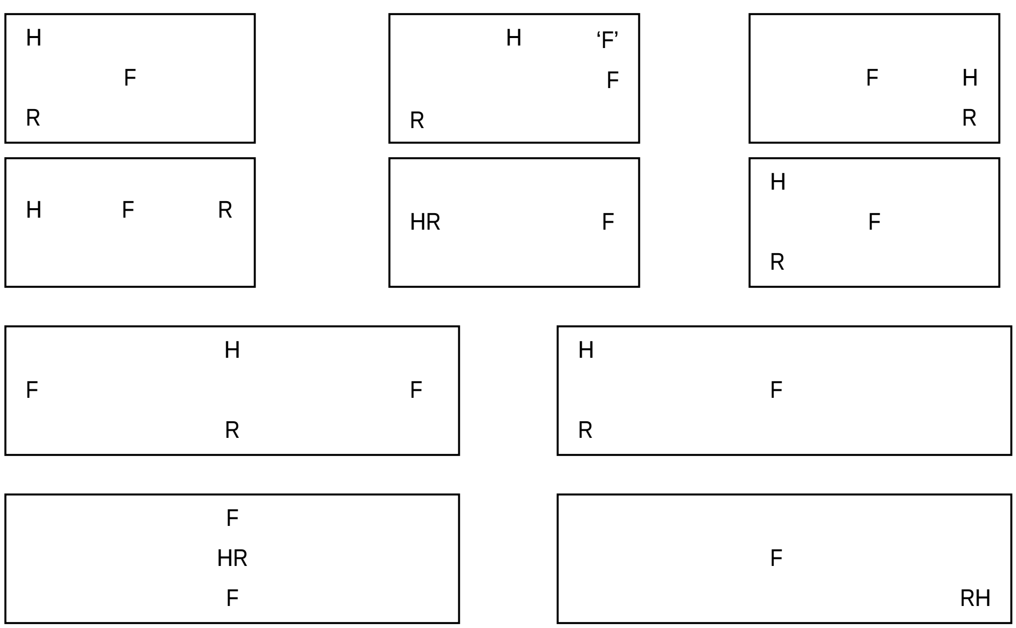
In the author's study of the use of some building sites, investigation result also shows that there are many good and some less optimum layouts found for large hospital projects. For good layout, over and above 50-60% of the foundation area (for all blocks required, nurse quarter is not counted) should be allowed for future growth. In many cases, about twice the hospital block area gives very flexible design. In order no to sterilize this site now for future use, this future area can be used to create a green hospital environment. Also, additional spaces (20-30%) for such scenery must also be thought about to compensate the loss of such green space should additional buildings be constructed later. Buildings for nurses and doctors are essential, there is also a need of sufficient space (say 100-120% of the hospital foundation area) for residential accommodation if feasible.

For some hospital building sites, it has been identified that these buildings pose difficulty to future expansion and the unavoidable alteration. The results from the study show that many of these sites do not have the right size, right aspect ration and less optimum positioning of the main hospital/blocks in the first place. Apparently, expandable site space required for future needs might not have high priority in design agenda. As far as buildings situated in the middle of the city are concerned, the limited site boundary would be the biggest constraint. It is often difficult to obtain useful and large spaces adjacent to the existing hospital building.

6. Arrangement of Buildings for Better Sustainability

As discussed earlier, the configuration of a hospital site has a direct bearing on the design of present and future hospital building. The author's study shows that there are no hard and fast guidelines on this aspect.

The site, of course, must be reasonable large (e.g. 15 hectares for a 1400-bed direct hospital and another 6-7 ha will be needed for staff accommodation). The length and width of the hospital site should have a good aspect ration of about (4 to 4.5 to 2 to 2.5). Long and narrow site may not be as good as big square. The location of buildings may be depicted in the following figures.



Legend

H = hospital,
R = residential accommodation,
F = future hospital buildings

These layouts are diagrammatic only; considerations must be given to layouts of access and roads, communication (e.g. hospital street) between various functional departments, green field, energy centre, etc.

In general, there are many possible ways that one can design a flexible hospital building. But there are three very common layouts which can be used for developing a good flexible site.

(i) A large site (i.e. large square or rectangle) with present hospital buildings located at either the lower or upper half of this site. This should leave about 50-60% (at least, 100% is more appropriate) for future growth.

(ii) Present hospitals to be located at the middle part of a large site, leaving some 30-50% are at both sides (L or R) so that new buildings can be added sideways.

(iii) A combination of (i) and (ii).

In addition, other factors such as transport, site environment, topography, boundaries, etc. must also be taken into consideration.

A design that can accommodate changes is needed but there are no simple universal solutions. It is always advisable to layout all present and possible future hospital buildings, etc. on different master plans, together with detailed analysis and appraisal for each layout. Consequently, all proposed layout must be studied in conjunction with future changes or needs, present and future cost implications, future town planning, site constraints, harmony of existing and new buildings together with harmonization of the surrounding environment, ease of expansion and contraction, extra capacities added on M&E services, empty shells for future use, effect on existing hospitals during new building construction, etc. These studies are deemed to be of vital importance to the planning of an expandable hospital. Teamwork is needed amongst all participants and the architect will be the lead designer at this stage.

7. What Can Be Done for New Projects

Based on the author's case studies and research findings from other hospital designers in U.K. and other countries, some important considerations about incorporation of future changes in new hospital building design are given below.

- Adequate allowance for reasonable spaces and the selection of a good site that can allow future growth in the outset of a design. The area and its configuration required should be decided by all parties concerned.

- The use of different forms of hospital layout that can allow future buildings.

- Superb multi-storey hospitals of the mechanically dependent type have been built during recent decades but there are few flexible examples especially dealing with growth and change. Multi-storey building is the only solution where ground space is at a premium. In general, unless the building is an innovative one, otherwise, it tends to be a design that cannot readily be altered or extended in any organic manner.

8. How to Improve Existing Projects

As far as existing buildings are concerned, major expansion or alteration are deemed to be difficult unless their original designs have incorporated changes over their lifetime.

When difficulties become apparent, the first step is to see the criticality of the problem and whether there are alternative ways of overcoming the problem. Sometimes, management solutions can alleviate some difficulties (e.g. with buffers of soft space between hard spaces (requires major changes) to allow for likely change), but not all. It is also possible to avoid or defer the need for expansion or replacement of existing facilities if circumstance can allow this. Detailed analysis of the building and the functions required must be carried out thoughtfully. In general, every means should be sought to modify the existing building to cope with the new or additional requirements. If this is found to be technically and financially not viable (The existing building is no longer useful and old), a new building with better service facilities is surely a better answer for a particular function. In one case, the building site is tight and land space is a problem, an additional block had to marry the existing building. Basically, upon the completion of the new building, the adjoining existing building would be modified or completely changed to a newer design. This should achieve better engineering economy and give better service to the community.

9. Conclusion

The aim of this paper to provide a commentary on inadequate thought given to growth and change in hospital design. The root cause is not technical issue but rather a problem in strategic planning.

Evidence collected by the author does confirm that there are excellent and less optimum hospital designs. Some can sustain the requisite quality of continuous improvement and satisfying the needs for growth and change. On the other hand, there are some hospital projects which do not meet the real need of a hospital-extendable and flexible for changes.

Some important findings are:

- It is impossible to predict changes to care delivery with absolute certainty but there are techniques and experiences that can help us to imagine the possibilities

- We know that the capital costs of health buildings are minimal compared with revenue costs and that there is an opportunity to improve utilization and healthcare service through design (i.e. adaptable or flexible buildings). In this context, we need design that can accommodate change, and may need more capital to do so. Life cycle costing and value engineering should be used for the following analyses.

    - Should we design and build all future hospitals now

    - Should we build present hospitals only and leave new buildings to later stage when future changes and needs are clear

    - Should we build a hospital for present needs but together with ‘shell space’ (i.e. empty floors with adequate support services allowed) that can be fitted out later when requirements are more clearly defined

    - Should we allow the building parts to retract or expand so that spaces can come under different tenures if required over time

    - Should we have innovative design of building spaces (both inside or outside) to allow interchangeable use on daily basis and also over time as requirements change

- The selection of a good site is based on the most appropriate form of site that can allow growth, extension and modification at some future date without difficulty.

The paper shed some light on the planning and design of hospital. Hopefully, this topic should start the debate amongst all professionals so that more attentions will be paid to the pursuit of sustainable hospital planning. In summary, we go for long life and expandable sustainable solutions for what will change during the 30-60 year life of a hospital.

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'HEALING ARCHITECTURE': DAYLIGHT IN HOSPITAL DESIGN

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Abstract

Recently, the move by the Malaysian government to reduce the energy consumption in public buildings including hospitals is seen as the call for sustainability in the built environment. On the other hand, designing a hospital building is generally accepted as a complex task both: functional and psychological. At this juncture, creating a healing environment with appropriate physical aspects (i.e. daylighting) to achieve sustainable hospital design seems relevant and in tandem with sustainability. Much literature suggest that adequate and appropriate exposure to natural light provides a positive impact on human health and well being of patients and medical staff in a hospital environment.

The paper reviews the role of daylighting design as one of the physical aspects in hospital design to create a healing environment. The effects of physical aspects on patients' outcomes are highlighted. Pilot studies on Malaysian public hospital buildings are carried out to investigate the design and implementation of lighting (i.e. artificial and natural light) and its relationship to other environmental factors. Key findings on the physical aspects affecting daylighting design in 4-bed ward environments are explicitly noted. The paper calls for a comprehensive consideration on the physical aspects (i.e. daylighting design) in a healing environment as a strategy for implementation on a sustainable hospital design. Beyond this, good daylighting will obviate the need for artificial lighting, thus also lead for energy conservation, contributing to sustainability.

Keywords: Healing Architecture, Healing Environment, Hospital Design, Lighting.

1. Introduction

The call for sustainability or *green building* in the healthcare system is a paradoxical situation. Does it treat sickness or promote the condition of health? In hospital building, it is difficult to conceive the link and benefit of sustainability in contributing to the patients' health outcomes. Perhaps, to explain this, discussion evolving sustainability in healthcare facilities should embrace the notion of creating a supportive environment in hospital design (i.e. healing environment) that is physically healthy and psychologically appropriate. As a matter of fact, it should be the aim of designing a hospital. For this, it is an imperative for the physical aspects to be considered in hospital buildings. The physical aspects (i.e. daylighting, window design, thermal conditions and others) should be cleverly designed to achieve the balance and the principles of economic, social and ecological sustainability without compromising the functionality of hospital building (Linda, 2004). This paper emphasises two important aspects that lead to sustainability in hospital design: The importance of physical aspects to achieve a healing environment and the impact of the physical aspects (i.e. daylighting) on health outcomes.

1.1. Healing Environment in Hospital Design

In hospital buildings, where patients seek medical treatment and staff provides continuous support, creating a healing environment with appropriate physical aspects is an imperative to sustainable design. Nevertheless, the restoration of health and well being is not merely a matter of physical science (Day, 2007). The aspects of healing environment in hospital design are primarily important and relevant within the context of sustainability in healthcare facilities. The term *'Healing Architecture'* (Lawson, 2002) is adopted to invoke a sense of a continuous process; in creating an environment physically healthy and psychologically appropriate. A healing environment with appropriate physical aspects would indirectly contribute to patients' outcome such as shorter length of stay, reduced stress, increased patients satisfaction and others (Ulrich et al., 2004). One may agree to the idea that sustainable hospital design in the form of healing environment is achieved if these measurable outcomes could be quantified through appropriate design of physical aspects. Apparently, most scholarly literature does acknowledge that the existing physical environment we live in has an effect on our well being (Lawson, 2002; Day, 2007 and Todd, 2007).

Most healthcare designers accept the fact that designing a hospital is a complex task: both functional and psychological. Apart from building services, healthcare designers are expected to conform to various requirements provided by the Ministry of Health (MoH) which includes medical specialist requirements and equipment both for diagnostics and for treatment. In the effort to comply with the explicit requirements, it seems that most healthcare designers pay less attention to the ultimate aim of creating a healing environment. This has been well documented in most scientific literature that modern hospitals designed and equipped with technology for diagnostics, curing and treating have contributed to stress, depression and anxiety which have a harmful effect on health to patients and staff (Malkin, 1991 and Schweitzer et al., 2004). On the other hand, adverse experiences of existing hospital environment were recorded from visitors by the Commission for Architecture and the Built Environment (CABE) in the United Kingdom (CABE, 2004) and from patients' memories by Simini (1999). Critique would include terms such as confusing, dull, shabby, windowless, long circulation, glare and little natural light, poor lighting, noisy, sleep deprivation, isolation, physical restraint and want of information.

As a response to this, most literature in the healing environment have outlined that noise control, air quality, thermal comfort, lighting, communication, colour, texture, privacy and view to nature are among the physical factors which have to be thoroughly considered in hospital design (Malkin, 1991; Gross et al., 1998; Schweitzer et al., 2004 and Richard et al., 2005). These factors have a more pronounced influence in hospitals than in other buildings especially for patients who are bedridden or have limited freedom of movement. Ulrich (1984) established in a scientific study of a suburban US hospital that surgical patients who had view of nature through a window from their ward room not only spent less time in the hospital but required less analgesic medication as well. This study has spurred further tests and reviews by other disciplines involved with healing environments. They arrived at similar findings particularly that appropriate physical environment in the design of hospitals can ensure better health outcomes to patients, staff and visitors physically, mentally and psychologically (Horsburgh, 1995; Jones, 2002 and Lawson, 2002). In short, careful consideration of the physical aspects would significantly contribute to create a better healing environment which brings about sustainable hospital design.

1.2. Daylight and Health

Hosking and Haggard (1999) noted that creating a healing environment is not like building up a garage workshop, where cars are sent for repairs before continuing their journey. It is an imperative for a hospital environment however, where 'repair' of the body (i.e. healing) is the concern, to have the optimum level of comfort and care physically, socially and symbolically. For this the luminous environment plays an important role and an integral part of the hospital's healing environment. As a matter of the fact, natural daylight is often regarded as part of the healthy environment. Therefore, daylight is required in most areas in hospital buildings and is one of the crucial physical aspects to be considered in the healing environment. In the hospital wards indoor environment, appropriate window design would allow the potential benefit of daylight to be experienced by patients and staff. Their physical attributes are intertwined in the healing environment of hospital wards (Markus, 1967 and Todd, 2007).

Numerous studies have indicated that daylight has significant effects on the well being of humans both physically and psychologically. In fact, it has been recognised for many years that light has a significant effect on our circadian rhythm (i.e. biological cycles that repeat 24 hours). Campbell et al. (1988) imply that light is the most important environmental input in controlling bodily function after food (La Grace, 2004). Similarly, CABE (2004) clearly indicate that access to natural light is one of the crucial factors affecting patients' recovery. The presence of visible light in an indoor environment does influence the physiological responses, mood as well as visual needs (Schweitzer et al., 2004). Most psychiatrists generally agree that seasonal affective disorder (SAD) with symptoms of depression; fatigue and irritability may be triggered by shorter hours of exposure to daylight due to the seasonal change (Morriss, 2001, Evans, 2003 and Bower, 2005).

Research evidence by means of observations and qualitative analyses has found that lighting strategies (i.e. combination of daylight and artificial light) in a controlled environment have a positive impact on managing behavioural disturbances of the Alzheimer's type (Noell-Waggoner, 2002). In this aspect, most physicians together with other studies are in agreement in their findings that appropriate balance of daylight and artificial light may positively affect for Alzheimer's patients (Campbell et al., 1988; Noell-Waggoner, 2002 and La Grace, 2004). Therefore, related issues with regard to good lighting design in the hospital wards should be taken to task seriously. Issues which are crucial factors in achieving a healing environment would include glare control, flickering-free lighting, orientation of the light to the visual task, colour rendering and temperature, and balance between electric and daylight.

Much literature do suggest that access to daylight not only has a positive impact on patients' outcomes, it can also provide restorative benefits to other users in their respective environments such as medical staff, school children and office workers. In a survey conducted in a hospital environment on access to natural light Jana et al. (2005) claim that 70% of the medical staff rated increased natural light as having a positive impact on their work life. CABE (2004) produced similar findings that improved physical environment has a significant influence on the nurses' performance in their work and has positive impact on their recruitment and retention. Another study by Kuller and Lindsten (1992), in a selected class of a school environment, found that absence of daylight may influence children's performance and eventually have an impact on annual body growth and sick leave. However, the quantitative relationship of daylight and productivity has not been established.

In short, these findings and others provide compelling evidence on how daylight may influence human health, behaviour and performance. For this reason daylight in hospital design should rigorously be pursued as one of the physical aspects in creating a healing environment. However, it is believed that experimental studies of daylighting in hospital design are very few and far in between. Many studies on the subject of daylight focus on schools, offices and commercial buildings but few on hospitals. Therefore, the present study calls for a comprehensive consideration on the physical aspects (i.e. daylighting design) in a healing environment as a strategy for implementation on a sustainable hospital design. Daylight should be incorporated into lighting design in hospital buildings, not only because it is beneficial to patients and staff, but also because it is light delivered at no cost. Adopting and implementing good daylighting will obviate the need for artificial lighting, subsequently lead for energy conservation, contributing to sustainability.

2. Methodology

An extraction and assembly of the body of knowledge and on-going research of healing environment in hospital design is apprehended in this paper. It is intended to identify potential research areas on the physical aspects of healing environment in hospital design particularly in daylighting. Methodology employed in this research is literature review, desktop analysis and pilot studies of hospital buildings.

2.1 Literature Review

Aspects of healing environment in hospital design which include the physical aspects, daylighting and its effects on human beings are critically reviewed. An understanding of the subject of 'healing architecture' is established to provide substantial evidence on the link between the physical aspects of hospital environment and human health physically, psychologically and mentally within the context of sustainability. For this, desktop analysis through the thematic and content reviews is to provide clear arguments on the subject discussed. A cross examination of the project briefs (medical, architectural and engineering briefs) of Malaysian public hospitals is to investigate the provisions of physical aspects in the design. Three public hospitals in Malaysia are then identified for the pilot studies.

2.2 Pilot Studies

The critical examination of the existing conditions of physical aspects is carried out in a pilot study of three public hospital buildings in Malaysia. Criteria of building type (i.e. healthcare facilities) and level of care in the Malaysian healthcare system are explicitly listed out and the focus area for the analysis is clearly established. A critical analysis is expected to arrive at key findings on the physical aspects of ward environment. Patients and medical staff are used as subjective testing and their experiences will be explicitly noted to substantiate the personal observation made.

3. Pilot Studies: Public Hospitals in Malaysia

3.1 Brief Description

In accordance to the Malaysian healthcare referral system (i.e. a concept defined by World Health Organisation (WHO) as a channel of filtering and referring patients to appropriate care), the progress of the physical development of healthcare facilities has been rigorous since independence in 1957. It encompasses primary, secondary and tertiary level of care. The medical approach of promotive, preventive, curative and rehabilitative is being refined and implemented at all levels of care (Suleiman and Jegathesan, c2000). The Ministry of Health Malaysia (MoH) is responsible for establishing a framework to ensure that the health system could develop and adapt the changing environment and need.

In the context and limitation of this study, three Malaysian public hospital buildings are selected namely Selayang Hospital, Serdang Hospital and Sultan Ismail Hospital. These hospitals are categorised by MoH as *'referral hospital'* (i.e. patients must be referred by other medical professionals before they are seen and would receive treatment). The *'referral hospital'* will eventually become specialised (e.g. liver, hand and micro-surgery cases for Selayang Hospital and lung cases for Serdang Hospital). Based on the information gathered, it has been found that the medical brief, technical and environmental requirements prepared by MoH and Public Works Department Malaysia (PWD) were first established for Selayang Hospital to function as referral hospital with '*paperless'* technology. The project brief of Selayang Hospital was further refined for Serdang Hospital and Sultan Ismail Hospital. The common parameter (i.e. same project brief used) has been the basis for the selection of the pilot studies. Further similarities in the pilot studies selected as referral hospitals set by the Ministry are found in their technical requirements, complexity, level of care, day to day operation, number of beds, location and building heights. Interestingly, the outcome of the hospital environment varies in their design approach, building configuration and concept. The implementation of *'one-off'* design hospitals with different outlooks is a result for the calls made by MoH to be ecologically sustainable and environmentally friendly. Furthermore, the change of procurement system from traditional to design and build could have been the driving factor for *'one-off'* hospital design (Aripin, 2006).

These *'one-off'* hospital designs in Malaysia with different outlooks and mechanical aids do not necessarily conform to the principle of sustainable design. These may lead to energy waste, confusion and other negative aspects in the functioning of the hospital. Hence, the ultimate aim of creating a healing environment for staff, patients and visitors physically, mentally and psychologically may not be achieved. To establish this concern, investigation on the provision of the physical aspects of the selected public hospitals design in Malaysia is relevant and pertinent.

3.2 Methodology and Scope of Work

The main objective in conducting the pilot studies is to investigate the implementation of the physical aspects in a healing environment of *'one-off'* hospital designs in Malaysia. Gathering such primary data would enhance the body of knowledge of daylighting in the context of Malaysian climate. Visits to the three hospitals were made separately with a minimum 4 to 5 days stay at each building. The physical conditions of 4 bed ward indoor environments were used as the subject to be reviewed.

The reviews made are qualitative; based on the researcher's critical observation and understanding on retrospective studies of both aspects: healing environment and daylighting in hospital wards. The primary data gathered is further enhanced and confirmed by the information received from the medical staff working in the wards. The key findings will focus on the physical aspects affecting daylighting design in the ward environment emphasising on physical design and the implementation of lighting and its relationship to other environmental factors. These would include building orientation, window design, access to view, visual comfort of the ward environment, lighting (daylight and artificial) and colour. These are the most pronounced influential physical factors affecting bedridden patients. In the following text, the three referral hospitals in the pilot studies will be identified with acronyms: Selayang Hospital with SH-1, Serdang Hospital with SH-2 and Sultan Ismail Hospital with SIH.

4. Findings: Physical Aspects Affecting Daylighting Design

The physical factors affecting daylighting design have been identified in the pilot study of 4-bed indoor wards environment. The key findings on the physical aspects are explicitly noted qualitatively based on the critical observation and subjective testing. Hence, analysis is required in the next study to corroborate the qualitative observation and opinion with the quantitative data of luminance and illuminance of daylight in the ward environment with regard to visual comfort.

4.1 Building Orientation

In hospital building, orientation plays a major part in the early process of the design. In fact, it can be argued that is the highest priority in the design decision for achieving sustainable hospital environment. Regrettably, a preliminary finding seems to indicate that most healthcare designers regard physical planning issues as the topmost priority to be sorted out at the early stage of hospital design. This is due to the fact that designing a hospital building is generally accepted a complex task both: functionally and psychologically.

In theory, the decision on building orientation will subsequently influence the design of the physical aspects (i.e. shading devices, window opening, placement and profile). Similarly in hospital design, where creating a healing environment is the primary concern, orientation of the building does influence the design of the windows directly affecting the quality of daylighting (i.e. glare effect and daylight distribution) and access to outside view (i.e. optimise the surrounding scenery). Hence, it would have a significant impact on the end users' (i.e. patients, medical staff and visitors) experience and well being. Providing access to outside view through a window would provide patients in the ward environments with a sense of orientation and connection to the external environment. Absence of this would have a negative impact on building users' as discovered by Verderber and Reuman (Jana et al., 2005). Investigation conducted in the pilot studies on building orientation illustrates the following:

4.1.1 It has been found that in the SIH building; most of the 4-bed wards are placed to face North-South direction. As a result, no direct bright light appears on the floor surface of the ward during the day. Most importantly, disability glare or discomfort glare are avoided. This would certainly be the outcome if the building orientation is placed in East-West direction, allowing the main elongated façade to face North-South.

4.1.2 Nevertheless, the SH-1 and SH-2 hospital buildings are not exactly oriented in the East-West directions. As a result, it is estimated that 20 to 30 per cent of the 4-bed wards are almost directly facing East and West. This results in the wards having direct bright light (at low angles) on the floor surface of the wards at certain period of the day. Consequently, patients and staff do experience unwanted warmth and discomfort glare.

4.2 Window Design

In the research fraternity of healing environment, there is a growing consensus recognising the window as one of the most significant physical aspects for patients and medical staff physically, psychologically and mentally. There are two benefits of windows: one is daylight and the other is view. In an empirical research conducted by keep and others as quoted by Jana et al. (2005); of two groups of individuals in the intensive ward therapy unit: one was unit without windows, and the other with translucent windows; indicates that patients with translucent widows were more oriented during their stay and gain better health outcomes such as avoiding sleep disorders, hallucinations and delusions. Even with translucent windows in this aspect do provide the vital link to the outside world for patients and the feeling of orientation helped to maintain their normalcy (Jana et al., 2005). Conversely, a well designed window is not an intuitive task; it requires careful architectural, environmental and cultural considerations (Todd, 2007). The following account is an investigation on window design in the pilot studies:

4.2.1 A survey conducted in the three Malaysian public hospitals indicates that the need and importance of windows in the wards environment are clearly acknowledged by all parties (i.e. patients, medical staff, healthcare designers and providers). It has been observed that windows are provided in all 4-bed wards in the pilot studies.

4.2.2 Windows in all hospital buildings are specified as tinted glass with various degree of darkness: dark tinted for SH-1 building, blue tinted for SH-2 building and light dark tinted for SIH building. The connection to the outside world with tinted windows may not be an issue to patients but it may affect their judgments on outside weather. Nonetheless, it can be observed that tinted windows help to reduce the brightness of outdoor sunlight.

4.2.3 It has been noticed clearly that the provision of windows in all 4-bed wards in the pilot studies is different in term of windows' profile and placement. Two types of windows' placement have been identified in all three public hospitals and it may have some impact on access to outside view for patients in relation to their beds. Type A window placement has been adopted by SH-1 and SH-2 buildings which is categorised as *symmetrical and balanced*: the 2 panels of windows are located symmetrically at both sides with a blank wall in the middle. The placement appears to be balanced. Type B window placement is categorised as *centre grouping*: the 4 panels of windows are grouped and located at the centre of the perimeter wall. The placement seems to be centralized. This type B placement has been adopted by SIH building. Based on the observation made on these two types, it can be deduced that either patients in a lying or sitting position on the bed, it is most preferable to have window placement of type A (i.e. symmetrical and balanced) in a 4-bed ward environment. It has been noticed that two patients from their bed positions have a better chance to have access to outside view through type A window placement. The justification would be the ratio of 1:2 (windows to patients) for type A: *symmetrical and balanced* placement whereas, the ratio of 1:4 for type B: *centre grouping* placement. Another aspect which has been noticed on the consequences of window placement is that different outcome of daylight distribution in the ward environment in either type of placements. However, this has to be quantified by means of measuring the luminance and illuminance of daylight distribution in the next study.

4.2.4 It has also been observed that the overall window surfaces in SH-2 building may appear to be more than the other two hospital buildings (i.e. SH-1 and SIH). As a result, the two beds near the windows are warmer than the other two in a 4-bed ward environment. The observation and experienced had been confirmed by the ward nurse during the visit to SH-2 building that they received complaints from the patients who had been regularly admitted to the same ward. The patients would normally request not to be positioned near the windows. Evidence based design such as this has confirmed that the conflicting issues *'physical to physical'* (e.g. daylight vs. heat gain) and *'physical to psychological'* (e.g. daylight vs. undesirable glare) have to be addressed.

4.2.5 Another critical observation has been explicitly noted is that daylighting method and strategy seemed to be designed intuitively. Only horizontal concrete shading devices are provided for SIH building however, its effectiveness is not convincing. Implementation of daylightng design appears to be very limited in all hospital buildings. Articulation of daylighting through window treatment is rarely found. This aspect is extremely important and relevant for building design in a Malaysian climate (i.e. tropical climate) particularly in a healing environment which would contribute to the sustainable hospital design.

4.3 Access to View

There is growing research evidence that access to view in the ward environment would provide a positive impact on patients physically, psychologically and mentally. Evidently, research by Ulrich (1984) of surgical patients with a view through a window may provide shorter length of stay. This evidence and findings by others send a clear message to the professionals involved in the healthcare services that coordinated effort must be taken beyond the requirements of the project briefs. Initial investigation on the hospital project briefs proves that there is no requirement explicitly stated emphasising this aspect. On the same tone, the quality of outside view has to be positively promoted in a ward environment for patients and staff psychological well being: view of a children playground instead of a view of a blank wall. However, in reality of the building design, the availability of view for the users is not always positive quality. In healthcare design, to achieve quality view depends highly on the site selection, building orientation, wards layout, bed positions and windows design. Further investigation conducted in the pilot studies on access to outside view reveals the following:

4.3.1 An average measurement of the window height from the finished floor level in all 4-bed wards of the three hospital buildings is 1000mm. Subjective testing was conducted at level 4 of SH-1 building in a 4-bed ward environment with a panoramic view (i.e. greenery of hill, trees and sky), at the extreme bed position (i.e. the farthest from the windows) in both situations: lying and sitting on the bed. It has been discovered that a minimal view of the trees (about 5% of the view in a standing position) can be seen from the bed when a patient in a sitting position. However, when a patient in a lying down position on a bed, it has been found that only view of the sky can be seen. This indicates that access to positive view (i.e. greenery) by patients is even more critical when the wards are at a higher level. Assumption has been made that when one is at the highest level of the building, view of the surrounding area would be most enjoyed. This could have been true for other building functions in a standing position but may not be applicable in hospital buildings when the patients are bedridden.

4.3.2 Bed layout and windows placement may affect access to view by patients in the 4-bed wards environment. As mentioned in the section of windows design, SIH buildings has adopted window placement type B: *centre grouping* (see 4.2) at the parameter wall of 4-bed ward environment. It has been discovered that access to view by patients is almost being denied due to the narrow angle from their bed positions. Healthcare designers may not be aware of this phenomenon until the subjective testing playing the role of a patient is conducted and experienced.

4.3.3 On the aspects of the availability of outside view in the 4-bed ward environment, the study arrives to three different types of outside view: Type 1 is of panoramic view (greenery with open field and housing development in surrounding areas), type 2 is of building facades own view and type 3 is of a blank wall (a coloured blank wall). It has been noticed that patients experience view of type 1, 2 and 3 in SH-1 building, whereas, views of type 1 and 2 are experienced by patients in both SH-2 and SIH buildings. From the study, it can be deduced that wards with outside view of type 3 (i.e. coloured blank wall) is the worst quality of view experienced by patients in SH-1 building. Strong dissatisfaction was expressed by patients in these wards. It has been estimated that 25% of the 4-bed wards facing view of type 3. This is in fact due to the building configuration of the wards are arranged in the form of a letter 'W'. It has been confirmed by nurses that regular admitted patients in the wards facing view of type 3 have requested to transfer to the opposite wards. Unfortunately, the request could not be met as the opposite ward is provided for the opposite gender. Evidently, the quality of view in ward environment does psychologically influence patients' well being.

4.4 Visual comfort

4.4.1 It can be deduced that the visual comfort of a 4-bed ward environment in all hospital buildings has been generally satisfied under both sky conditions (clear and overcast) during the day. However, it has been explicitly noted that discomfort glare was experienced by patients at a particular time at some of the 4-bed wards in all hospital buildings (SH1, SH2 and SIH). It has been noticed that patients had to either use curtains or not facing the window to avoid discomfort glare when lying on the beds near the windows. Therefore, physical conflict does occur between wanting to have a view and avoiding direct disability glare. Nevertheless, to corroborate the patients' view and observation on glare, the question must be further pursued in the next study with the analysis of in-situ measurements. It can be generalised that tinted windows help to reduce outside bright light condition, but it did not resolve issue of discomfort glare.

4.5 Lighting (Daylight and Artificial)

4.5.1 In most of the hospital buildings visited, access to daylight in the 4-bed wards environment seems to be sufficient during the day under both sky conditions: clear and overcast. Patients were observed not to be keen to switch on the artificial lights unnecessarily during the day. However, artificial lights were required in between 5 to 7pm depending on the sky conditions and heavy rainfall.

4.5.2 In all 4-bed wards environment, the artificial lighting at the ceiling is noticed to be arranged along the centre line of the wards' space and not located above patients' bed. Insufficiency of lighting conditions has been confirmed by nurses when retractable dividing curtains had to be pulled during the conduct of medical procedure on patients. It has also been noted that some patients experienced discomfort glare from the artificial lighting at the ceiling when they were in a lying position on the bed for resting.

4.5.3 It has also been observed that the size of the artificial lighting at the ceiling is inconsistent. For instance, smaller size of 600mm x 600mm square box of fluorescent luminaire has been found used in the SIH building instead of 600mm x 1200mm rectangular box luminaire in the other two hospital buildings.

4.6 Colour

4.6.1 In the study, pastel colour scheme is used in almost all 4-bed wards environment. Patients seem to be satisfied on this aspect. Wards and levels are differentiated by means of different colour schemes and tones for SH-1 and SH-2 buildings. It has also been noted that in the 4-bed wards environment of SH2 building, perimeter walls are painted with dark colours (e.g. dark green) instead of continuous pastel colours, thus increasing the luminance contrast with adjacent windows. It is important to note that this requires further analysis on the aspect of reflectance of daylight, as it may have an effect on the perception of patients' skin colour subsequently affecting the visual task of doctors during medical examination.

Conclusions

Achieving sustainable hospital design through appropriate physical aspects is not an impossible task. The growing research evidence and the pilot study conducted in the Malaysian public hospitals provide unequivocal direction to suggest that the physical aspects have a significant role in creating a healing environment. In the context of hospital buildings, the measurable patients' health outcomes in a healing environment are indirectly the result of appropriate design of physical aspects. Thus, the role of daylighting as one of the physical aspects having a significant impact on the well being of the patients, staff and visitors. It is without doubt that well designed daylighting will obviate the need for artificial lighting. The effort to reduce dependency on artificial lighting would directly contribute to the energy consumption of hospital buildings, subsequently assisting sustainability.

Creating a healing environment with appropriate design of physical aspects (i.e. daylighting) in hospital buildings in Malaysia should be rigorously pursued. Professionals in the healthcare services should be inspired with the availability of natural environment (i.e. daylight and natural view) in the Malaysian climate without sacrificing clinical functionality and design visions. One must accept the fact that the subject of healing is a multidisciplinary discipline. Thus, a coordinated effort by healthcare professionals and others (psychologist and lighting specialist) will be able to achieve a better hospital building not only for healing environment that is physically healthy and psychologically appropriate but also for aiming to contribute sustainable design.

The effort to have *'one-off'* design for public hospital in Malaysia through improved procurement system is a commendable starting point. However, stringent requirements on the physical aspects to meet environmental issues should be explicitly stated in the design briefs of hospital developments. These requirements must be conform by healthcare designers and validated by the healthcare providers. The present scenario suggests that healthcare designers ought to consider issues beyond the project brief and requirement. It should be noted that conflicting issues in hospital environment: *'physical to physical'* (e.g. daylight versus solar heat gain) and *'physical to psychological'* (daylight vs. undesirable glare) can only be resolved with good understanding of daylighting design. In conclusion, the study embarked upon the physical aspects (i.e. daylighting) of healing environment in hospital design could significantly reinforce the project briefs provided by the healthcare provider (Ministry of Health Malaysia).

Acknowledgements

The author would like to express his gratitude to Honorary Professor Dr. Steven V Szokolay for his constructive comments on this paper. This paper would also be an impossible without the assistance of the following government departments and private agencies in conducting the pilot studies of hospital buildings and gathering information of Malaysian healthcare systems: The Ministry of Health Malaysia (MoH), Public Works Department Malaysia (PWD), Directors of State Health, Hospital Directors, Radicare (M) Sdn. Bhd., Ministry of Higher Education Malaysia (MoH) and International Islamic University Malaysia (IIUM).

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POST OCCUPANCY EVALUATION INDOOR ENVIRONMENT QUALITY TOOLKIT :ENVIROBOT:

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Abstract

This EnviroBot is part of an Indoor Environment Quality Assessment toolkit that is used in the U.S. General Services Administration (GSA) “WorkPlace 2020” project. The goal of the project is to investigate the relationship of physical environment, building attributes and best practice workplace strategies to workers performance and organizational effectiveness. The toolkit has been beta-tested at more than 30 “WorkPlace 2020” project sites. The collected data are used as an environmental benchmark to capture baseline before and after thermal, visual, acoustic, air quality, and spatial quality in buildings. The data can be used to quantitatively prove the impact of sustainable strategies related to indoor environmental qualities on occupants’ health, comfort and satisfaction. The development of easy to use, cost effective techniques for evaluating the actual thermal, acoustic, visual and air quality conditions in occupied buildings is crucial to ensure building performance and the effectiveness of sustainable strategies.

Keywords: Post Occupancy Evaluation (POE), Indoor Environmental Quality (IEQ) Assessment, sensor, environmental benchmark, thermal, air quality, acoustic, visual, spatial

1. Introduction and Motivation

Beginning in 2001, Public Building Service (PBS) assembled an interagency research team and retained recognized academic and private sector leaders to identify ‘best practice’ workplace strategies and the research tools holding the most promise for evaluating their effect. In 2002 PBS launched a program of applied research, “WorkPlace 20.20”. This has become a cooperative research effort among US General Services Administration (GSA), Public Works and Government Services Canada, five major Universities (including the Center for Building Performance and Diagnostics at Carnegie Mellon University), and nearly a dozen leaders in the design and building products industries. The premise of the WorkPlace 20.20 program is PBS’ acknowledgement that their ability to serve their customer is fundamentally linked to their ability to transform the workplace into a tool to support organizational performance. A focus of this research effort is the development of a set of building evaluation protocols linking environmental, technical and spatial quality to individual and organizational effectiveness - the National Environmental Assessment Toolkit.

A number of subjective evaluation techniques are needed to understand the effectiveness of the physical environment to support the changing nature of work and individual and organizational productivity, health and satisfaction. A range of tools are being developed by the larger GSA team, including collaboration/trust analysis, social network analysis, nature of work analysis, and user satisfaction questionnaires. The Center for Building Performance and Diagnostics at Carnegie Mellon University (CBPD) team has taken primary responsibility for the development and testing of an affordable, robust, and portable suite of instruments for thermal, air, and lighting quality field measurements. This effort has included the development of a National Environmental Assessment Toolkit (NEAT) cart for affordability, robust measurements and for portability; the refinement of a field sampling strategy and PC interface for affordability and robust measurements; the refinement of direct data entry from instruments into a database that includes other field measures; data mining for drawing baseline environmental assessment and automatic reporting; and the graphic presentation of all measures for comparisons and potential linkage to physical attributes.

The key thrust of the WorkPlace 20.20 program at CMU is the development of cost effective techniques for evaluating the actual thermal, acoustic, visual and air quality conditions in occupied buildings. Information acquired will be used to:

- Measure whether the performance specified in design documents and contractually guaranteed has been achieved
- Evaluate whether the whole building performance differs from sub-assembly performance
- Serve as a necessary first step in identifying whether the minimum IEQ standards establish an adequate threshold for occupant health and satisfaction
- Establish baseline data allowing the effect of environmental quality to be correlated with individual and organizational performance

NEAT, developed by CBPD, comprises the following tools: Envirobot, environmental instrumentation cart, 24-hr continuous measurement unit, eGIS[1] (PDA-based physical indicator recording), eSoft[1] (web-based online surveys), eDatabase[1] (web-accessible database, with graphing capability). Subjective questionnaire tools (EnviroQuest) as well as tools to capture the technical attributes of building systems (TABS) are used. This toolkit supports field data collection, web-based data download, storage and analysis. These tools are used to conduct indoor environmental quality assessments of buildings.

This paper provides an overview of the Envirobot.

2. The Current State of Practice

A number of standard setting organizations have established recommended levels of performance for certain building systems. GSA has incorporated many of these standards as policy and criteria in the document "The Facilities Standards for the Public Buildings Service (P-100-2003)". These standards, however, lack the methods for verifying that the required level of performance is actually delivered in an occupied building. Moreover, there is little data correlating the physical criteria established by these standards with occupant satisfaction or organizational performance. Finally, these standards are applied independently in separate design and engineering documents, and therefore may not accurately predict the cumulative effect of the constituent sub-assembly's contribution to whole-building performance.

Furthermore, buildings are constructed with the assumption that they will function as designed and will be operated as intended. Environmental quality measurements are necessary to validate the design intent and the proper operation of the facility. Off-the-shelf commercial environmental sensors vary in their ease of use, data-logging capabilities and cost. Some toolkits have been developed by other research institutions. A summary of some of these toolkits[2] studied is presented in Table 1.

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[1] 'e' here implies environmental

[2] AEC (ENFORMA & MDL): http://www.archenergy.com/aecproducts.htm
Casella CEL (Microtherm): http://www.casellausa.com/en/acrofiles/casella/microtherm_iaq.pdf
Berkeley Chair "Mark II": http://arch.ced.berkeley.edu/resources/bldgsci/bsl/cart.html
Australian Chair "Sputnik": Cena, Krzysztof and de Dear, Richard (1998)
Field study of occupant comfort and office thermal environments in a hot-arid climate, ASHRAE RP-921, December 1998
"Suitcase" by James Woods: The Building Diagnostics Research Institute, Inc., Bethesda, MD
NRC-CNRC Cope: http://irc.nrc-cnrc.gc.ca/ie/cope/02-3-Details_e.html

From this literature search it was concluded that no integrated sensor package that includes all 5-performance criteria of acoustic, visual, spatial, thermal, and air quality, is available on the market. The decision was made to purchase off-the-shelf sensors and dataloggers and integrate them as required for this project.

		AEC (ENFORMA & MDL)	Casella CEL (Microtherm)	Berkeley Chair "Mark II"	Australian Chair "Sputnik"	Suitcase (J.Woods)	NRC Chair	Dantec Vivo
								
Thermal	Air Temperature	X	X	X	X	X	X	X
	Relative Humidity	X	X	X	X	X	X	X
	Globe Temperature		X	X	X			
	Operative Temperature							
	Radiant Temperature Asymmetry			X	X			
	Air Velocity	X	X	X	X		X	X
	Turbulunce Intensity (calculated)				X			
	Draft Risk (calculated)			X	X			
	Dew Point Temperature			X	X			
	Wet Bulb Temperature		X					
IAQ	Carbon Dioxide		X	X		X	X	X
	Carbon Monoxide		X					
	Ozone		X					
	Particulates / Aerosols		X			X		
	Volatile Organic Compounds					X		X
	Air Flow	X						
	Ventilation Effectiveness							
	Mold							X
Visual	Light Level	X		X		X	X	X
	Light Intensity		X					
	Luminance							X
Acoustics	Sound Level		X	X		X	X	X
	Reverberation							
Data	Acquisition	X	X	X	X	X		X
Analysis	Software	X	X			X		

Table 1: A comparison of some toolkits

3. The Envirobot Development

The Envirobot (Fig. 1) is developed as an integrated sensor package to objectively capture indoor environmental quality of a space within a building. The current generation of the Envirobot includes sensors measuring air temperature at 3 heights, radiant surface temperature, relative humidity, carbon dioxide, carbon monoxide, volatile organic compounds, particulates, air velocity, light levels at 3 locations, sound

Fig. 1: From left, Generation 1 Envirobot, Generation 2 Envirobot, Generation 3 Envirobot, the Acoustic Cart

levels, and a photometric camera that analyzes brightness/contrast and glare. Attached to this cart are a data logger, a PDA, and a digital camera. This entire toolkit is designed to be packed and shipped in standard cases via air planes.

The development of the Envirobot involved multiple generations, each improved over the previous. The first generation Envirobot cart had mounting plates and telescopic poles attached to a walker to support the sensors, a photometric camera, a notebook computer and the portable dataloggers. The toolkit had a self-contained power supply (multiple batteries) and could be packed into two standard-sized travel suitcases for transport. In generation 2, a foldable luggage carrier was used as the base and OEM sensors were integrated to a notebook PC (Fig. 2) based data acquisition card. This version was easily maneuverable in the restricted space of offices and required about 15 minutes for assembly and disassembly. A sealed lead acid battery was used to extend the operation time of the computer.

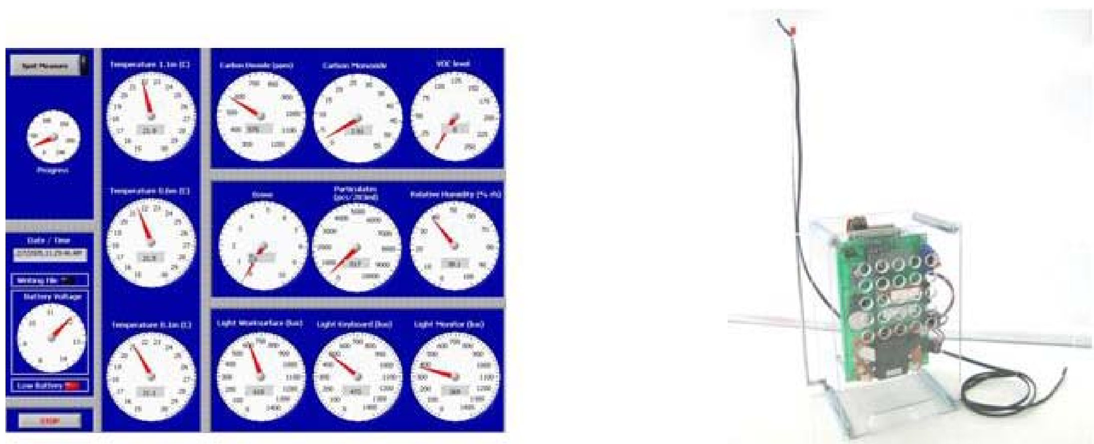

Fig. 2: From left, Generation 2 Envirobot interface, the 24 hour unit

The current generation of the Envirobot, generation 3, replaces the notebook computer with an embedded micro controller custom programmed by the CBPD. This controller has a removable flash memory card providing easy data transfer capability. This development allowed a substantial reduction in power requirements and allowed the replacement of the lead acid battery with a smaller lithium ion battery. A new, lighter camera for photometric analysis was integrated and the sensor suite was upgraded to improve accuracy and robustness. This version of the Envirobot requires less than 5 minutes for assembly and disassembly. A hand held sensor unit (HSU) (Fig. 3) was developed to measure light levels, radiant temperature and air velocity. The HSU communicates with the Envirobot via blue tooth. An acoustic cart was also developed and integrated into the toolkit. This cart includes a sound generator and power supply to measure acoustic qualities.

Fig. 3: From left, front view of HSU belt in operation, rear view of HSU belt in operation

Along with spot measurements using the Envirobot, stationary measurements of indoor air quality (IAQ) are recorded to establish base levels for the space being measured. The stationary unit (Fig. 2) measures 6”x9.5”x4.5” and uses an embedded micro-controller as a data logger. This unit is designed for long term (24 hours to 72 hour) IAQ measurements and is connected to a wall outlet. The sensing capability is designed the same as the Envirobot – air temperature at 3 different heights, relative humidity, carbon dioxide, carbon monoxide, volatile organic compounds, and particulates. Custom software for this unit has also been developed by the CBPD.

4. Operation Procedures and Sampling Strategy for the Toolkit

The protocol for sampling is as follows – the instrument cart is placed in the position of the occupant’s chair (Fig. 4) for approximately 15 minutes for each workstation sampled. For the first few minutes, the sensors are allowed to acclimatize to the environment in the workspace. Immediately thereafter, hand held readings of light levels (at 3 locations in the workstation), radiant temperature (2-4 locations), and air velocity (2 locations) are logged into the data logger. Then, automated sensor readings of temperature at three heights, relative humidity, and four air quality indices are taken over the next four minutes, at 15-second intervals, and averaged to obtain the final measurements in that workstation.

Fig. 4: The Envirobot being used to measure a space

During the time when the physical measurements are recorded in a workstation, the occupant is asked to complete the ‘User Satisfaction Questionnaire’ nearby. Finally, four digital pictures with a fish-eye lens are taken to capture brightness contrast. Conventional digital photographs are taken to record the workstation configuration and furniture as well as the primary worksurfaces. Environmental indicators revealing local control or modification of lighting, thermal, indoor air quality, acoustic, and spatial/ergonomic conditions are logged into a PDA with GIS identified locations.

For each floor or workgroup, approximately 20% of the occupied workstations are sampled. The workgroup is divided into spatial/environmental zones with a minimum of two sample workstations selected in each zone. These are based on several factors including:

- Distance from the building perimeter sampling – The work group is divided into perimeter zones (those workstations at the exterior wall or window), interior zones (occupants seated less than 20 feet from the window wall, but not at the window wall), and core zones (workstations more than 20 feet from a window wall).
- Orientation sampling – This sampling of three zones is then completed at each basic orientation of the occupied floor – north, south, east or west.
- Open versus closed office sampling – Within these three zones and four orientations, the number of open workstations and closed offices sampled reflects the proportion of these two types of workstations on the floor.
- Unique condition sampling – Based on information obtained about the idiosyncratic nature of the mechanical or lighting system, variations in work tasks, distributed equipment/service areas, or specific occupant concerns, additional samples are taken.
- Special function spaces sampling – Conference rooms and copy rooms are considered separately. Additional samples are taken for acoustic privacy in meeting rooms and closed offices as needed.

5. Results and Conclusions

The GSA WP20•20 project has now completed subjective questionnaires and field measurements at over 40 sites in 18 federal facilities allowing for cross site comparison (Fig. 5) of thermal, air quality, acoustic, and visual quality measures.

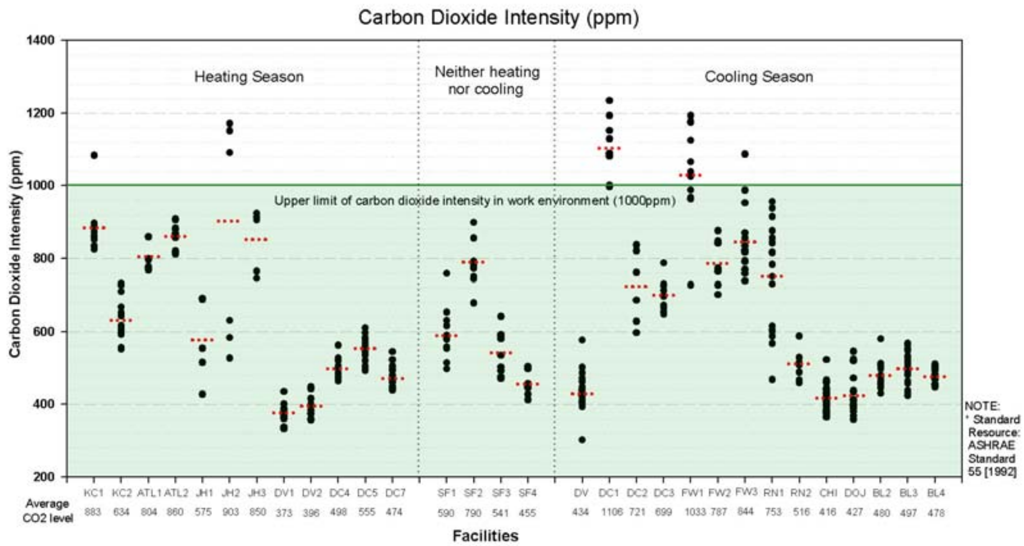

Fig. 5: An example of cross site comparison – a chart displaying carbon dioxide levels measured across multiple sites

A report has been prepared for each of the measured sites containing the following information:

- o Executive Summary: a briefing for decision makers, containing a synopsis of the physical measurements ("EKG's"), results from the User Satisfaction Survey, and recommendations for change;
- o Detailed Report: a comprehensive description of thermal, acoustic, visual, and air quality conditions, relevant spatial attributes and background information about the building's design, operation and systems; and
- o Appendices: data sheets that provide aggregated and raw toolkit data, photographs, floor plans, descriptions of test methods, specifications of toolkit instrumentation and complete User Satisfaction Survey results in a digital format.
- o

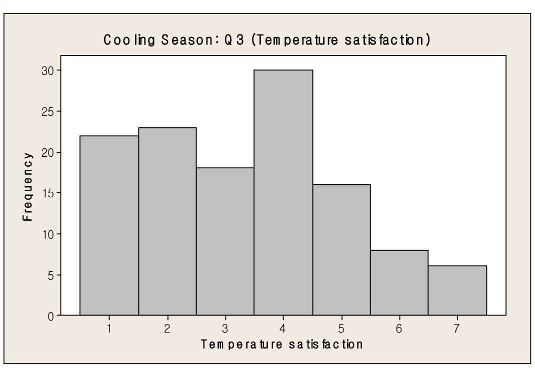

Fig. 6: A chart displaying occupant responses to the question "Satisfaction with Air Temperature (1..7)"

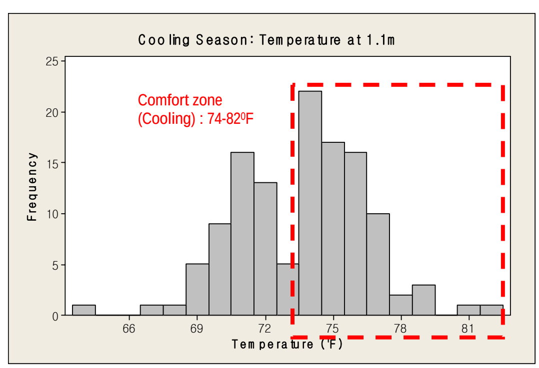

Fig. 7: A chart displaying air temperature measured at 1.1m

As an example of the analysis performed on the collected data, on average (mean = 3.50) it was found that a group of occupants were somewhat dissatisfied with the temperature (Fig. 6) during the cooling season with only 54% of the measured temperatures (Fig. 7) recorded within the ASHRAE recommended comfort range (74^0F – 82^0F). The average measured temperature at 1.1m during the cooling season was 73.61^0F and average relative humidity was recorded at 38%. During the cooling season, almost 40% of the occupants were very dissatisfied or dissatisfied with the temperature compared to 21% occupants during the heating season. Occupants have a tendency to be more satisfied with higher temperatures during the cooling season (P = 0.099). A conclusion therefore is that the buildings studied are typically overcooled during the summer months.

Thus, the toolkit developed by CBPD is capable of coordinating a range of subjective and objective measures relating physical attributes, environmental quality, user satisfaction, and organizational behavior. A range of output vehicles, key to the effective "diagnostics" linking the quality of the physical environment to subjective and objective assessments of quality and business goals are obtained through this toolkit. NEAT provides a path for the research community to coordinate baseline measures and methods of data collection towards creating an international database for comparative assessment of the role of real estate and facilities in individual and organizational effectiveness.

6. Future Developments and Applications

This toolkit is used to measure and analyze indoor environmental quality (IEQ) as well as a teaching tool in building diagnostics. The CBPD team continues to develop a database and an intuitive input and output interface for the range of physical attribute data sets, subjective/occupant measures and objective /expert measures collected in before and after productivity/workplace effectiveness studies. It is our objective to develop this toolkit into a robust commercial product for assessment of indoor environmental quality for use by Facilities Management staff, Building Commissioning Agents, and for use in Architecture/Building Engineering courses. Development work for the toolkit is underway such that automated data may be collected as described in the following scenario: the Envirobot is deployed in an office and programmed to independently navigate the facility, collecting IEQ data from office to office. Collected data are transmitted and downloaded into a central server and a report is automatically generated. The report contains baseline information (the current state of the facility) and recommendations if necessary. The development of such easy to use, cost effective techniques for evaluating the actual thermal, acoustic, visual and air quality conditions in occupied buildings is crucial to ensure that buildings are performing to their full potential.

Acknowledgements

The authors acknowledge the contributions and technical expertise obtained from James Jarrett (Research Technician, CBPD) in the design and construction of the NEAT toolkit. The authors also acknowledge the contributions of the students of the Center for Building Performance and Diagnostics, School of Architecture, Carnegie Mellon University who have worked in the development and testing of this toolkit.

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PRELIMINARY STUDY ON THE EFFECTS OF BUILDING DESIGNS ON ITS INDOOR TEMPERATURE

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Abstract

The recent increase of electricity tariff in Malaysia has created much interest in energy saving opportunities. Building designs can easily provide energy saving with minimal cost impact. Since Malaysia has a generally hot climate, most of the domestic electricity consumption is used for cooling. To encourage undergraduate students to learn more about sustainable building designs, a final year project has been conducted to study the effects of building designs on its indoor temperature. A miniature model house equipped with customized indoor temperature sensors has been built for this purpose. The building design parameters that are studied are the roof colour, window type and wall colour. These three parameters have been varied to study their impacts to the indoor temperature. This paper describes the study methodology and results in detail. The study shows that the three studied parameters have significant impacts on the building's indoor temperature.

Keywords: Energy efficient buildings, Sustainable building designs

1. Introduction

Malaysia is a tropical country that lies on 2° 30' N latitude and 112° 30' E longitude. It possesses a climate with uniformly high temperatures, high humidity and abundant rainfall throughout the year. However, the climate condition of Malaysia might have negative impact on the comfort of the occupants. Like other developing countries with hot and humid climates, Malaysia has been experiencing dramatic growth in the number of use of air conditioners, and the usage will be higher in the future.

The usage of residential electrical appliances for the last two decades has increased rapidly in Malaysia together with the increasing income per capita. According to Tenaga Nasional Berhad (TNB), about 83.268% of total user of electricity in Malaysia to housing area, 0.394% to industrial area, 15.677% to commercial, 0.001% to mining and 0.66% to public street lighting.

Creating a successful indoor thermal condition require more than satisfying thermal design criteria but depends upon the extent to which the internal environment is considered acceptable by the occupants (Forwood, 1995). The reduction of building energy usage has a vital role in reducing the emissions of greenhouses gasses and it is important to understand that the use of energy is to cool the resident in the building rather than the building (Loveday,et.al.,2002).

Passive climate control is the concept completely in line with the notion of sustainable building. It is an alternative to a mechanical air-conditioning system and as such is an essential part of sustainable building. Passive climate control implies that the repository is built and arranged in such a way that the thermal and hygroscopic properties of the building and its contents create a good stable indoor climate (Teygeler et.al., 2001).

Passive cooling uses non mechanical methods to maintain a comfortable indoor temperature. The most effective way to cool a building is to keep the heat from accumulating. The primary source of heat build up is sunlight absorption by the building through the roof, walls and windows.

To encourage undergraduate students to learn more about sustainable building designs incorporating passive cooling element, a final year project has been conducted to study the effects of building designs on its indoor temperature. A miniature model house equipped with customized indoor temperature sensors has been built for this purpose. This paper presents the effect of building design parameters; roof color, wall color and window type to indoor temperature.

2. Theory

2.1 Roofing System

About a third of the unwanted heat that builds up in a house comes in through the roof. Thermal considerations in the design of roofs can be divided into two general categories: control of heat loss and heat gain of the space below the roof, and the effects of extremes and variations of temperature on the roof system. The effects of extremes and variations of temperature are of major importance because they influence the durability of the total roof system. The size, capacity and cost of heating and cooling systems are determined on the basis of maximum rates of heat loss and heat gain, and can be reduced by increasing the over-all resistance to heat flow through the roof. This is normally achieved by the insertion of insulation in the roof system.

Heat gain can be further reduced by using a light coloured roof surface. Solar reflectance, or *albedo*, is the fraction of the incident solar energy that is reflected by the surface material. Solar energy consists of a spectrum of wavelengths, including ultraviolet, visible and infrared light. Surface materials that reflect solar energy over all wavelengths will have better performance in reducing roof solar heat gain. Colour is a good indicator of solar reflectance only in the visible light range, with reflectance typically increasing from a dark-coloured to a light-coloured surface. Traditional dark-coloured roofing materials have a solar reflectance of about 0.04 to 0.18, whereas light-coloured roof surfaces have a reflectivity of 0.70 or higher. However, roof is not a perfect reflector, as all surfaces absorb some solar energy as heat. The thermal emittance of most common roofing materials is approximately 0.80.

2.2 Wall Colour

Colour plays an important role in daily lives of human living. The right choice of colour in the built environment can affect the mood and the well-being of psyche. In interior designs colour choice is of paramount importance in creating value to the interior of buildings. In environmental science especially in the hot-humid climate as experienced in Malaysia, the choice of colours can help in the reduction of energy consumption for cooling purposes.

Dull, dark-coloured home exteriors absorb 70% to 90% of the radiant energy from the sun that strikes the home surface. The absorbed energy is then transferred into the home through conduction, resulting in heat gain. In contrast, light-coloured surfaces effectively reflect most of the heat away from the home surface.

The white paint is the first passive solar design element strategy before employing an active system to assist in the lowering of indoor air temperature (Rahman, 2004). Simulation was done for a residence house in the United States in a hot and arid climate which showed a reduction of 33.6% (cooling load) on the average achieved over the base case where no reflective paint was used when the outer surface of the roof and wall were painted white (Samir, 2003). Study carried out by (Cheng, 2005), reveals that the use of lighter surface colour and thermal mass can dramatically reduce maximum indoor temperatures in hot humid climates.

2.3 Windows

Windows transmits not only sunlight but also both indoor heat and solar heat through the building envelope. Estimated, 40% of the unwanted heat that builds up in a house comes in through windows. A window's ability to resist heat flow, its insulating value, is defined by R-value and U-factor. The U-factor is the reciprocal of the R-value (R=1/U). The larger the U-factor the greater the heat flow through the window.

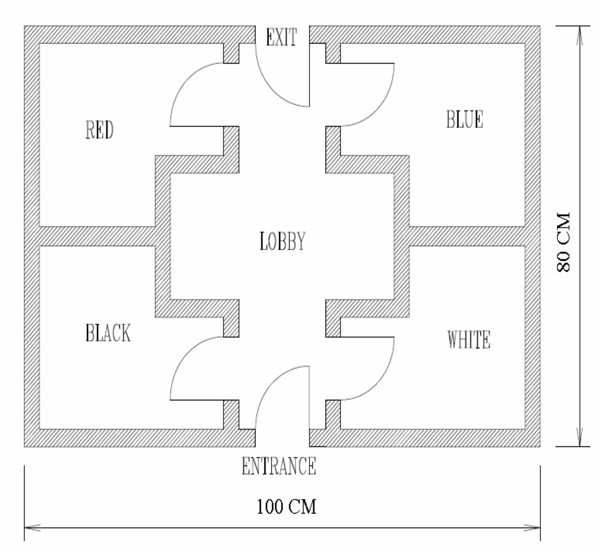
Typically, 75% of the exposed surface of a window is glass. There are three key factors which determines the quality of a glass window; thermal insulation, control of solar energy and visual clarity. Solar control refers to a window's ability to allow the daylight to pass through the glass while filtering out solar heat.

Window glass allows short-wave solar radiation get into an interior space. This radiation is absorbed by the interior of the building. The interior then radiates long-wave, thermal radiation. Glass is opaque (not transparent) to this long wave radiation. Thus energy is trapped in the building and the indoor air temperature rises.

Today, a window is considered energy efficient if its U-factor is less than 0.40. To achieve this energy efficient standard, the glass is coated with an engineered layering to transmit certain frequencies of radiation. This coated glass is called low-emissivity (low-e) glass.

3. Methodology

The miniature model house has been built to study the effects of building design parameters to its indoor temperature. This model house consist of an entrance door, eight windows, a lobby , a hallway and four L-shape rooms that are linked to the lobby. The plan and isometric view of the model house is illustrated in Figure 1 and 2.



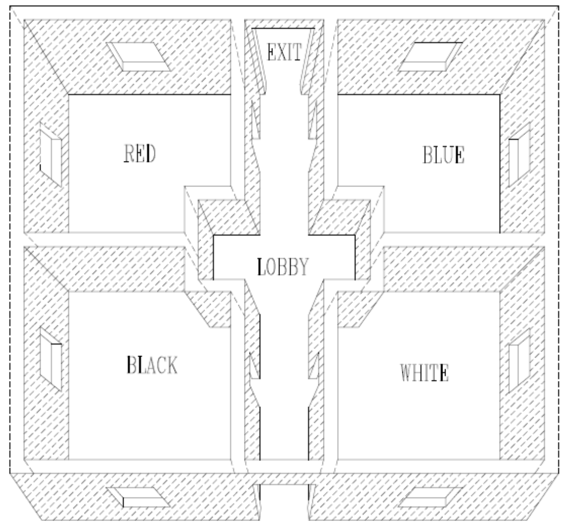


Fig.1 Plan of the model building

Fig.2 Isometric View of the Model Building

The miniature model house has four rooms of the same size. All the interior and the exterior walls of the four rooms are painted with four different colours namely white, black, red and blue. The lobby of the miniature model house is painted with white colour. However, this study focuses on the indoor temperature of these four rooms only.

The combination of the experimental parameters of various window shades, roof colour and room wall colour are presented in Table 1.

Table 1. The combination of various shades of window, roof colour, and room colour.

Roof Colour	Window Shade	Room Wall Colour
Silver	Type 1 - Clear Type 2 - Tinted	White Blue Red Black
Black	Type 1 – Clear Type 2 - Tinted	White Blue Red Black

4. Results and Discussions

Data of the indoor temperature of the miniature house are collected and analyzed to conclude the effect of the building parameters to its indoor temperature. Table 2 presents the indoor temperature of the miniature house versus the combination of various shades of windows, roof colour and room colour.

Table 2. Indoor temperature versus the experimental parameters.

Date/Time	Roof Colour	Window Type	Outdoor Temperature (°C)	Indoor Temperature (°C) Room Colour / Shades			
				White Room	Red Room	Blue Room	Black Room
16th Jan 12.30 pm	Silver	Type 1 Clear	39.5	37.1	37.6	37.6	37.8
17th Jan 12.40 pm		Type 2 Tinted	38.4	34.3	34.4	34.5	34.8
18th Jan 12.20 pm	Black	Type 1 Clear	40.5	38.2	38.6	38.5	38.8
19th Jan 12.40 pm		Type 2 Tinted	40.0	36.1	36.4	36.4	36.7

As the outdoor temperatures are different each time the measurements taken, percentage of drop in indoor temperature compared to the outdoor temperature is computed for accuracy in comparison. The computed values are tabulated in Table 3.

Table 3. Percentage of drop in indoor temperature to outdoor temperature.

Date/Time	Roof Colour	Window Type	Outdoor Temperature (°C)	Percentage of Drop of Indoor Temperature Compared to Outdoor Temperature (%) Room Colour / Shades			
				White Room	Red Room	Blue Room	Black Room
16th Jan 12.30 pm	Silver	Type 1 Clear	39.5	6.08	4.81	4.81	4.31
17th Jan 12.40 pm		Type 2 Tinted	38.4	10.68	10.42	10.16	9.34
18th Jan 12.20 pm	Black	Type 1 Clear	40.5	5.68	4.69	4.94	4.19
19th Jan 12.40 pm		Type 2 Tinted	40.0	9.75	9.00	9.00	8.25

Figure 3 distinguishes the percentage of drop in temperature between Indoor and Outdoor for Silver roofed model house and Figure 4 for Black roofed model. The observations are as follows and read in conjunction with the Figures 3 and 4:-

i. Silver roof generally shows higher percentage of temperature drop compared to black roof. This illustrates the effectiveness of the silver roof in reflecting away the heat.
ii. The rooms with darker shade reveal lower percentage in temperature drop with both silver and black roof.
iii. Tinted windows have greater effect in reducing the envelope's indoor temperature, providing a comfortable environment to occupants of the house. In average it reduced the

indoor temperature 10% for silver coated roof and 9% for black coated roof. Tinted window glass is made by altering the chemical composition of the glass with chemical additives. The primary usage of this glass is to reduce solar heat gain and glare.

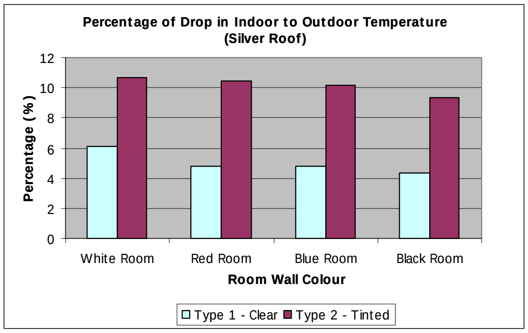


Fig. 3 Percentage of Drop in Indoor to Outdoor Temperature for Silver Roof

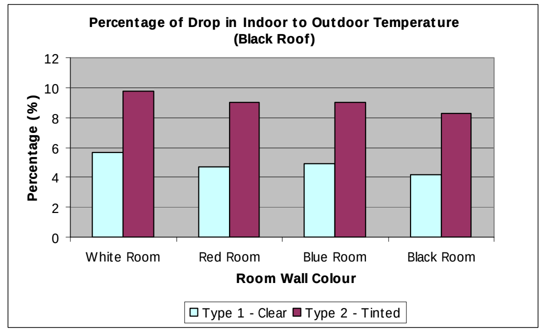


Fig. 4 Percentage of Drop in Indoor to Outdoor Temperature for Black Roof

Figure 5 and 6 presents the effect of roof colour to the indoor temperature of rooms with white and black shades/colour. Black roof has low solar reflectance while silver has a high solar reflectance. The results of the experiment carried out shows that the silver roof reduces the indoor temperature. The percentage in temperature drop due to roof colour is minimal about 1% compared to effects of tinted to clear glass window is about 4.5%. This shows that the effect of roofing is minimal and major heat transfer is through the window panels.

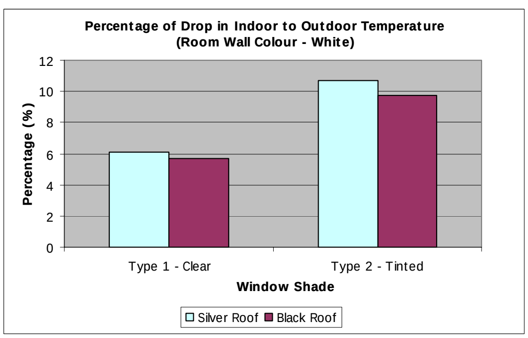


Fig.5 Percentage of Drop in Indoor to Outdoor Temperature (Room Wall Colour – White)

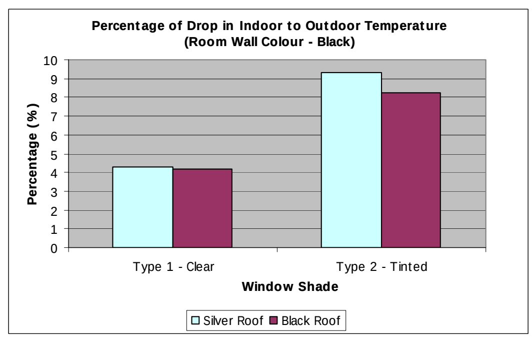


Fig.5 Percentage of Drop in Indoor to Outdoor Temperature (Room Wall Colour – Black)

5. Conclusions

In this research the authors through their analysis have clarified the effect of building design parameters; roof color, wall color and window type to indoor temperature by means of a scaled down mini house. It is apparent that usage of highly reflective material for roof, white shaded / coloured rooms and tinted window panels significantly affects the indoor temperature. The numerical values attained form this research is highly dependent from the scaled down model house. Relevance of these results to full scale house has to be studied. The results may change if the model house is insulated below the roof and the material used for the construction of the house is changed. On the other hand, silver roofing, white rooms and tinted glass windows is and effective passive methodology to reduce the indoor temperature of a building.

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THE INTERRELATIONSHIP BETWEEN ENVIRONMENT, URBANISATION AND HEALTH INDICATORS IN ASEAN COUNTRIES

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Abstract

According to United Nations' projections, by the year 2030, more than half of the world's urban population will be living in Asia. In the face of this intensifying urbanisation and the emergence of mega-cities in ASEAN, with the associated health and environmental issues, it is imperative that an interdisciplinary approach be taken in the design and planning of cities.

This paper describes the interrelationship between Environment, Urbanisation and Health indicators in Asean Communities. It is concluded that, there exist some significantrelationships between the three sectors, infrastructures and other indicators. Hence they should be taken into account as a basis for setting policies and introducing intervention policies in the design and planning of ASEAN cities.

1. Introduction

A set of baseline data for the ASEAN Member Countries (AMCs) was compiled. The selected data covers geography, land use, population, urbanisation, economy, education, environment, health and infrastructure though the emphasis is on the environment, health and urbanisation. Within each of these categories, the various indicators will be defined, comparisons made and interesting facts or aberrations/confounding factors highlighted and explained. The ten AMCs comprise Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar (Burma), the Philippines, Singapore, Thailand and Vietnam.

Urbanisation

The urbanisation data includes data on the urban population, urban population growth rate, degree of urbanisation, population in largest city and social data on total recorded crime.

Environment

The environmental data includes data on green house gases (carbon dioxide emissions, carbon dioxide emissions per capita, carbon dioxide damage and methane emissions), air pollution (total suspended particulates, particulate matter of 10 micron, sulphur dioxide and nitrogen dioxide), water pollution (emissions of organic water pollutants and industry shares of emissions of organic water pollutants), solid waste (solid waste generation per capita, solid waste collection and solid waste collection per capita) and on threatened species.

Health

The health data includes data on the birth rate, death rate, net migration rate, sex ratio, infant mortality rate, adult mortality, life expectancy at birth and total fertility rate.

2. Interrelationships of Indicators

The data were analysed using various statistical analysis methods such as the Pearson correlation and Spearman correlation, scatter graph, multiple regression and interrelationship analyses.

2.1 Environment

The analysis of the data shows that there are significant, positive (bivariate) correlations between CO2 emissions and PPP as well as electricity production and consumption. The result of regression analysis also shows a multivariate relationship between CO2 emissions and the variables PPP and electricity production. Regarding CO2 damage, there are also significant, positive correlations between the CO2 damage and CO2 emissions, GDP composition by industry, electricity production and consumption in the AMCs. That is, the CO2 damage value will increase with the increase in value of any of these variables.

Further analysis shows that there are significant, positive correlation coefficients for CO2 emissions per capita with the following indicators: energy consumption per capita, GDP per capita, degree of urbanisation, HDI ranking, motor vehicles, ratio of paved highways and electricity produced by fossil fuel. The result of regression analysis shows a multivariate relationship between CO2 emissions per capita and the variables GDP per capita and energy consumption per capita. Another equation shows the multivariate relationship between CO2 emissions per capita and the variables GDP per capita and motor vehicles.

The other environmental indicators TSP per capita, SO2 per capita and NO2 per capita have significant, positive correlation coefficients with motor vehicles. There are significant, positive correlation coefficients for TSP per capita with GDP per capita and paved highways per area but a negative correlation coefficient with HDI ranking. This makes sense since the GDP per capita has an inverse correlation with HDI ranking. However, it has to be pointed out that the sample size for these environmental indicators was small due to the limited data available.

Analysis of the data on emissions of organic H2O pollutants per capita shows that there are significant, positive correlation coefficients for emissions of organic H2O pollutants per capita with the following indicators: GDP per capita, electricity produced by fossil fuel, safe water, sanitation (urban areas) and life expectancy at birth. There are significant, negative correlation coefficients with HDI ranking and infant mortality rate. This means that as the value of the emissions of organic H2O pollutants per capita increases, the values of the HDI ranking as well as the infant mortality rate will decrease, that is, AMCs with higher GDPs (and hence lower HDI rankings and infant mortality rates) emit more organic H2O pollutants per capita. Further analysis of data shows that the industry shares of emissions of organic water pollutants per capita has the highest, significant correlation coefficients with the chemicals as well as the stone, ceramics and glass industry, showing that these two industries emit the most organic water pollutants per capita.

It is interesting to note that analysis of the AMC solid waste data shows that there is no significant correlation between the per capita solid waste collected per day and the per capita solid waste generation. However, there are significant correlation coefficients between the per capita solid waste collected per day and per capita GDP, per capita energy consumption, electricity produced by fossil fuel, degree of urbanisation, population density, population growth rate, highways per area, paved highways per area and per capita health expenditure. The result of regression analysis shows a multivariate relationship between per capita solid waste collected per day and the variables energy consumption per capita and paved highways per area. Obviously, the necessary infrastructure has to be in place before the solid waste can be collected.

It can be summarised that, for the AMCs, there is not only a strong linear relationship between these environmental indicators and the obvious economic indicators but also the health, urbanisation, infrastructure and social indicators, and that a change in the value of the health, urbanisation, infrastructure or socio-economic indicator will be accompanied by a change in the value of the environmental indicator.

2.2 Health

The analysis of the birth rate data shows that there are significant, positive correlation coefficients with the HDI ranking, urban population growth rate, infant mortality rate, low weight babies, total fertility rate and years lived in poor health, and significant, negative correlation coefficients with the data on electricity from fossil fuels, literacy of the total population and life expectancy at birth. The analysis of the death rate data shows that there are significant, positive correlation coefficients with the HDI ranking, infant mortality rate, low weight babies and years lived in poor health, and significant, negative correlation coefficients with the GDP per capita, energy consumption per capita, electricity from fossil fuels, literacy of total population, degree of urbanisation, access to improved sanitation and access to essential drugs.

The analysis of the infant mortality rate data shows that there are significant, positive correlation coefficients with the HDI ranking, inflation rate, low weight babies and years lived in poor health. There are significant, negative correlation coefficients with economic indicators such as GDP per capita and literacy of total population, with environmental indicators such as CO2 emissions per capita and organic H2O pollutants per capita, with urbanisation indicators such as the degree of urbanisation, with infrastructure indicators such as electricity produced by fossil fuel, energy consumption per capita, safe water, access to improved sanitation and ratio of paved highways, and with other health indicators such as child immunisation rate, access to essential drugs and number of physicians. The results of regression analysis show that the infant mortality rate is influenced by the GDP per capita and literacy of total population.

The analysis of the life expectancy data shows that there are significant, positive correlation coefficients with economic indicators such as GDP per capita and literacy of total population, with environmental indicators such as CO_2 emissions per capita and organic H_2O pollutants per capita, with urbanisation indicators such as the degree of urbanisation, with infrastructure indicators such as electricity produced by fossil fuel, energy consumption per capita, safe water, access to improved sanitation, per capita solid waste collected per day and ratio of paved highways, and with other health indicators such as child immunisation rate, access to essential drugs and number of physicians. There are significant, negative correlation coefficients between the life expectancy and the inflation rate, HDI ranking, low weight babies and years lived in poor health. The results of regression analysis show that the life expectancy is influenced by the variables GDP per capita and literacy of total population. Another equation shows that the life expectancy is also influenced by the variables degree of urbanisation and literacy of total population.

Analysis of the total fertility rate data shows that there are significant, positive correlation coefficients with the urban population growth rate, population aged 0 to 14 years and human development index, and a significant, negative correlation coefficient with the literacy of total population. In the AMCs, the total fertility rate is declining with the increase in the literacy of the total population. The results of regression analysis show that the total fertility rate is influenced by the variables literacy of total population, degree of urbanisation and population aged 15 to 64 years.
It can be summarised that, for the AMCs, there are significant relationships between the health indicators and the socio-economic, urbanisation and infrastructure indicators.

2.3 Urbanisation

The analysis of the degree of urbanisation data and socio-economic data shows that there are significant, positive correlations between the degree of urbanisation and the GDP per capita, CO_2 emissions per capita, energy consumption per capita, net migration rate, population density, population growth rate and recorded crime. Analysis of the degree of urbanisation data and health data shows that there are significant, positive correlations between the degree of urbanisation and the life expectancy at birth and the number of physicians but significant, negative correlations with the death rate, infant mortality rate, smoking prevalence (male) and health expenditure per capita. Analysis of the degree of urbanisation data and infrastructure data shows that there are significant, positive correlations between the degree of urbanisation and safe water, sanitation, solid waste disposal (by incineration) and electricity produced by fossil fuel. However, there are significant but negative correlations with solid waste disposal (by dumping) and hydro-produced electricity. As the degree of urbanisation increases in the AMCs, solid waste is disposed of by incineration instead of dumping, and electricity is fossil fuel generated rather than hydro-generated.

The results of regression analysis show that the degree of urbanisation is influenced by the GDP per capita. However, the degree of urbanisation cannot be solely accounted for by the GDP per capita. Another equation shows that the degree of urbanisation is also influenced by the net migration rate and the death rate. Yet another equation shows the degree of urbanisation as being influenced by the number of physicians as one variable and the GDP per capita as another variable. Hence, it can be seen that urbanisation in the AMCs is interrelated with the health, infrastructure and socio-economic development of the AMCs.

3. CONCLUSION

It can be concluded from the analysis of the compiled baseline data that there exist significant interrelationships between the environmental, health, urbanisation, infrastructure and other indicators. Hence, socio-economic, environmental, urbanisation and other conditions are important aspects which should be taken into account as a basis to set policies and to introduce intervention priorities in the design and planning of ASEAN cities.

SUSTAINABILILTY OF A GARDEN CITY IN A HOT ARID REGION: PROBLEMS AND REMEDIES

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Abstract

Many neighborhoods and cities were built in many countries based on the garden city principles proposed by Ebenezer Howard in 1898. Most of these cities were subject of research investigations assessing their performance from different angles. While most of this research is conducted for cities in moderate climates and shows a western perspective, not much has been reported about garden cities in the hot arid regions. The notion of a garden city in an arid environment appears to be contradictory and raises questions regarding its sustainability.

This paper tries to asses the energy efficiency of a garden city in the United Arab Emirates as an indicator of the sustainability of this planning approach in this particular climatic zone. The paper focuses on energy consumption for domestic use, street lighting, transportation and water desalination. Based on the data collected and the discussion, recommendations for improving sustainability are presented.

Keywords: Sustainability, Hot Arid Regions, Energy Efficiency, Urban Density, Renewable Energy, Social Structure.

1. Introduction

Many neighborhoods and cities were built in many countries based on the garden city principles proposed by Ebenezer Howard in 1898. Garden cities were planned, self-contained communities surrounded by greenbelts, and containing carefully balanced areas of residences, industry, and agriculture. The main objective was to raise the standard of health and comfort of all true workers of whatever grade. A central park, boulevards, gardens and houses each standing in its own ample grounds were some of the main features of these cities. Most of these cities were subject of research investigations assessing their performance from different angles. While most of this research is conducted for cities in moderate climates and shows a western perspective, not much has been reported about garden cities in the hot arid regions. The notion of a garden city in an arid environment appears to be contradictory and raises questions regarding its sustainability.

It is argued that high-quality liveable cities must be the basis for sustainable urban development and policies should be implemented to achieve that objective. Economic development, comfort and improved quality of life are generally considered to be consequences of energy expansion programs. In recent years energy expansion plans worldwide have forced the consideration of important issues such the environmental, social, economic and financial impacts. One of the major challenges for urban planning in the 21st century is to achieve a high level of quality of life while consuming less energy thus increasing the energy efficiency of the city. Using Al-Ain city, a garden city in the United Arab Emirates, as a case study this paper tries to asses the energy efficiency as an indicator of the sustainability of this planning approach in this particular climatic zone. The paper focuses on energy consumption for domestic use, street lighting and transportation. Based on the data collected and the discussion, the paper tries to sketch out the choices available to decision-makers to achieve sustainable urban development.

2. Case Study

Al-Ain city (N 24.2 – E 55.7) is the second largest city in the emirate of Abu Dhabi, the capital of the United Arab Emirates. The modern development of Al-Ain comes about with the successful exploitation of oil in the Emirate of Abu Dhabi and the foundation of the United Arab Emirates as a sovereign state in 1971. During the subsequent period, a radical transformation of the area took place, both in urban development and style of living. The introduction of the motor vehicle and electric power made Al-Ain both a more accessible and more comfortable place in which to live. As the hometown of the ruling family of the Emirate it benefited from the desire to see Al-Ain develop as a modern garden city, blooming on the edge of the desert. The population jumped from 13,000 in 1968 to 142,000 in 1985 and to 421,000 in 2004 according to the latest statistics of the Planning Department in Abu Dhabi, which is nearly three times the population in 1985. Major investment programs were initiated in housing, education, health, parks, roads and utilities. These, together with the dramatic increase in population, have radically transformed Al-Ain into a modern town.

3. Al-Ain Social Structure

The UAE has a cosmopolitan population of 4.1 millions and exhibits a unique demographic structure as UAE nationals only make about 20% of the total population, with a total population of 825000 nationals only. The expatriate population in the UAE consists of a mosaic of large and small ethnic groups representing most Arab, Asian (Indian, Pakistani, and Filipino), and Western communities, making 25%, 50%, and 5% of the total population, respectively giving it a distinct socio-cultural identity and characteristics..

Since 1973, the UAE has undergone a profound transformation from an impoverished region of small desert principalities to a modern state with a high standard of living. As a result, there has been a striking shift from the traditional Arab pattern of life to a more western way of living. Due to the high percentage of foreign workers, males constitute more than 60% of the population. The size of the national family is usually large with a household size of about 10 persons.

Al-Ain city, as a case study for low density garden cities (figure 1), has undergone very rapid growth and development. Most of the expatriates in Al-Ain come from social classes, which would fall between what are termed as middle and working social classes in Western countries. Most nationals would fall into a higher economic class. Al-Ain is still an example of a traditional society in the UAE.

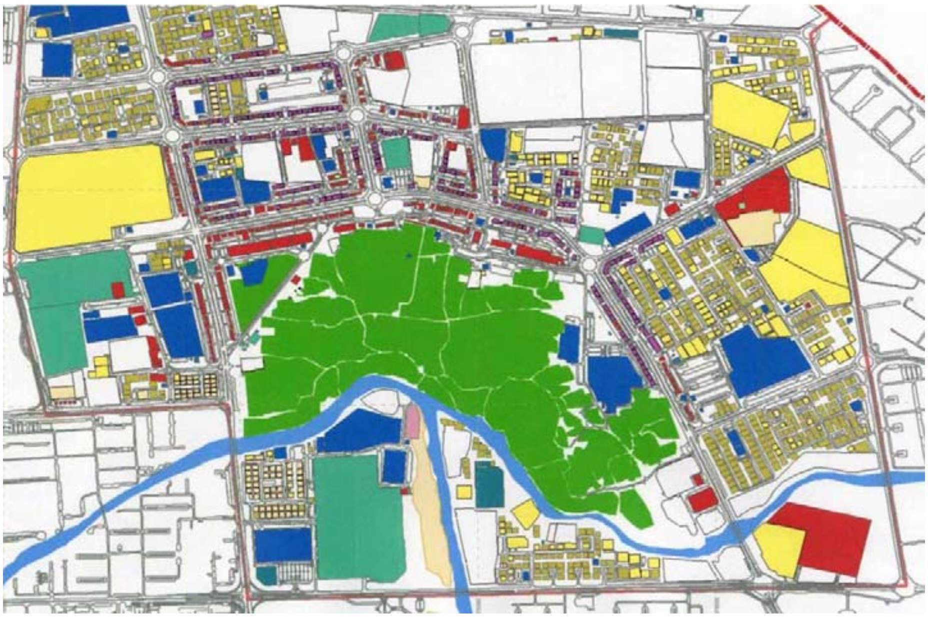

Fig.1 Al-Ain map showing city center area and Al-Ain oasis

By observation and statistical evaluation, it could be said that the most important factor that influences the energy consumption in Al-Ain is the population size and structure. The next most important predictor may be household income by population classification. The social structure of Al-Ain city consists of three different types of housing types. These types are one-to two-storey housing for national citizens, two-storey housing for non-citizen families, and four-storey housing for non-citizen single workers; each of these types has its own typology and energy consumption rate.

Although the citizen population is only about 20% of the total population, it consumes about 72% of all electricity sold in Al-Ain (Ministry of Economy statistics 2005). Al-Ain offers a different style of living for each type of social structure (figure 2). National citizens live only in single- or two-storey detached buildings. The average plot area varies between 45x45 meters and 100x100 meters for one family for middle income nationals. Areas allocated for national are usually segregated from other nationalities and characterized by a very low density about 12 persons per Hectare. Non-citizen families usually live in two-storey attached houses with population density 25 to 35 persons per hectare. Al-Ain city center area has the highest population density in, where single workers live, with a ratio of about 60 persons per hectare.

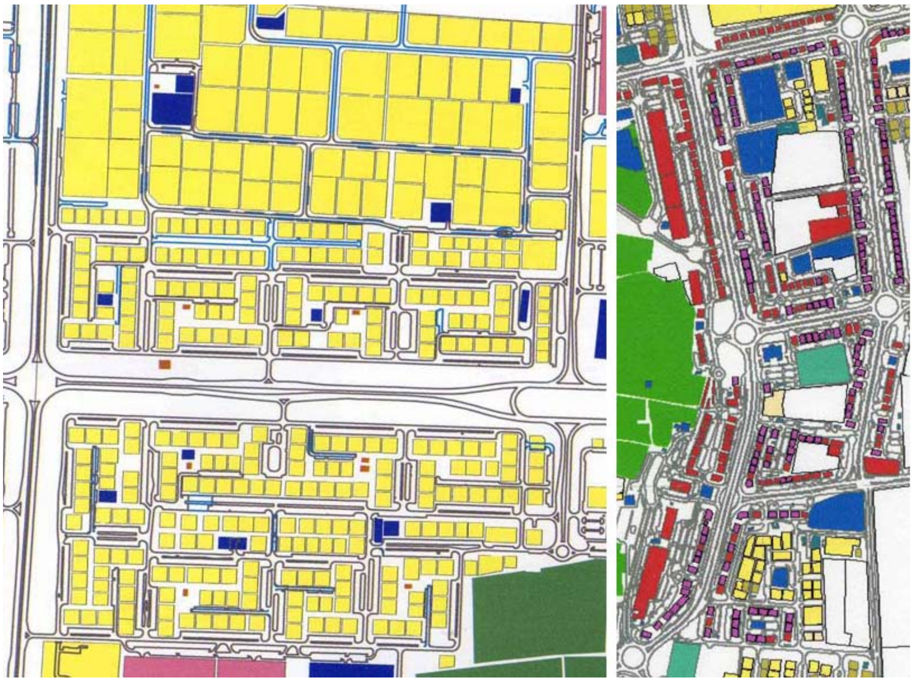

Fig.2 Housing typology in Al-Ain city;
Right image: single workers 4-storey housing in city center, population density 60 P./hectare
Lower left image: Non-citizen families 2-storey housing, population density 30 P./hectare
Upper left image: citizen families, population density 12 P./hectare

4. Modes of Energy Consumption

4.1. Energy Consumption for Domestic Use

Statistics indicate that the domestic sector in Al-Ain consumes more than one-third of the electricity in Al-Ain (citizens and non-citizens). Over half is consumed by the government, schools and commercial, and less than 10 percent is consumed by agriculture and by all other categories. Energy consumed in the residential sector is used either in air-conditioning, lighting, refrigeration, cooking or water heating. The high domestic use of Al-Ain City is attributed to housing that is more dispersed and thus requiring more electricity for cooling. According to daily system load report, by Al-Ain municipality 2005, 60 % of summer peak load in the domestic sector is accounted for air-conditioning, a situation similar to countries in the cold region where 50% of the energy consumption per household is dedicated to heating.

To sustain the images of a garden city, building regulations are implemented which limit building heights to low-rise and keep buildings apart from each other. Residential density of Al-Ain was 16 persons / hectare. Typical types of residential building in Al-Ain and it's expected energy efficiency have been surveyed as seen in table 1. A building count done in 2005 shows the following types of buildings in Al-Ain: 4420 multi-storey buildings, 18566 villas, 12235 low cost courtyard houses, 5200 one storey houses, 3950 two storey houses and 14497 others types. This shows that less than 8% of the residential buildings are more than two floors high and can potentially use central A/C. The remaining 92% are cooled using the less efficient A/C types such as split and window units.

Table 1 Energy Efficiency of Residential Building Types in Al-Ain

Residential Building Type Description	A/C Type	A/C Efficiency	Exposure to Outer Climate A/V	Photo
Low Cost Court House Single storey house with courtyard where most rooms open to the courtyard. Old doors and windows are not airtight allowing hot air to flow inside and cooled air to flow outside.	Window	Low	High	
Villa Modern 1-2 storey single (extended) family buildings some times with excessive use of glazing. High m^2/resident ratio.	Split - Central	Medium - High	Medium - High	
Multi Family House Found in suburb areas. Accommodating 4 families, 2 at each floor. Upper floor protects lower floor from solar radiation	Window - Split	Low - Medium	Medium	
Row House 2 storey row houses. Upper floor protects lower floor from solar radiation. Side units protect middle units from outer climate. Central Air conditioning is used.	Split - Central	Medium - High	Low	
Multi-storey House 4-5 storey buildings found only in the CBD. Ground floor dedicated to commercial use while upper floors for residential apartments or office space. Upper floor protects lower floors from solar radiation	Central	High	Low	

4.2. Energy Consumption for Street Lighting

More than 45.000 masts (single, double or quad) are used to light all primary, town and district distributors. Due to the low urban density in most areas, providing street lighting for local distributors and access roads is not feasible. Considering quality of life this could be a negative point. In some areas fence lighting is used to enhance the feeling of security. Street Lighting is provided 12 hours each night regardless of time of the year. The amount of energy consumed for street lighting is estimated to be about 5% of total annual per capita consumption, which does not appear in the electricity bill every month. Providing street lighting to local distributors and access roads would increase the energy consumption dramatically. A continuous horizontal expansion of the city using current urban density will be possible only if local distributors and access roads remain unlit. Vertical expansion of the city would allow lighting local distributors and access roads without increasing the per capita energy consumption.

4.3. Energy Consumption for Water Desalination

Based on the policy of creating a garden city, numerous public gardens and parks have been established within the city boundaries. All major roads are landscaped; the shoulders, medians, and traffic circles are planted with trees, gardens, and grasses. The landscaping on the roadsides extends well beyond the city limits. Al-Ain City has been chosen to be the Host City for the final stage of the worldwide competition "Nations in Bloom 98". The international environmental competition seeks to identify those cities that have best adopted landscape management practices to the improvement of the quality of life of all citizens. The water demand for landscaping represents about 17% of the total demand or 40%, if agriculture and forestry are not taken into consideration. The water demand for landscaping is almost equal to the water demand for domestic and trade use. It should be noted that water demand for domestic and trade use is related to population size whereas water demand for landscaping is related to urban density.

As the population continues to grow shortages of water will be covered by the use of desalinated water. Desalinated water has a high cost estimated at 2.8 US$/m3. Should no measures for reducing water consumption for landscaping are taken, and the remaining demand covered by desalinated water, then the energy consumption for desalination would continue to grow and, according to some estimates, could reach about 66% of the total electricity consumption of Al-Ain city. Reused water from the domestic and trade sector represents 70% of the water used for landscaping while the remaining 30% come from underground water.

4.4. Energy Consumption in the Transportation Sector

Al-Ain is a car-oriented city with a main road network that has been constructed to a road grid system with a five level road hierarchy (figure 3). All roads have spare capacity even in peak hours. The primary and town distributors form a two to three kilometer grid around a district. The district distributor roads consist of a finer grid of 500-700 meter spacing and normally border a neighborhood. Local distributor and access roads are provided as loops or cul-de-sac to provide for efficient plot layouts.

In the United States one of every two people owns an automobile. At the other extreme are many developing countries, with one privately owned car for every 75,000 people (Energy Efficiency in Transportation). Low urban density reinforces automobile dependency and promoting environmental destruction through excess land and energy consumption and air pollution.. Private vehicle (cars, pickups and motor cycles) ownership per head of population in Al-Ain has been growing rapidly in recent years. A clear difference in private vehicle ownership between citizens (high-income group) and non-citizens (most belong to the low-income group) can be seen in figure 4.

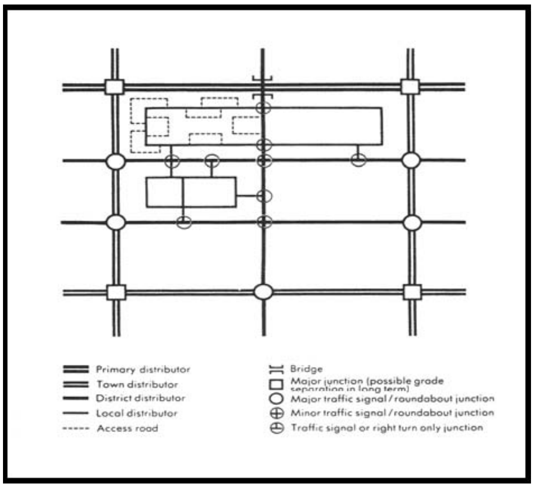

Fig. 3 Al-Ain road network (Cox, 1985)

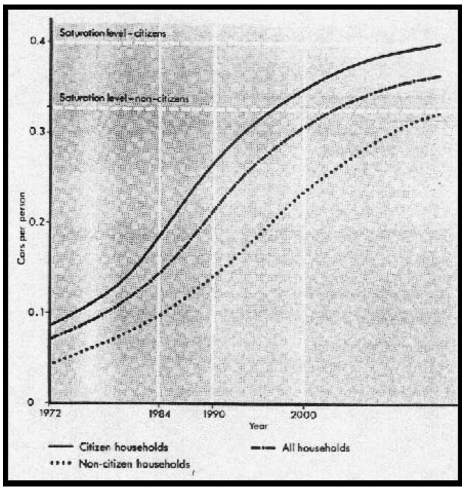

Fig.4 Al-Ain car ownership (Cox, 1985)

Energy efficiency of a transport system can be achieved through a modal Shift to environmentally more friendly transport modes consuming less energy. According to a study in 1993 by the Energy Branch of the United Nations private cars in the USA have the highest specific energy consumption in kwh/passenger-km (0.5-1.45) compared to busses (0.21-0.67) and rail (0.2-0.8), particularly for short distance transport. Intercity trains and buses are the most efficient energy consumers. Transit has the potential to reduce oil consumption. European cities, which are more transit-oriented, use much less energy per capita than U.S. cities (Black, 1995). Owning a car does not necessarily mean that owners will use their cars for all trips. Facilities falling within walking distance could be reached on foot or by bicycles and thus saving energy. Low urban densities do not allow available facilities to fall within walking distance for most of the residents they should serve.

Urban development in Al-Ain, as a case study for garden cities, has induced the spatial segregation of working, residential, shopping, service and recreational functions. Development patterns remain highly centralized in the city center, which often contains most of the local administration offices, financial houses, and warehousing activities. Plans for retail-employment decentralization in Al-Ain still do not function, probably due to the absence of catchment population sufficient to give a viable turnover. The pattern of shopping in Al-Ain is still highly centralized and the population so dispersed that it is difficult to provide economically viable small local shopping centers. This means that long traveling distances to the city center promoted by a street network with plenty of spare capacity remains the only option for most residents of remote districts.

5. Energy Efficiency Imporvement

5.1 Domestic Use

Electricity savings from air-conditioning could be achieved through the following strategies:

- Implementing building codes to reduce the cooling demand through more effective thermal insulation. This has proven success in European countries. Energy consumption in German households has been reduced through building codes from 250 kWh/m2 to 160 kWh/m2 in 1984 to 100 kWh/m2 in 1995. In Sweden it was reduced to 70 kWh/m2 to reach the range of a low energy house. Published research work showed that energy consumed for cooling in a two-Storey residential building in Al-Ain City, UAE, is much higher than buildings in Europe and estimated as 186 kWh/m2. (AboulNaga, 1998)
- Careful planning of residential building aiming at reducing exposure to outer climate. This is difficult to implement on single storey buildings and require an increase in urban density.
- Using high-efficiency central air conditioning units for new construction. This is difficult to implement on detached and single-storey buildings and require an increase in urban density and the use of more multi-storey buildings.

5.2. Street Lighting

Vertical expansion of Al-Ain city would allow investing resources in lighting available local distributors and access roads instead of expanding the infrastructure beyond the current city boundaries. That is an increase in the quality of life without increasing the per capita energy consumption.

5.3. Water Consumption

Reused water from the domestic and trade sector represents 70% of the water used for landscaping and the remaining 30% come from underground water. This means that the current population size on a unit area (density) does not produce enough reused water for landscaping on the same unit area. A balanced ratio between population and landscaping on a unit area requires raising the current density. The population density increase (persons/hectare) will help protecting the existing plant cover against desertification. Further horizontal expansion with the current level of landscaping will be difficult to sustain. The forecast decrease in non-citizen population size will leave large areas of landscape with less water resource to be reused.

5.4. Transportation

Energy conservation in transportation is possible through careful city planning. Two basic strategies are available to the transport planner for achieving higher energy efficiency of a transport system: (a) Reduction of the transport demand through an integrated land use/transportation planning, (b) Modal shift from less to more environmental friendly transport modes through economic and technical penalizing the car use as well as upgrading alternative transport system.

One promising instrument for reducing car travel is the coordination of land use/infrastructure planning and redistributing densities and functions according to decentralization theory so that each area becomes self sufficient (services and daily needs). Development patterns in Al-Ain based on spatial segregation of working, residential, shopping, service and recreational functions with highly centralized local administration offices, financial houses, and warehousing activities in the city center should be reversed. With the continued expansion of Al-Ain city at very low densities, there is increasing pressure for decentralization. This could be achieved through: 1) Decentralize retail-employment facilities to district centers, 2) Provide for limited shopping at local level. Retail facilities should be accessible to customers by their preferred mode of transport including transit, located in centers near to similar or complementary shops, located close to residential areas, and should concentrate shops within walking distance together with complementary community facilities. Raising urban density would help implementing plans for decentralization of retail facilities and thus increasing energy efficiency.

For transit to be attractive it should fulfill its objectives which are: (1) to provide transportation that is reliable, comfortable, clean, safe, fast and reasonably priced; (2) to provide transportation that is energy efficient and cost effective; and, (3) to decongest traffic along its route. Although the high-income group in Al-Ain will still find the service offered by a public transport system unatractive, the low-income group of non-citizens could create the demand required for a transit system to function. But the obstacle is that the current low urban densities make economical operation of the proposed transit system a difficult task, because scattered trip ends are virtually impossible to serve.

6. Utilizing Solar Energy

The ecological necessity of using solar energy comes from the fact that is becoming clear that the climatic system is being threatened through carbon dioxide emitted when fossil fuels are burnt to give out their energy. Although the potentials of utilizing solar energy in the UAE are very high, no attempts have been made to utilize it. This high potential is mainly due to the narrow seasonal variation of global solar radiation from winter to summer which varies between 5.0-8.3 kwh/m2/day, a narrow range if compared to the global solar radiation in Germany 0.5-5.0 kwh/m2/day. The most predominant characteristic of the electricity consumption curve in Al-Ain is the seasonal variation (figure 5). The degree of variation means that power capacity required to meet peak summer loads is not needed for the season from November through April when the large air-conditioning loads are not required. The main advantage of using solar energy for cooling in the hot arid regions, contrary to other colder climates, is that the daily and seasonal energy demand cycles match the daily and seasonal solar radiation cycle. This means that energy storage problems experienced in colder climates could be eliminated.

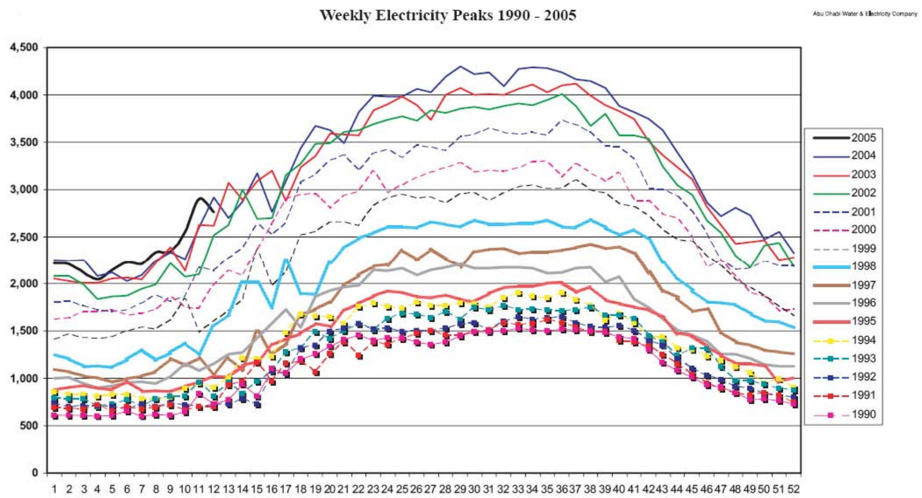

Fig.5 Weekly electricity peaks in the period from 1990 to 2005

Solar energy in Al-Ain can be utilized to cover part of the energy demand in the following sectors:

- Air conditioning using passive or active cooling systems.
- Street lighting using Photovoltaic
- Desalination of water for domestic use and landscaping

Utilization of solar energy in Al-Ain can follow a centralized or a decentralized approach. The principle of decentralized solar energy utilization is the uniform distribution of solar radiation, the decentralized energy conversion and its decentralized energy use. This means a further energy distribution system is not necessary thus reducing the infrastructure system. In Europe many solar settlements were built with detached or row houses each equipped with 20m2 PV panels (2kW) producing 1400-1500 kWh yearly and thus covering about 50% of the household needs. Experiments on zero-energy houses were also conducted. The energy-autarky solar house by the "Fraunhofer Geselschaft" in Freiburg was built to demonstrate that in Germany with help of solar energy the energy needs of a house could be covered (Stahl etal, 1994). The high solar radiation over Al-Ain and the vast areas of desert land around the city suggests an attempt to utilize it through a PV solar farm or a thermal solar power plant at the borders of the city.

7. Conclusion

In Al-Ain City, there has been a striking shift from the traditional Arab pattern of life to a more western way of living. The number of Al-Ain population has tripled in the last twenty years from 142.000 in 1985 up to about 421000 in 2005. Urban development has followed a policy restricting high and medium urban density and promoting horizontal expansion and intensive landscaping. As a result, there has been a striking shift in the energy consumption rates in Al-Ain city. This paper identified areas for improving energy efficiency of Al-Ain city, such as domestic use, street lighting, water desalination and transportation have been discussed.

Energy consumed for air conditioning is the main area where consumption reduction can be achieved. Taking the Air-condition efficiency, mutual shadowing and exposure to outer climate as evaluation criteria, it is clear that urban forms with higher density multi-storey houses and Row houses consume less energy for air-conditioning than lower density urban forms like detached single-storey units.

The proposed population density increase (persons/hectare) will help reduce energy used in transportation, street lighting, and water desalination for landscape purposes. It will also help in protecting the existing plant cover against desertification by increasing the amount of water to be reused in relation to the green area around. Further horizontal expansion with the current level of landscaping will be difficult to sustain. Any future decrease in non-citizen population size will leave large areas of landscape with less water resource to be reused.

To increase energy efficiency, future developments in Al-Ain city should be vertical within the current boundaries without loosing the available efficient road network and pleasant landscaping. It is also recommended to avoid creating new segregated neighborhoods before utilizing the unused areas within the urban boundaries of the city. A mixed use instead of segregated use for these areas with the use of advanced solar energy systems will help improve the sustainability of Al-Ain as a garden city.

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ENERGY AND BIOCLIMATIC EFFICIENCY OF URBAN MORPHOLOGIES:

A COMPARATIVE ANALYSIS OF ASIAN AND EUROPEAN CITIES

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Abstract

Cities and buildings are key energy users. The fundamental energy pattern of a city consists of various buildings and spaces. This urban morphology interacts with buildings, with people behaviour and local climate. The growth in energy consumption in cities simple laws derived from physics and thermodynamics. A sustainable building is an integrated entity: structurally, functionally and environmentally with the city through the city morphology. The proposed comprehensive analysis takes into account all the energy processes that happen in and around buildings in order to optimize bioclimatic design and new energies at building, neighbourhood and city scale.

By using the passive zone concept and a set of indicators, such as density, roughness, porosity, sinuosity, occlusivity, contiguity, solar admittance and mineralization, and by using an environmental oriented conceptual model of urban fabric, the analysis will connect architectonics, urban planning, energy flows, climate, and human patterns of behaviour. Comparing different urban morphologies, this cross-regional study will sample such six cities as Beijing, Shanghai, Paris, London, Toulouse and Berlin and make comparison and contrast of their development in bioclimatic and energy efficiency. What we will draw is an understanding of how the city morphology governs the patterns of energy flow in the urban texture, affects local climate and what the most suitable morphologies for renewable energies are at building and city scale.

Keywords: Energy, Urban morphology, Climate, Passive zone

1. Introduction

As noted by the Intergovernmental Panel on Climate Change [1] "the balance of evidence, from changes in global mean surface air temperature and from changes in geographical, seasonal and vertical patterns of atmospheric temperature, suggests a discernible human influence on global climate". Home of interaction between people and buildings, the city is where human civilization changes patterns of living and of energy consumption. Its development challenges the future of our human society. UK data show that the energy requirements for buildings in the domestic and non-domestic sector exceed those for transport and industrial processes [2,3]. In urbanized countries like UK buildings represent half of energy consumption; and with transportation, cities represent more than three quarters or energy consumption.

The carrying capacity of the Earth, that is to say the quantity of biosphere available to support human life is only an average of 1.7 ha per human being. The struggle against Global Warming and fair Earth share (an equitable share of the biosphere) implies a radical transformation of urbanism. Rural people in developing countries use less than 0.8 ha of biosphere per inhabitant. Urban dwellers use between 12 ha (USA) and 6 ha (Europe, Japan). The massive transition from rural to urban (which is a key feature of South east Asian societies) is the main reason of the ecological footprint overshoot, i.e. the fact that mankind uses 1.4 planets Earth now and will need at least 3 planets Earth by 2020. This urban transition is the most important driver of Climate Change.

A massive social, economic, cultural and political transformation takes place as Southern Asian countries develop vast mega-urban regions. The future of this populated region is an urban one, and the majority of its people will inhabit cities by 2020. Asia as a continent has overshoot its ecological carrying capacity as early as 1970, that is to say 15 years before mankind as a whole has overshoot the carrying capacity of planet Earth in 1985. The ecological footprint of Asia is already 1.75 times its carrying capacity. If the creation of mega urban regions in Manila, Jakarta, Bangkok, some of them 100 km radius, leads to a Los Angeles type urbanization of South east Asia, the subcontinent would need 10 to 12 times its carrying capacity. By following globally a Los Angeles urban pattern of development, Asia would need by itself the biosphere of several planets, with at least one planet for China alone with levels of efficiency similar to those of Canada and 3 planets with current Chinese levels of efficiency (see below the comparative analysis of Shanghai and Paris).

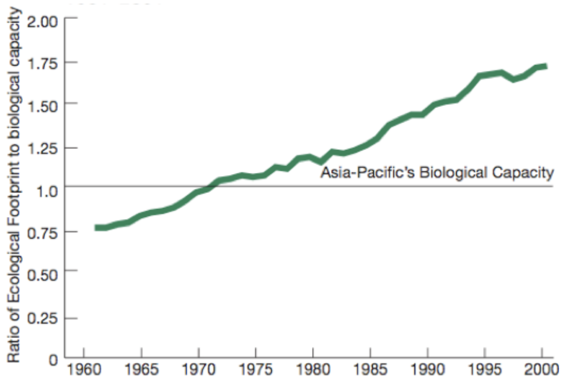

Fig. 1. Asia-pacific ecological footprint, 1961-2000

There is a specificity of the “Asian urban experience” [4]. Asian countries share a lot in common (high speed urbanization). Through comparative studies between Asian and European urban morphologies, in particular between Shanghai and Paris, we will better understand this specificity and contribute to develop a specific Asian way of sustainable development. Shanghai ecological footprint per inhabitant is already higher than Paris ecological footprint (6 ha per inhabitant in Shanghai against 5.58 in Paris) while energy consumption per inhabitant is almost double in Shanghai than in Paris (2.16 kilotons equivalent oil/year in Shanghai against 1.28 in Paris). This is partly due to the structure of economic activity (primary industry in Shanghai and services economy in Paris) but also to the huge differences in urban morphologies (urban sprawl in Shanghai compared to a density 6 times higher in the centre of Paris than in Shanghai). As the GDP per inhabitant is 8 times lower in Shanghai than in Paris, the result is an ecological efficiency 8 times lower in Shanghai than in Paris and energy efficiency 16 times lower in Shanghai than in Paris. In other terms, it requires 8 times more biological resources and 16 times more energy to produce a unit of GDP in Shanghai than in Paris. In this huge efficiency difference, urban morphology at various scales accounts for a big part. In 1980, the inhabitants of highly dense Hong Kong were consuming 50 times less energy than Australians for comparable standards of living.

The urban morphology interacts with buildings, with people behavior and with the local climate. An energy efficient urbanism associated with bioclimatic architecture, new systems and fundamental changes in people behavior and patterns of consumption can lead to a division of energy consumption and associated Greenhouse Gas Emissions by a factor 20. This is the goal to reach if we want to achieve a fair Earth share while using one planet only and limiting climate change. Sustainable construction movement concentrates mainly on the improvement of building systems (factor 2) and not enough on people behavior (factor2) and on urban and architectural bioclimatic and energy efficient forms (factor 5). Working on all the factors, and on urban design, and not only on systems, we can reach a factor 20. So, in a planet where 1 billion people are urbanized every 10 years, which represents a factor 100 in the intensity of urbanization, the urban planners and architects must take the leadership in the fight against Global Warming.

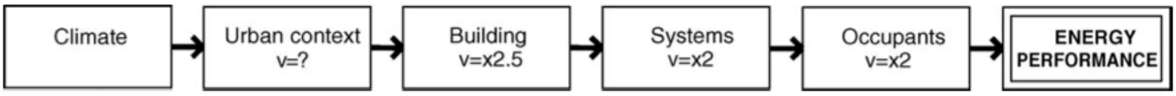

Fig. 2. Factors that affect the energy performance of cities according to Baker and Steemers

2. Morphology study

The growth in energy consumption in cities obeys simple laws derived from physics and thermodynamics. At present, cities are thermodynamics machines, which transform solar radiation into heat. They transform low entropy solar energy into high entropy heat. They must become positive energy cities and transform solar radiation into energy.

2.1 Problems considered

Cities are simultaneously human systems and complex porous physical surfaces that exist on several scales at the same time. They associate a high level of variability and a more or less organised subjacent structure.

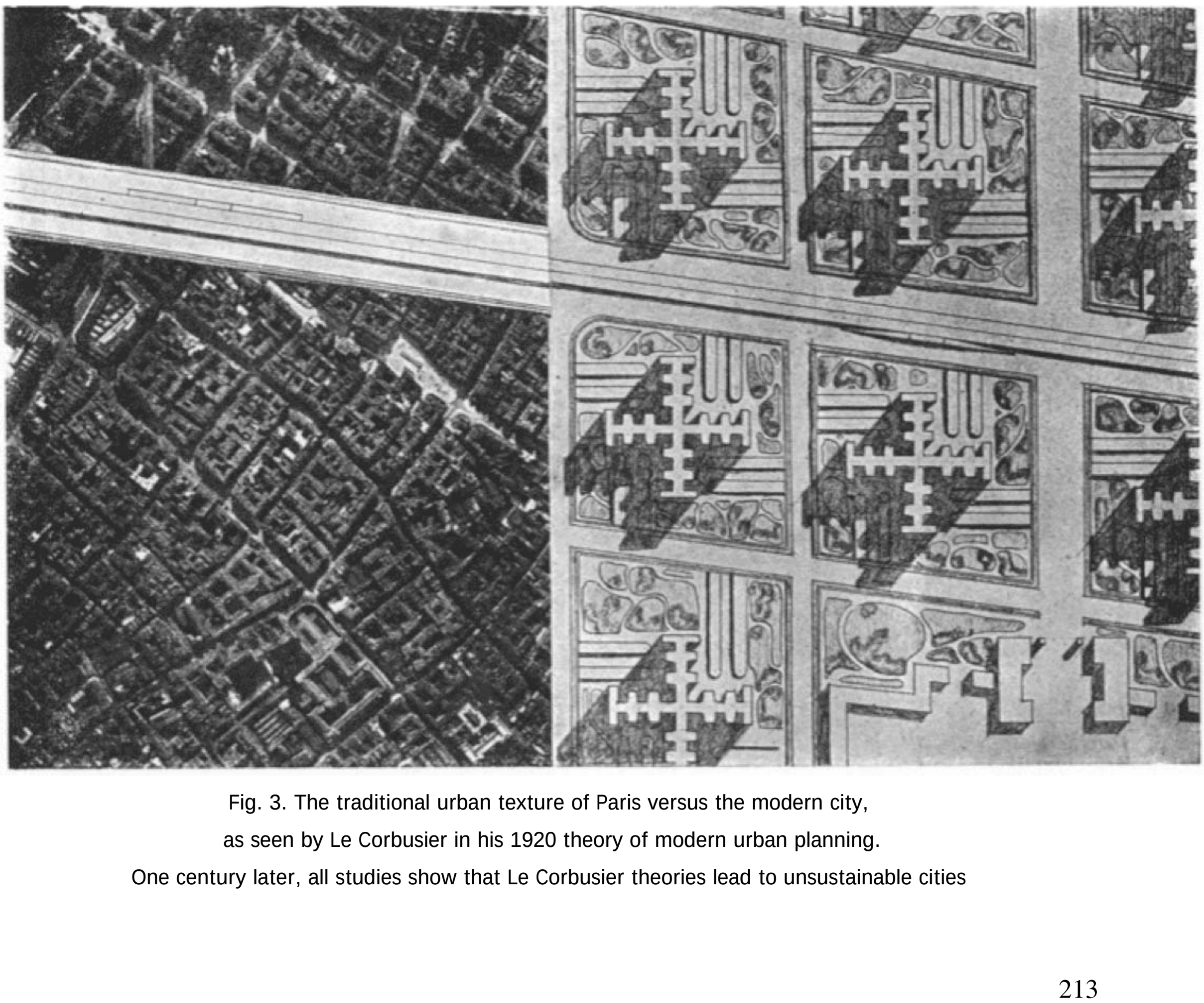

Fig. 3. The traditional urban texture of Paris versus the modern city,
as seen by Le Corbusier in his 1920 theory of modern urban planning.
One century later, all studies show that Le Corbusier theories lead to unsustainable cities

A survey carried out on 32 cities across the world by P. Newman and J. Ken worthy on the effects of density on energy consumption linked to transport, revealed a strong relationship between the transport of persons and population density. In 1980, around twice as much fuel was consumed for transport in American cities than in Australian cities, four times more than in European cities and six times more than in the considered Asian cities[1]. In 25 years, the situation has dramatically changed in South East Asia with the creation of mega-urban regions and an increased dependence on automobile in South East Asia. Newman & Kenworthy (1989) defined four criteria representing the automobile dependency of cities: the intensity of the use of space, the move towards non-automobile modes of transport, the constraint represented by traffic levels, and the centrality and performance of public transport systems. The relationship discovered by Newman & Kenworthy has remained steady and even increased over the last two decades. In Europe, according to Julien Allaire (Allaire 2006), there has been a tendency over time for energy consumption to increase in parallel with a reduction of density levels.

However, studies on the relations between density and energy remain too general to be able to define operational action criteria for existing cities. Global studies do not analyse the various morphological components of the cities, the impact of the grid, the fragmentation of the distribution of activities on the generation of mobility, or the impact of size, hierarchy, accessibility and connectivity of movement networks. The city is seen as a homogenous entity and the complex linking of factors resulting in the global relationship between energy and density is not analysed. Cities are both built volumes (solids) and empty spaces. The analysis of the discrete spaces forming the solids (being the buildings) has undergone considerable developments in terms of their bioclimatic and energetic aspects. However, far less work has been devoted to the overall texture of the city (grain size, porosity, grid density, connections between empty spaces, major and minor breaks). To attain operational results, it has become necessary to refine and quantify the morphological description of the various types of density in terms of their impact on mobility and the microclimate. The urban texture offers various degrees of insulation from the natural climate. While the urban microclimate affects external spaces it also needs to have an effect on the internal climate of buildings to create passive bioclimatic architectures able to reduce energy intensity and the carbon footprint. For example, the possibilities of using natural ventilation depend on the morphological properties of the buildings as well as the climatic conditions next to the buildings, such as air movement and atmospheric and noise pollution. These conditions depend on the urban morphology. It has now become necessary to study the link between modes of travel, urban density and energy consumption through the interaction between transport systems, activity morphologies and grids, and to specify the role of speed as a pivotal variable in urban organisation.

2.2 Cases analysed

The comparative analysis of Shanghai and Paris that we envisage carrying out and that we will further extend to mega urban regions of South east Asia will reveal how population and activity density gradients and profiles can be used as variables for urban interactions and the way that these now affect the possibilities of modal transfers towards other modes of transport with reduced energy intensity and a lower carbon footprint. In order to form a database that can help identify the underlying interaction mechanism between the urban morphology and the energy patterns, a number of cases were constructed by studying the GIS of different cities one square kilometre morphology.

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[1] This relationship between energy consumption and the population density of the city was confirmed by subsequent studies: P.Naess (1996) concerning Scandinavian cities, V. Fouchier (1997) for the Ile- de-France, ECOTEC (1993) for Great Britain, etc.

Fig. 4. Paris (lower left) and Shanghai morphologies at the same scale

2.3 Methodology

The analysis include the following stages:

(i). The construction of a typology of urban forms and the intensity of the connection of these urban forms on the global scale of Shanghai and the various density modes.

The construction of this typology will result in the calculation of quantitative parameters. The parameters will describe morphological types:

- On the one hand, through their physical characteristics: form of constituent units, grids, sizes, degree of regularity, modes of assembly, degrees of connectivity,
- On the other hand, their economic and social characteristics: levels of mixed uses, intensity of activities, density of occupation and uses, size of the use grid, distribution of activities, density (number of inhabitants per hectare).

This morphological and typological analysis will be carried out on several scales, from the agglomeration to the district and the plot, and concern the urban fabrics of Geneva and Paris.

(ii) Evaluation of energy consumption and greenhouse gas emissions of the various urban fabric typologies in Paris and Shanghai.

The important variation of the microscopic morphology of cities has direct effects on the disparity of the outdoor climates as well as indoor climates: wide range of dry air temperature, of wind speed, of the heat radiation exchanged with the sky voltage and of the natural lighting. Thus, as it is difficult to describe and simulate the interactions between urban morphology and climate conditions, this paper is proposing a simplified spatial modelling of urban morphology complexity resulting in defining a set of environmental indicators. The DEM (Digital Elevation Model) is a compact way of storing urban 3D information using a 2D matrix of elevation values; each pixel represents building height and can be displayed in shades of grey as a digital image. The analysis of DEMs with image processing techniques has already proven to be an affective way of storing and handling urban 3D information, and being very conducive to a number of urban analyses [6,21–23].

Our ongoing project with Tongji University in Shanghai is structured into the following main tasks:

• The proposition of a set of innovative environmental indicators typical of microclimate conditions in urban spaces, through a large bibliographic survey, and experts' analysis,

• The validation of a set of indicators, such as density, roughness, porosity, sinuosity, exclusivity, compacity, contiguity, solar admittance and mineralization, through the environmental survey,

• An implementation of the final set of indicators in a comparative GIS analysis of Shanghai and Paris, using an environmental oriented conceptual model of urban fabric.

2.4 Urban morphology parameters

Computer-based analysis techniques and methodologies will be applied to various datasets, including digitized buildings, land use/land cover, and other essential datasets for the Shanghai and Paris. This effort will use a database of urban morphology parameters:

• Mean and standard deviation of building height

• Mean and standard deviation of vegetation height

• Building height histograms

• Area-weighted mean building height

• Area-weighted mean vegetation height

• Surface area of walls

• Plan area fraction as a function of height above the ground surface

• Frontal area index as a function of height above the ground surface

• Height-to width ratio

• Sky view factor

• Roughness length

• Displacement height

• Surface fraction of vegetation, roads, and rooftops

• Mean orientation of streets

3. Energy study

3.1 Modelling the passive zone concept

According to C. Ratti et al. (2005[7]), the surface-to-volume ratio is an interesting descriptor of urban texture. It defines the amount of exposed building envelope per unit volume, and can be used in a number of different applications. Its relevance to the energy consumption of buildings, however, must be considered carefully. Minimizing heat losses during the winter requires minimization of the surface-to-volume ratio; but this implies a reduction of the building envelope exposed to the outside environment, thus reducing the availability of daylight and sunlight and increasing energy consumption for artificial lighting and natural ventilation.

In fact, the main energy distinction to be drawn within buildings is a function of the exposure to the outside environment. This concept is made explicit with the definition of passive and non-passive zones, which quantify the potential of each part of a building to use daylight, sunlight and natural ventilation. By a simple rule of thumb, based on empirical observations, all perimeter parts of buildings lying within 6 m of the facade, or twice the ceiling height, are classified passive, while all the other zones are considered non-passive.

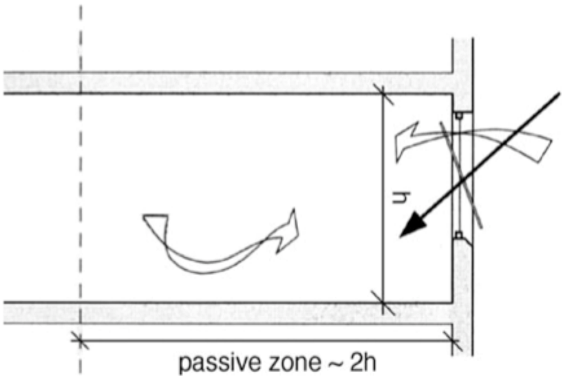

Fig. 5. Parts of a building, which can be naturally lit and ventilated, are called 'passive zones'. By a simple rule of thumb given by the LT method, they extend approximately for 6 m (or twice the ceiling height) from the facade. Image adapted from Baker and Steemers [2].

According to C. Ratti et al. (2005[7]), the surface-to-volume ratio, while being an interesting morphological parameter, does not describe the total energy consumption in urban areas. A better indicator seems to be the ratio of passive to non-passive zones, although accurate energy consumption values can only be derived from an integrated simulation such as LT (where LT stands for lighting and thermal). The proportion of passive to non-passive areas in buildings provides an estimate of the potential to implement passive and low energy techniques. It should be noted, however, that this is only a potential: the perimeter zones of buildings can still be wastefully air-conditioned or artificially lit. In some cases, passive zones can consume more energy than non-passive zones, especially when excessive glazing ratios and untreated facades make them particularly vulnerable to overheating during the summer and to heat losses during the winter.

Fig. 6. London (left), Toulouse (upper right) and Berlin (lower right) urban morphologies at the same scale. Three examples of European urban textures (Victorian, medieval and modern). The most sustainable is the medieval one.

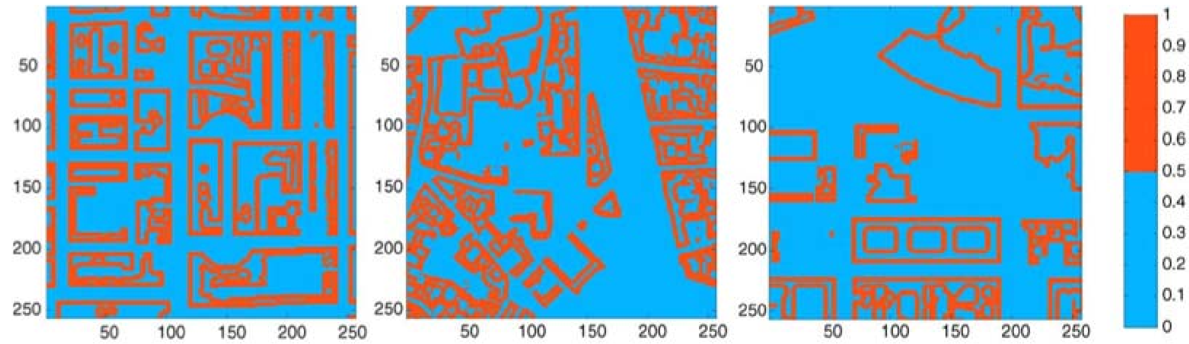

Fig. 7. Passive zones (within 6 m from the facade) in London, Toulouse and Berlin, second floor.
The image was obtained by thresholding the Euclidian distance transform (from C. Ratti et al. 2005[7]).

	London	Toulouse	Berlin
Total passive volume [%]	77	84	61

Fig. 8. Data for London, Toulouse and Berlin(from C. Ratti et al. 2005[7]).

According to C. Ratti et al. (2005[7]) two conflicting exigencies for energy conservation appear: reducing the building envelope, which is beneficial to heat losses, and increasing it, which is favourable to the availability of daylight and natural ventilation. Which of the two phenomena prevails in the global budget of buildings? The above question is not likely to have an absolute answer. At very high latitudes, where solar gains are scarce and temperatures harsh all year long, heat conservation strategies might well be prevalent over the collection of daylight and natural ventilation. In these cases energy efficient buildings should probably minimize the external envelope, while at low latitudes they might try to maximize them. More generally, the relative importance of the two phenomena (losing heat and receiving beneficial gains through the facades) will be climate-dependent and differ between, say, Beijing and Shanghai. For a given climate, it can only be assessed by a comprehensive analysis, which takes into account all the energy processes that happen in buildings.

3.2 Coupling of the Digital elevation model analysis with the light and thermal simulation tools

The analysis of DEMs (Digital Elevation models) will be used to explore the effects of urban texture on building energy consumption in various areas of Shanghai. DEM is an effective support to derive morphological urban parameters quickly. Some of these will then be passed to a simulation tool (LT), in order to get energy consumption figures. CSTB's LT (where LT stands for lighting and thermal) models are well suited to simulate energy consumption at the urban scale, as they capture the principal energy flows of buildings with reasonable accuracy without necessitating the computational demands of full dynamic simulation. Nevertheless, the LT models requires numerous inputs to perform energy consumption calculations, including building U-values, interior and exterior reflectances, illuminance data, heating efficiency and setpoint, etc.

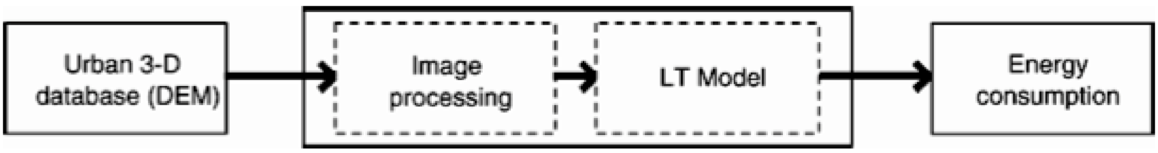

Fig. 8. The image processing/LT interface and data exchange (from C. Ratti et al. 2005[7]).

4. Conclusions

Studying multiple cities at different periods of time, we will make a comprehensive comparison and contrast of city morphology efficiency between regional cultures in the west (Paris, Berlin, London, Toulouse) and in the east (Shanghai, Beijing, Guangzhou, Shenzhen , Hong Kong), between periods of time of the rapid growth (Shanghai and Beijing) and the steady growth (Paris, Berlin, London and Toulouse). A number of results will emerge on the relationship between Shanghai city texture and energy consumption. The morphology of Shanghai will be characterized and quantified in considerable detail primarily for simulation, and analyses, but this can also be used for improved urban planning, and other urban related activities. A new integrated computational analysis for the prediction, evaluation and optimization of Shanghai morphologies will be developed. This will be applied to several case study sites to develop new knowledge regarding optimal means for urban growth and change, based on a scientifically rigorous interpretation of sustainability. The proposed approach allows a simplified diagnosis of urban sustainability, useful for comparing the bioclimatic and energy efficiency of different urban morphologies, useful for design and planning, but also monitoring of the long term urban planning. This cross-regional study therefore, is an attempt to explore the general laws that govern energy flows and climate in cities in many distinct ways. It is also an attempt to maintain in this global world the cultural distinctiveness in city evolution and architectural design. In a second step, we plan to extend it to Vietnam and to the mega urban regions of South East Asia.

Acknowledgements

The results and methodologies reported in this paper are part of a broader international research effort on the characterization of urban texture and its analysis with digital techniques. We are indebted to many people and in particular to Cambridge University and to the Massachusetts Institute of Technology for their extremely stimulating research papers which have been the main source for extending this methodology to Asian cities. Of course, any shortcomings are our responsibility.

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THERMOSTATS, CLIMATICALLY RESPONSIVE CLOTHING AND REDUCING BUILDINGS' GREENHOUSE GAS EMISSIONS

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Abstract

There have been increasing reliance on mechanical heating, ventilation and air-conditioning (HVAC) systems in order to achieve thermal comfort in office buildings. The use of universal standards for thermal comfort adopted in air-conditioned spaces often results in a large disparity between mean daily external summer temperatures and temperatures experienced indoors. The extensive overuse of air-conditioning in warm climates not only isolates us from the vagaries of the external environment, but is generally dependent on non-renewable energy.

Research conducted at the Queensland University of Technology (QUT) involved altering the thermostat set-points to two or three degrees above the normal summer setting in two air-conditioned buildings during the subtropical summer. It was expected that this minor temperature change would reduce energy usage of air-conditioned buildings and in turn, reduce greenhouse gas emissions. The aim of this project was to measure the social, economic and environmental value of a different approach to thermal comfort, facilities management, corporate culture and acceptance of the benign subtropical climate.

Surveys were administered periodically to workers in the buildings to assess their comfort levels during a four month period. Internal and external temperature, humidity and air movement were measured. Data collected was used to compare weather data and energy use of the buildings from the same period in the previous year; and also to analyse users' physiological and psychological responses, including the acceptance of appropriate climate responsive clothing as acceptable business attire.

This paper presents the findings of the research, including 'lessons learned' and a set of strategies that may be used by facilities managers who adopt a similar initiative, to ensure that users of buildings are positively engaged and consistent protocols are communicated to all stakeholders.

Keywords: thermal comfort; air conditioning; non-renewable energy; corporate culture; climate appropriate clothing;

1. Introduction

This research project set out to confirm whether a simple "no capital cost" approach to reducing a building's energy consumption such as the adjustment of AC set-points by one or two degrees can effect significant change in reducing greenhouse gas emissions (GHGE). Together with this technical adjustment, we monitored the occupants' responses and documented the findings of both the energy usage and survey results. From these findings and review of current literature, we share insights from our research in that we need to recognise that holistic and multi-disciplinary approaches to solutions are required to address both the causes and effects of climate change. [1]

The multi-disciplinary project team encompassing the disciplines of engineering and humanities, as well as Facilities Management (FM) staff, undertook the following tasks:

i) Resource Usage. Monitoring and measuring ventilation and cooling cycles, and electricity use during the study period.
ii) Analysis of the data for comparison with previous summer use, including weather data for each period.
iii) Determining savings in kWh, greenhouse gas emissions and actual costs.
iv) Analysis of dollar savings in comparison with total building electricity costs with a view to the potential to fund further resource efficient energy management activities on QUT campuses.
v) Devising and implementing promotional and communication strategies and materials to encourage active participation of stakeholders.
vi) Participant Response and Survey Analysis. Conducting surveys to analyse and evaluate building users' responses, both physiological and psychological.
vii) Review of Current Research. Review of current literature to identify research on the effects of reducing indoor temperature on energy usage and how occupants respond to such an action.

2. Project Setting and Background

The Queensland University of Technology (QUT) is located in Brisbane and operates 4 campuses with over 3000 staff and 38,000 students. Brisbane has a subtropical climate characterized by warm and humid summers with mild and dry winters.[2] The research was carried out at QUT's main campus at Gardens Point in Brisbane's CBD and predominantly involved the staff and buildings of the Faculty of Built Environment and Engineering (BEE). Two buildings used for the alteration of the thermostat set points were selected on the basis of their use (predominantly BEE staff, with some general administration staff), shared AC plant (they are both fully conditioned and use the same chiller plant) and location (adjacent to each other). Conditions of the buildings were varied – Building D was commissioned in 2000 and the Building A was constructed circa 1919 and has been retrofitted with air-conditioning.

The spaces included a combination of open plan workstations, individual offices, lecture rooms, meeting rooms, photocopying / resource centre and a public cashier/student payment area. Participant surveys were sent out to all staff in the BEE Faculty on GP campus every two weeks. Although the physical environment would be altered in only two buildings, all staff of QUT's BEE Faculty were invited to participate, offering a "control group" of staff occupying a further four buildings.

The set-point for buildings D and A was raised from 23^{o}C to 25^{o}C on 11th December 2006, one week after notifying staff that the temperature would be changed. Building D remained on this set point until the first week in April. Building A was changed to 24^{o}C on 24 January 2007 due to a high number of combined formal and informal complaints from staff on levels 2 and 3.

3. Measuring Resource Usage

In lieu of actual metered data (because separate metering was not currently available), QUT FM contracted Multitech Solutions (consulting engineers) to undertake a series of energy simulations based

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[1] see full report on our website http://www.subtropicaldesign.bee.qut.edu.au/

[2] S V Szokolay (1983) gives mean maximum temperature as 25.4°C and mean minimum as 16.0°C in *Climatic Data and its use in Design.* Canberra: RAIA. See also Bureau of Meteorology website for climatic information at http://www.bom.gov.au/climate/averages/tables/cw_040214_All.shtml

on D block, for three common occupancy types and temperature set points, to determine energy, water and greenhouse gas emissions from each variation. The aim was "to produce energy and resource usage results that would be applicable to buildings at the University, not to simulate actual energy consumption of existing buildings."[3]

3.1 *Weather Data Collation and Analysis.* Long term climate data for Brisbane was compared with actual weather data for the period of the project to determine if this summer was significantly hotter or colder than long term averages. This data was correlated to the measured temperature and relative humidity data collected from 5 offices in the affected buildings. Further information and associated tables and graphs can be accessed in our full report on our website at http://www.subtropicaldesign.bee.qut.edu.au/

3.2 *Savings Analysis.* Data from each of the modelled scenarios was used to determine, for each occupancy:

i) the total end use electricity per year (in MWh)
ii) the primary energy use (electricity sector efficiency of .32)
iii) greenhouse gas emissions (assuming 1.05 tonnes per MWh)
iv) water usage (litres per day, then litres per year, based on occupancy assumptions)
v) annual costs (assuming 8c/kWh)
vi) chiller plant capacity (size of plant needed to supply the required cooling)

These results are shown in Table 1. It is clear to see that, for all occupancy types, raising the summer thermostat setting 2 degrees would result in savings in end use energy, associated electricity costs, primary energy, greenhouse gas emissions, water use and capital costs in the size of chiller plant required.

Table 1: Resource usage per occupancy under 3 HVAC operational scenarios

	End use Energy MWh/yr	Primary Energy MWh/yr	CO^2 emissions (tonnes/yr)	Water usage L/day	Water L/year	Electricity costs $/yr	Chiller Plant Capacity
Lecture Current	32.51	101.58	34.13	33	8125	$2,600	76
Lecture Summer	30.55	95.47	32.08	29	7150	$2,444	67
Lecture Winter	33.30	104.06	34.96	33	8125	$2,664	76
Office Current	35.86	112.05	37.65	20	4908	$2,868	46
Office Summer	33.39	104.33	35.05	18	4485	$2,671	42
Office Winter	35.78	111.80	37.56	19	4810	$2,862	45
Computer Current	133.50	417.19	140.18	50	17892	$10,680	64
Computer Summer	111.52	348.51	117.10	47	16529	$8,922	59
Computer Winter	116.44	363.88	122.26	50	17892	$9,315	64

Based on the typical occupancy usage of buildings A and D, this data was then used to calculate the savings in electricity usage, greenhouse gas emissions and costs that could be attributed to this project. This data is shown on Table 2.

Table 2: Estimated resource savings for Buildings A and D, QUT

Indicative annual savings from summer thermostat setting at 25°C			
	Block A	Block D	Combined
End Use Energy MWh / yr	13.64	51.33	64.97
Primary Energy MWh / yr	42.63	160.41	203.04
Water Use KL / yr	3.51	10.72	14.23
Greenhouse gas emissions tonnes / yr	17	61	78
Electricity costs $/yr	$1,295	$4,646	$5,941

[3] Energy Analysis for Queensland University of Technology D Block Level 1 and Lecture Theatre, Multitech Solutions, March 2007

The above indicates that there are quantifiable savings in end-use and primary energy, water use, GHGE and electricity costs that are significant enough for a building owner such as QUT, to justify further investigation into this simple method of energy savings via thermostat controls, in addition to the usual Building Management System (BMS) control strategies.

4. Current Research – Energy Usage In Commercial Building Sector

4.1 *Energy Usage*. Current research indicates that the increased need for heating and cooling of commercial buildings in urban centres is being implicated as one of the contributors to increased heat islands in cities. This, in turn, increases energy use and GHGE due to increased burning of fossil fuels.

The Australian Greenhouse Office (AGO) reports in the National Greenhouse Gas Inventory that the "commercial sector has the highest share of energy supplied as electricity and consequently the highest emissions intensity." (Dept of Env. and Heritage 2006) This picture becomes grimmer as the AGO also projects that "GHGE from the operation of commercial buildings will increase by a staggering 94% during the period 1990-2010." (Bldg. Comm. 2007) Although this scenario is in Australia, it would be similar in other developed or developing countries as well.

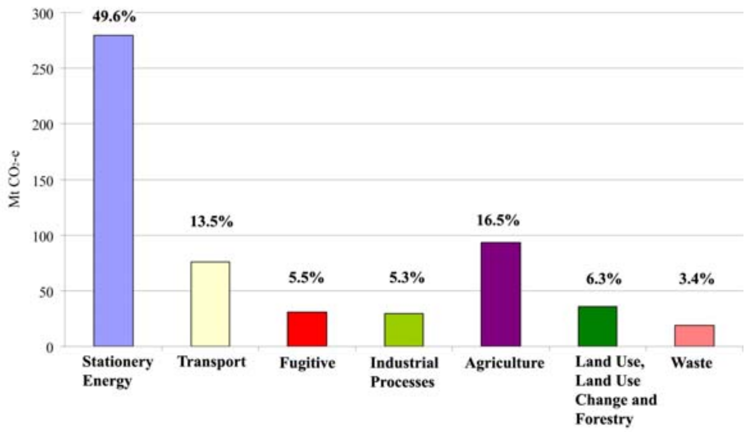

Fig.1 – C0² equivalent emissions by sector showing stationary energy as highest in 2004 in Australia (National Greenhouse Gas Inventory – Dept of Environment and Heritage & AGO, Sept 2006)

4.2 *Thermal Comfort Standards.* It has been accepted industry practice in the design of commercial or institutional buildings in Australia and many parts of the world that internal spaces need to be conditioned (heated or cooled) to between 21ºC and 24ºC. This standard of comfort is assumed as universal without regard to gender, age and level of activity; and thermal variation outside of the band is considered undesirable. However, comfort has different meanings for the mechanical engineer and for a user occupant. Thermal Comfort Standards have been derived from a purely deterministic stimulus response in laboratory settings. Recent work by de Dear, Brager and Cooper promote a more holistic approach to thermal comfort, i.e. an adaptive model of comfort which "embraces the notion that people play an instrumental role in creating their own thermal preferences." (de Dear et. al 1997) These researchers note that the ASHRAE method for defining a comfort range of acceptable temperatures is based on associating the idea of feeling neutral which ignores all contextual and cultural influences.

4.3 *Historical, Social and Cultural Influences.* Methods used to date for defining thermal comfort have placed an undue reliance on laboratory testing. This has led to a "one size fits all" method of determining air conditioning temperature and totally ignores the importance that social and cultural influences have on determining comfort level. The traditional business suit used by most male workers has become the norm in offices around the world and does not respond to local climate, thereby perpetuating a global standardization of indoor thermostat setting.

Cultures in the Middle East, for centuries, have a ritual migration within the house to spaces that are built either for the winter or summer season. This kind of connection to natural seasons seems lost to modern city living where we do not even dress for the season. Morgan and de Dear (2000) conducted a six month study of clothing behaviour of office workers in Sydney and found that "clothing insulation was constant year-round, having no correlation with outdoor temperatures." (Cole & Lorch eds. 2003)

However, countries like Japan have started to see how our cultural notion about clothing can be altered to help combat climate change. In a bid to reach its Kyoto Agreement targets, Japan has adopted a 'CoolBiz' [4] program. Under this program, all government offices were required to set the thermostat to 28°C in summer (2 – 3 degrees higher than Japan's usual practice). The program was championed by former Prime Minister Mr. Koizumi, who signalled an acceptable change of business attire through his well-known "no tie and shirtsleeves approach" which has also been adopted by cabinet ministers and other leaders of the movement. (Min. of Env., Japan 2005) A similar 12-month trial of a new parliamentary dress code is currently promoted in the Queensland Parliament in order to raise air-conditioning temperatures, thereby saving water and energy. (Hon. P. Beattie 2007)

4.4 *Social Influence:* Studies so far have pointed to the fact that social conditioning leads to physiological conditioning. Our expectations of a much cooler or warmer indoor environment in summer / winter respectively, have evolved to the point that our acceptable range has significantly narrowed.

Fishman and Pimberts' (1982) studies into the difference in thermal responses of occupants of air-conditioned and naturally ventilated offices, as cited in de Dear's 1997 report, revealed that people in air-conditioned offices "were less tolerant of higher temperatures and expected homogeneity in their thermal environment." De Dear also cites Rohles' (1977) studies which found that "Michigan subjects were more tolerant of high indoor summer temperatures (32ºC) than Texan subjects." This supports the notion that social conditioning could lead to physiological conditioning in that the "Texans took summer air-conditioning for granted and came to expect or even demand cooler temperatures" than their counterparts in cooler areas of the country. (de Dear et. al 1997, pp.25-26)

4.5 *Historical:* Brager and de Dear traced the formulation of American people's attitudes to air-conditioning back to marketing in the 1950's where increased post-war demand for air-conditioners could have been influenced by advertisements that linked air-conditioning to increased social status. Women whose homes were air-conditioned were portrayed as elegant and free from the toil of housework. People wanting a clean and healthy environment were targeted as providers of homes for happy families. The advertised images gave people "total mastery of the environment" so that "homeowners had the ability to maintain an indoor environment of constancy, independent of the natural diurnal or seasonal fluctuations outdoors" Ironically, pictures of air-conditioners beside elegant women sitting in the great outdoors overlooking mountains and the setting sun actually do not achieve what they claim to do, that is, have a more intimate relationship with nature. (Cole & Lorch eds. 2003)

4.6 *Cultural:* Cultural perceptions also influence our thermal preferences. Stern (1992) as cited by Brager and de Dear, found evidence from various studies to show that "comfort bands do vary across cultural groups." (Cole & Lorch eds. 2003) They also point out that the Japanese view artificial heating and cooling more in terms of heating/cooling the person as opposed to the American view of heating/cooling a space. The Japanese are perceived to readily adopt 'task ambient' air-conditioning systems with more individual control as this seems a logical progression from the traditional Japanese residential heating system 'kotatsu' which is a person heater placed under the dining table.

The rapid increase of a global style of architecture for our commercial buildings with its inherent large internal air-conditioning load has not only resulted in an increased energy use but has succeeded in distancing ourselves from the 'natural' world and the culture around us. Ken Yeang believes that "by designing closer to climate, you are designing closer to culture" [5] Our loss of regional distinctiveness and cultural diversity in buildings has commonly been blamed to our dulling of a sense of place or a sense of climate as well. One of the various possible reasons could be the dulling of our senses by air-conditioned spaces which offer thermal monotony with no opportunity to respond to the changing climate outside.

Real estate agents commonly consider air-conditioning as added property value and whether this promotes or reflects our cultural values may still be a debate – however, the increased use of energy is still present. Guy and Shove as cited by Chappells informs us that "air-conditioning in UK is becoming common not necessarily for comfort but constitutes a signifier of 'quality' and prestige and part of

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[4] There is also a WarmBiz program that encourages heavier clothing in winter and building climate control systems are seasonally adjusted.

[5] Informal discussion at RAIA's continuing professional development seminar "Retrofitting using bioclimatic principles : looking for value adding" held in Brisbane 8 May, 2007

property value." (Chappells and Shove 2005). This attitude seems to be reflected in the South-east Queensland real estate market, with many developers believing that they will be unable to sell or rent properties that are not air-conditioned.

5. LOCAL versus CENTRAL CONTROL Over Indoor Climate Conditions

Studies in thermal comfort and office productivity show that users' perception of personal control over their local indoor climate conditions affects their feeling of well-being, level of thermal comfort and productivity level. They know they cannot control the weather but perceive that they should be able to control indoor temperature as it is artificially produced or man-made.

5.1 *Personal Control.* Rowe (1995) in de Dear et al concluded from his studies that "people have a wider tolerance of variations in indoor thermal conditions if they can exert some control over them, and that a considerably higher level of satisfaction will be reached if occupants have means of controlling the upper and lower temperature limits." (de Dear et. al 1997, p.25). It would appear that an adaptive model of comfort as promoted by de Dear would be more useful in defining thermal standards as it acknowledges that occupants play an important role in creating their own thermal preferences.

Khedari 2000 and Nicol 1999 studies cited by Peterson et. al. (2006) show that "residents of temperate climates accept 27º to 30ºC as 'comfortable' in summer, and that native populations of tropical countries will accept over 33ºC if sufficient air flow is in their personal control." This study not only reveals the cultural differences in the level of acceptance of warmer indoor temperatures but also that higher / lower temperature settings can be used for air-conditioning set points if occupants are given some mechanism of personal control. This can be in the form of an operable window and blinds, under desk space heater or small desk fan.

Further research by de Dear (2004, p.37) noted that "thermal environmental conditions perceived as unacceptable by the occupants of centrally air-conditioned buildings can be regarded as perfectly acceptable, if not preferable in a naturally ventilated building." He also concluded that "it was something about the actual context of the buildings in question, and in particular, the expectations that their occupants brought to those contexts." He noted that people who know that they do not have control over their air-conditioning temperature at work have the expectation that their thermal comfort will be automatically achieved at a constant level. On the other hand, people who worked in a naturally ventilated building know that the indoor climate will be more variable and that they need to be more actively engaged in making their indoor environment more pleasant.

5.2 *Central Control.* Though research shows that occupants are able to tolerate lower/higher indoor temperatures if given some degree of control over their indoor environment, our buildings are still mostly constructed with centralized mechanical and electrical control. Bordass (1990) notes in his paper "The Balance between Central and Local Systems" that controls are not usually seen as part of the architectural design as engineers seldom design overall systems and outline limits with the user in mind. It is evident that end users are not consulted and therefore their needs are seldom addressed.

Bordass (2001) also notes that there is a lack of feedback on the energy performance or post occupancy evaluation of a building's system from the user (local control) to facilities management (central control). Centrally controlled systems are designed for the range and not for the mean. Air-conditioning set points are usually viewed as universal settings rather than adjusted to the building or its users. De Dear's research into Adaptive Comfort Standards would encourage management with central control to have more of a connection with the users so that they have more local control. This, in turn, would promote happier occupants and a more productive workplace. Leaman and Bordass (2005) conclude that the absence of effective control adjustments to indoor climate in a building especially in generic space planned offices makes the difference between tolerable comfort and dissatisfaction.

Management with central control should be encouraged to embrace a more customer oriented approach in finetuning the building systems. Bordass advises that:

> "we need appropriate technology, and not always advanced technology: BEMS (Building Energy Management Systems) don't run themselves: they need considerable effort at the design stage to make them user-friendly, care during installation and at handover, careful

training, and constant vigilance during operation. They are a management tool and not a fit-and-forget item" (Bordass 1990)

6. Building Design

Brager and de Dear (Cole & Lorch eds. 2003) also suggest that another contributing factor to the increased use of air-conditioning is the rapid advancement in building technology and cheap energy supply after the Second World War. The ability to build large floor plates and curtain walls with sealed facades soon made mechanical air-conditioning necessary. This type of non-naturally ventilated building has to rely exclusively on a mechanical means to deliver a comfortable working environment. Perhaps this has evolved to our present day dilemma of being socially conditioned to expect an office environment that is unrelated to outside

Leaman and Bordass (2005) advise that buildings with a management strategy developed from the beginning of design are more likely to perform better. A building is better designed and will function more efficiently if ventilation strategies are integrated with the design process rather than treated as a separate element. Bordass (2001, p.9) notes that "it is easier to design a crude building and use AC to sort out the environment than it is to prepare an integrated design." Very often building design is split into architectural and building services with little integration between them. The management of the facilities or end-user requirements are often not well considered at the design level which would sometimes negate the original intent of the building design.

Leamann and Bordass (2005) also cite Edward Tenner's 'revenge effects' in buildings, where "technical elements often work reasonably well in isolation or in theory but when included as part of a wider system of operation induce inefficiencies which ultimately affect the ability of people to perform their work properly."

Leaman and Bordass (2005) note that naturally ventilated or mixed mode buildings tend to be simpler for users to understand and operate so, in this way, the design intent is better communicated to users. "Because users understand better what ought to happen, they are more tolerant if actual performance does not quite live up to expectations." As the subtropical climate of South East Queensland lends itself to naturally ventilation most of the year, it would be highly plausible that building occupants with local control will be more satisfied and productive at their workplace.

Comfort is not only determined from the nature of our physical environment but also from our attitudes. Our individual attitudes that have been moulded from our surrounding social values and our cultural milieu play a role more significant than is accounted for by architects who design buildings and engineers/maintenance personnel who determine set-points of air-conditions in commercial office buildings.

7. Current Literature

Our search of current literature and research projects, as summarised above, supports the intricate relationship between the occupant's perception of thermal comfort and the provision of that comfort via the office's HVAC systems:

i) *Thermal comfort* is difficult to define as a standard as it is perceived by occupants who are humans and thus variable in a biological and cultural sense. Application of universal air-conditioning temperature settings does not contribute to user satisfaction.

ii) *Social* norms and cultural influences define thermal comfort perceptions more strongly than previously realised.

iii) *Local vs Central Control:* Current literature reveals that building designers struggle with providing enough local control for occupant satisfaction while maintaining adequate central control of the systems in order to run efficiently.

iv) *Building Design***:** A building would be able to offer its occupants better thermal comfort if the architectural and mechanical elements were integrated right from the beginning of the design process.

8. Participant Response And Survey Analysis

With the knowledge gathered from our literature research above, the project team incorporated a survey instrument into the study both as a change management and a feedback tool that would enable the project team to monitor general levels of comfort and identify areas where intervention may be required.

Table 3: Measured Office Temperature Jan – Mar 07

		Office Measured Data				
		A105	A204	A312	D318	D521
Daily	Min ^oC	20.8	21.7	22.9	23.2	23.6
	Max ^oC	27.1	31.9	31.1	29.5	29.5
9am	Mean ^oC	25.2	26.7	27.4	27.4	27
	Min ^oC	22	22.1	23.2	25.2	24.4
	Max ^oC	26.3	30.3	29.5	28.7	27.9
	Mean RH	57%	56%	55%	51%	52%
	Max RH	67%	66%	65%	63%	65%
3pm	Mean ^oC	24.4	25.9	25.5	26	26.6
	Min ^oC	22.1	22.5	23.2	25.2	24.8
	Max ^oC	27.1	30.7	30.3	29.1	28.3
	Mean RH	56%	57%	57%	54%	49%
	Max RH	63%	67%	62%	65%	57%

8.1 *Survey Design.* A short questionnaire investigating levels of comfort and related circumstances was administered to building occupants on a fortnightly basis via email. At the conclusion of the project, a small focus voluntary group was also conducted with staff from D block. As a change management tool, it proved particularly useful with 106 staff taking the opportunity to provide feedback via the survey. Of the 106 participants, 47% were male and 53% female.

The survey included questions that enabled exploration of the relationship between levels of comfort and:

i) the age, location and submission times of the answers to the questionnaire
ii) participant location by building
iii) survey submission times
iv) respondents' level of clothing including footwear
v) mode of transportation to work
vi) usual method of transport and length of trip
vii) access to and use of air-conditioning in homes and car
viii) activity levels – previous 10 and 30 minutes
ix) internal and external mean temperatures of some rooms

8.2 *Change Management.* Feedback received on thermal discomfort led to data monitors being placed in some individual offices as follows:

A105 - a small cashier's office ($8.96m^2$) with no exterior windows.
A204 - an open plan office ($111.41m^2$)
A312 - an open plan office ($110.09m^2$)
D318 - a small office ($12.61m^2$)
D521 - an office ($12.16m^2$)

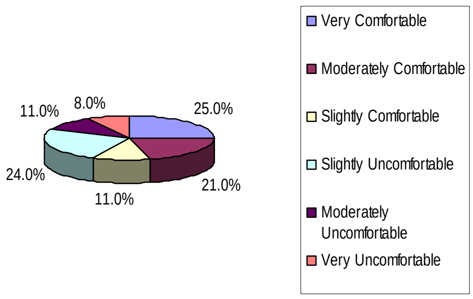
The collection of actual performance data in offices was restricted to access to appropriate measuring devices. The monitors were not in place for the whole 4 months, but for between 28 and 56 days between late January and late March. Office data was analysed for 8am – 6pm only, to reflect usual occupancy parameters. 9am and 3pm data was calculated as mean, max and min as recorded every 10 minutes between 9-10 am and 3-4 pm respectively, to correlate with BOM data.

Note that the mean maximum temperature for each of the offices measured was outside of the operating parameters of the HVAC system (25^{o}C) by 1.3 to 6.9 degrees. Refer to Table 3 below.

Staff discontent in A block in mid January culminated in a meeting of occupants, the project team and Facilities Management to discuss the project and the performance of the building. From a building management perspective, this meeting led to FM looking at the building's BMS more closely whereby it was discovered that raising the set point (to 25^{o}C) had unmasked pre-existing sensor calibration errors and control algorithm errors. The AC system in A block was consequently re-commissioned, allowing the AC system to perform to its design parameters, and there was a subsequent drop in the number of official (and unofficial) complaints from staff (compared to the same period the previous summer).

8.3 *Observations.* Some observations from the survey included:

- i) Over half of responses were from individuals wearing short-sleeved shirts (54%) and long trousers (53%). Approximately 8% of responses were from individuals wearing a sweater or a jacket. (This reflects normal standard of attire at QUT).
- ii) The most common methods of travelling to work were walking (44%), bus (39%), car (37%) and train (29%). Respondents tended to spend approximately 20 to 30 minutes either travelling by public transport or car or walking to work.
- iii) Although most of the sample have air-conditioning in their homes and/or cars, most had not used it on the day of response (e.g. 78% have air-conditioning in their cars, with 33% using air-conditioning in their cars on the day of response).
- iv) Most of the sample had been sitting typing in the previous 10 minutes (76%) and previous 30 minutes (59%), with only 18% walking around in the previous 10 minutes and 29% walking around in the previous 30 minutes.
- v) Participants generally found their office environments to be quite comfortable, with approximately 57% of participants finding their office environment to be slightly, moderately or very comfortable – see Figure 2.
- vi) Respondents were also asked to describe whether they would like to be warmer or cooler, with 39% of respondents identifying that they would like to be cooler, 21% identifying that they would like to be warmer, and 40% saying they would not like a change to how they are feeling.



Additionally the recorded that the AC system was not performing to specified appears to be related to temperature).

Some correlations drawn from this survey include:

- i) There was no significant association between general comfort levels and the **participant's location in a building.** This suggests that manipulating the HVAC settings did not significantly affect participant's perceptions of comfort.
- ii) Feelings of extreme heat or cold led to feelings of discomfort suggesting that the **'tolerance'** for smaller temperature changes is an important area of investigation.
- iii) Perceptions of **air movement** are an important part of people's perceptions of comfort. Refer to Figure 3.
- iv) **Comfort levels** were not associated with age or gender; whether they had used air-conditioning on the way to work, the clothing worn or levels of activity prior to completion of the survey.

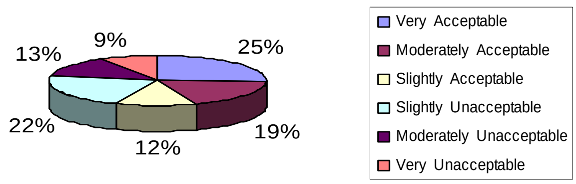


Fig.3 – Level of Acceptability of Air Movement

It is important to note that this survey was limited in a number of areas:

i) The sample size was small.
ii) A self-select sampling method was used where participants may have had particular motivations for participation.
iii) Participants could choose when they participated (eg: a participant may choose to participate only when he/she felt uncomfortable).
iv) There was a lack of directly correlating internal and external temperature data which limited exploration of the relationship between perceptions of comfort and internal and external temperature changes.
v) There were uneven participant numbers in experimental and control buildings.

Given these limitations, the findings from the survey cannot be extrapolated beyond this sample. They do, however, suggest some important areas for future research such as research into indoor thermal comfort in relation to occupant expectations; activity levels; past experiences; acclimatization; age; gender; race; cultural influences; and cognition (e.g. of environmental drivers as well as operational issues such as payment of electricity bills). Studies can also be carried out into the perceptions of fashion and comfort; and attitudes towards clothes / status and the adoption of climatically responsible clothing for business.

9. Main Findings

Our initial question was whether GHGE reductions could be achieved in institutional subtropical offices through altering of air-conditioning thermostats and this pilot project has revealed that it is possible to affect energy savings and GHGE reductions through this means. This research confirmed that raising the summer thermostat setting 2 degrees would result in:

i) **Cost savings** to the university through lower electricity usage and lower water usage.
ii) **Reduction in primary energy** that could have significant implications for Queensland's electricity generation and transmission / distribution infrastructure requirements.
iii) **Possible reduction in peak load** through lower AC load, affecting both QUT's electricity costs and south-east Queensland electricity network.
iv) **Reduction capital expenditure on assets** through reduction in chiller plant capacity.
v) **Opportunities for further savings** through behaviour change and procurement and maintenance practices.
vi) **No significant impact on comfort of staff** provided that HVAC systems are operating as per specifications.
vii) **Validation of incorporating a change management strategy** to maximise acceptance of change.

10. Recommendations

From our pilot research project, it was discovered that there was a strong and significant relationship between our technical manipulations of the indoor environment of the offices and the social responses to that technical adjustment. From the findings of our four month project, we share a number of recommendations:

i) **Consider holistic opportunities** and benefits in decision making because cost savings can be achieved through lowered water usage, purchase of Green Power and capital savings benefits.

ii) **Water and Capital cost reductions**: Lowering of thermostat temperature can include additional savings in other areas such as water and capital costs. Cost savings achieved through lower electricity usage also lower water usage. Capital savings can also be realised with lower energy use due to a reduction in chiller plant capacity.

iii) **Potential income** to fund further GHGE reduction strategies through a future carbon trading market. Savings generated through reduced energy usage could be invested in Green Power to further reduce GHGE by 20%.

iv) **Lighting and equipment heat load reduction**: Further energy savings opportunities could be obtained through staff awareness that heat generated from computers and lights contribute to the heat load. Behavioural changes from staff and students such as switching off lights and computers in spaces that are not in use can minimise energy use.

v) **Changes in procurement practices** such as requiring more energy efficient machines or Green star rated equipment are likely to produce significant savings.

vi) **Acknowledge the limitations of HVAC systems** as they are not perfectly calibrated systems that work all the time and in the way that they were originally programmed.

vii) **Ensure HVAC systems** are in good working order and operating correctly.

viii) **Any commissioning process** must involve the occupants and some measure of whether the aim of occupant comfort is being achieved (as opposed to whether the HVAC system is performing to its engineering design parameters).

ix) **Integration of the architectural and mechanical services** at the design stage which includes end-user requirements could lead to a better building design outcome. Our project involved retrofitted buildings where we encountered other associated problems of incorrect equipment calibration and improper commissioning.

x) **Response to cultural influences**: Energy savings have primarily focussed on the physical engineering solutions but our research reveals that energy use can be reduced through an understanding and response to the cultural and social influences of human comfort. Challenge the usual design approach to providing comfort by responding to cultural and social issues in building and HVAC systems design.

xi) **Encourage a dress code** that responds to local climate that would enable adjustment of thermostat set-points to reduce energy use.

xii) **End-users who have a better understanding** of how thermal comfort can be achieved in their space i.e. via timers or individual expectations / adjustments can attain greater satisfaction and productivity with the work space.

xiii) **Better communication:** Facilities maintenance staff who are trained to 'interpret' occupants' complaints are in a better position to identify the mechanical problem and resolve the issue satisfactorily.

xiv) **Establish a corporate environmental sustainability manifesto** for the institution to implement a formalised approach to sustainability practices in its core business.

xv) **Establish a change management process** to acknowledge social impacts of instigating energy saving measures in the work place, thereby achieving more support.

11. Conclusion

Any institution or commercial office desiring to reduce energy use by the adjustment of thermostat settings must consider the social and cultural influences that affect the provision of thermal comfort. This is crucial to the success of such an undertaking.

Our four month pilot project on air-conditioning temperature set points in two of our buildings at QUT has revealed our cultural attitudes, social habits, building design and building service methods need to be revisited in order to accomplish our goal of energy efficient buildings leading to a sustainable world.

Acknowledgements

This project and accompanying report was made possible through the valuable time contribution of the project team of QUT academic, professional and facilities management staff, as well as staff who participated in the trial itself. Financial assistance was provided by Facilities Management for the procurement of equipment and the engagement of consulting engineers for savings analysis. The project team would like to acknowledge the contribution of Dr. Richard de Dear, Associate Professor at Macquarie University for his early advice on this project. We would also like to thank Prof. Martin Betts, Executive Dean of the Faculty of Built Environment and Engineering, QUT and Mr. Andrew Frowd, Director of Facilities Management, QUT for their support throughout this project.

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BUILDING SCIENCE DRIVEN INSULATION SOLUTIONS FOR ENERGY MANAGEMENT

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Abstract

Buildings serve many purposes, some aesthetic, some emotional, and some practical. Within the practical realm, the purpose of a building can be described as a structure that is long lasting, sturdy, weather proof, and efficient. The Building Science behind development and application of materials which provide these practical requirements of a building will be described in this paper. In addition, the interplay and overlap of these requirements will lead to the need for system modeling, analysis, and solution.

The research labs at Dow Chemical in America, Germany, and China have developed a series of tools and models to guide innovation and development of solutions. Specifically, steady states models are used to ensure that a building envelope is properly insulated to ensure that moisture will not form within the walls and cause deterioration. These tools lead to effective application of STYROFOAM™ brand products. More advanced simulations which include both daily and seasonal weather fluctuations at locations across the globe are used to fine tune the application of existing products and develop new solutions. These were used to evaluate options available for peak load energy management.

Finally, the models which help to quantify the value of insulation and weather proofing in delivering sustainable efficient buildings with return cost savings and reduced carbon foot print, will be described.

Keywords: Insulation, Phase Change, Thermo Mass, Green Roof, Garden Roof.

1. Introduction

The rapid growth experienced over the last decade in Asia has resulted in a greater demand for energy. It is projected that in 2030, the energy required to heat and cool buildings will be as much energy as the entire Asian economy used in 1990. (Levine 2005) Much of this energy will be derived from locally mined coal, which may provide a better strategic use of energy sources, but coal is a particularly heavy contributor of atmospheric CO_2 at about 1 kg CO_2 generated / kWhr produced. (DOE 2000)

	2002-06		2007-11		
	New electric capacity from coal-fired plants, in gigawatts	Tons of CO_2 produced annually	Expected new capacity from coal-fired plants, in gigawatts	Tons of CO_2 produced annually	Percent change
China	112,613	739,867,410	55,490	364,569,300	-50.7%
India	12,138	79,747,974	36,477	239,651,591	200.5
US	2,660	17,472,915	37,723	247,840,110	1,318.4
EU Countries	2,508	16,477,823	12,856	84,463,920	412.6
Other Kyoto Nations	19,824	130,244,337	33,455	219,796,722	68.8
Non-Kyoto Nations	8,977	58,976,919	2,045	13,435,650	-77.2

Fig. 1 Global Scale of the Impact of Coal- Fired Power Plants (Clayton 2007)

There are several alternatives for electricity production which generate much fewer green house gas emissions, but, the cost to implement these alternatives varies significantly. For example, it is estimated that abatement cost for wind energy is valued at 20 EUR/ton CO_2 equivalent while implementing carbon capture and storage at a new coal plant is 25 EUR/ ton CO_2 equivalent. The cost drops to 15 EUR / ton CO_2 equivalent if the CO_2 can be sold for enhanced oil recovery. (Vattenfall 2007)

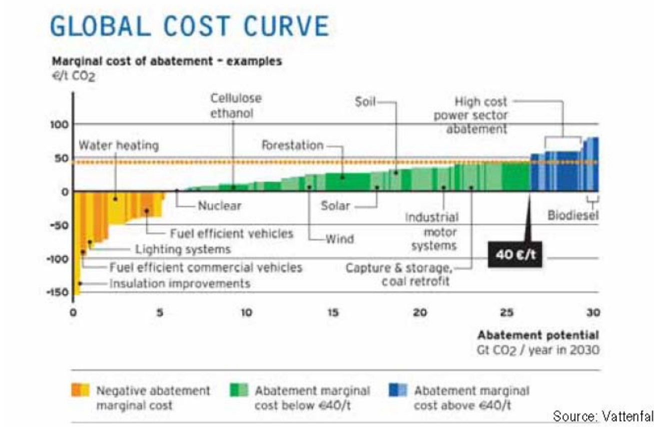


Fig. 2 Cost of CO_2 Abatement by Technology (Vattenfall 2007)

Further investigation reveals that there are even more effective methods to address climate change and high energy costs. These elements are classified as “negative abatements” in that they reduce green house gases and save money. Deploying these technologies is considered key to enabling both economic growth and CO_2 abatement in the next half century. (Vattenfall 2007) By this measure, the absolute best use of resources is to increase the use of insulation in buildings.

1.1 Dow Building Solutions

The Building Solutions Business Unit of The Dow Chemical Company has over 40 years experience in the development, production and commercialization of insulation systems. The Dow Chemical Company also provides critical solutions to the food, transportation, and health care industries, besides others.

Fig. 3 The Dow Chemical Company

The following figure describes the specific solutions developed by Dow to meet the needs of the construction industry in markets around the globe. Dow Building Solutions is global manufacturer of products for the building industry with manufacturing on 6 continents.

Fig. 4 The Business Vision of Dow Building Solutions

Dow Building Solutions focuses on several global brand portfolios as it works to provide solutions to the industry. The Energy Management Segment provides sustainable energy saving solutions while enabling comfortable living. The Protection Management Segment provides peace of mind by protecting the occupants from moisture, wind, and noise while ensuring good indoor air quality. Finally, the Performance Systems Segment is working to enable higher construction efficiency by improving installation and reducing maintenance effort.

TM Trademark of The Dow Chemical Company

Fig. 5 Brand Portfolio of Dow Building Solutions

2. Insulation

Insulation is a proven technology to save energy in the operation of buildings. The scale of the impact of insulation on energy efficiency is enormous. An estimate of the CO_2 not released into the atmosphere due to the use of a single class of Dow products in North American buildings, gives a perspective on the impact of insulation. Here, the additional energy saved by adding a 12 mm layer of STYROFOAM to a wood framed wall already insulated with fiberglass more than compensates for the natural gas energy that The Dow Chemical Company uses globally on an annual basis. The main drivers for the huge numbers are that the product is inert and works for as long as the building is occupied and standing. The annual savings from the product is a function of the total installed volume from product inception. There are small deductions made for product removal and building loss.

Recent changes in awareness and regulation have focused efforts on insulation in Asia. These changes will impact new construction, but a much larger energy savings can occur by modifying the existing housing stock. There are several ways to insulate concrete construction. In some cases, the insulation is placed on the exterior of the concrete wall and a surface coating is applied to finish the rendering. In other cases, the insulation is placed on the inside surface of the wall. Here, it is typically faced with a gypsum layer. Both methods are applicable for retrofit as well as new construction (Fig. 6).

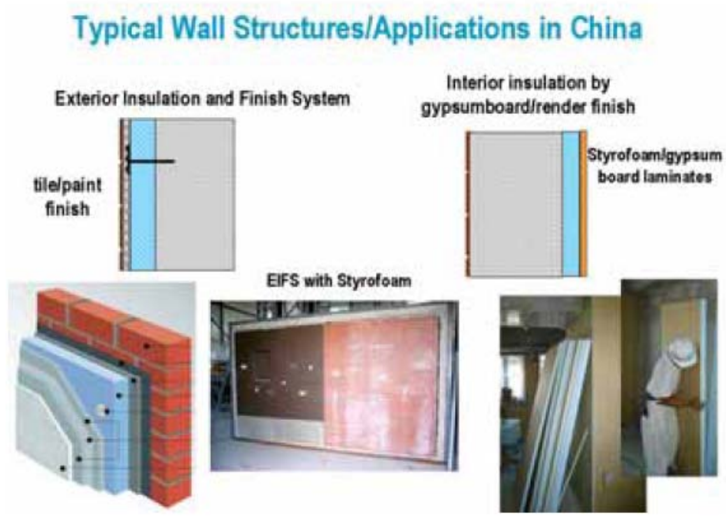


Fig. 6 Interior and Exterior Insulation Applications

Thermal Insulation provides a resistance to the flow of heat, however, one additional advantage of concrete construction is the high amount of thermal mass available for dynamic energy management. The mass of concrete in the wall absorbs some of the daytime heat before it can reach the inside. Given the proper weather conditions, the concrete releases heat in the cooler evening period. This effect is further enhanced when the thermal mass is located on the air conditioned space side of the wall (i.e. with the insulation on the outside). (Kossecka, et al., 2001) The annual energy savings impact of retrofitting interior or exterior insulation to a residential construction in a climate like Beijing was simulated using the ORNL Thermo Mass Calculator. (Kosny 2001)

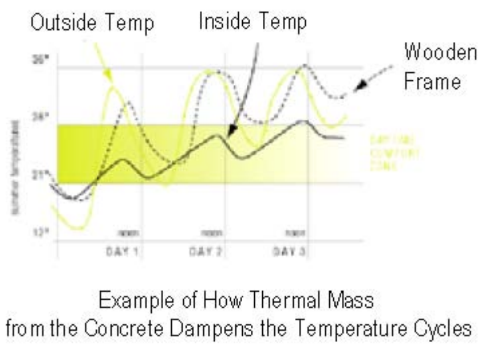
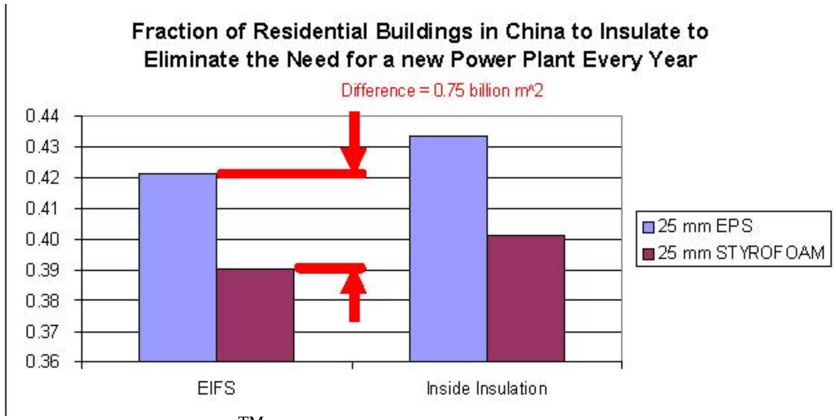


Fig. 7 Example of the Influence of Mass on Temperature Cycles in a Building

The results of a series of simulations on a single building were converted to estimate the national savings impact of insulation. Here, the concept was to determine how many existing residential buildings would need to be retrofitted to eliminate the need for a coal fired power plant every year. These results show the effectiveness of external insulation over internal insulation when using concrete construction. It should be noted that every 0.01 fraction in Fig. 8 is equivalent to ¼ of a billion square meters of residential living space. Given space limitations of 25 mm, the STYROFOAM™ based EIFS system is the most effective form of exterior insulation. Fig. 8 shows that many millions fewer square meters of residential housing are required to meet the goal of eliminating a power plant per year.



TM Trademark of The Dow Chemical Company

Fig. 8 Advantages of Using 25mm of STYROFOAM™ in EIFS

3. Peak Load Management

In addition to using insulation and thermal mass, the ability to more completely capture the daytime heat enters the home via the attic, enables the reduction of the summer peak energy demand (Fig. 9 Note that the peak is driven by AC cooling load). Two methods will be discussed to achieve peak load capture and shifting. One is the use of phase change materials and the other is utilizing garden or green roofs.

Difference = 0.75 billion m^2It was discovered that in warm climates, it is not the phase change melting that drives the energy capture; it is the night time freezing. If the product is initially sized to absorb (by melting) all the heat delivered during the hot part of the day, the critical element is to ensure that all of it is frozen again the following evening. If incomplete freezing occurs, the heat delivered in the following day will completely melt the phase change material during the hot part of the day, thus requiring peak energy to maintain the interior temperatures. Over sizing the amount of phase change material will only work for a few days. Once the additional material is melted, only the amount frozen the following day will be available for energy capture. The solution is to actively cool the phase change material at night to ensure that it is 100% frozen at the start of the next day. This can be done by blowing air (conditioned if necessary) over the material at night. This research demonstrated that active phase change solutions do not save much energy, they shift the energy usage to the off peak period.

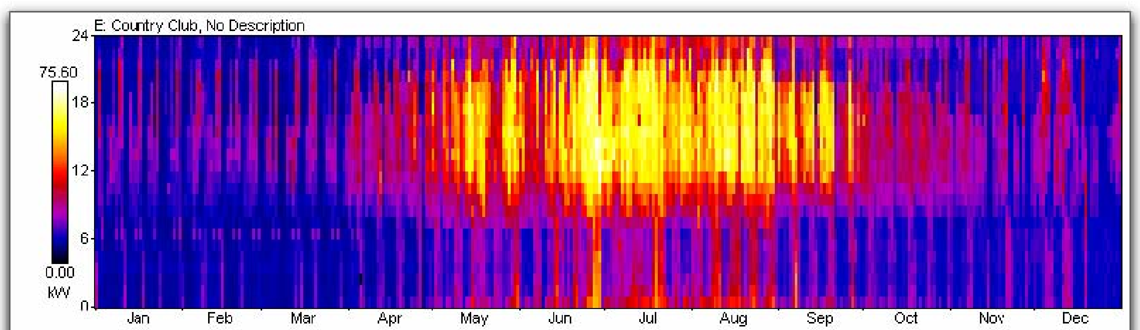


Fig. 9 Energy load as a function of time of day (Y axis) and month (X axis). Blue is base load, and yellow is peak load.

3.1 Phase Change Material (PCM)

When the temperature is high, the heat flow into the living space is reduced because some of the energy is used to melt the phase change material. (Shramo, et al., 1999) When the temperature is low, heat flows out of the material causing it to freeze. This concept was tested in identical buildings at the University of Nevada at Las Vegas. (Halford, et al., 2005) The study showed a 17% reduction in peak energy consumption. Further research explored the changes required to improve the effectiveness of the PCM as an insulating material.

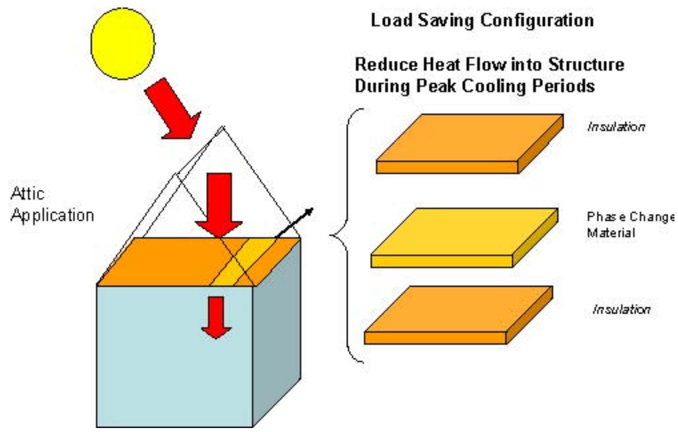


Fig. 10 Phase Change Material Used in Conjunction with Insulation for Peak Load Management

In conjunction with the tests, the Energy Research Center at UNLV developed a simulation program to determine the optimal placement for the PCM.

3.2 Garden Roofs

A second method for peak energy management is to employ a garden roof over an insulated synthetic membrane and plastic drainage layer. (Liu, 2002). This technique has many advantages for urban settings. The natural plants absorb CO_2; they reduce the heat island effect; they protect the membrane; they help manage rain water runoff and purity; and they absorb the high daytime summer heat. Another advantage is that the membrane lifetime is enhanced by elimination of the high temperatures experienced during the summer.

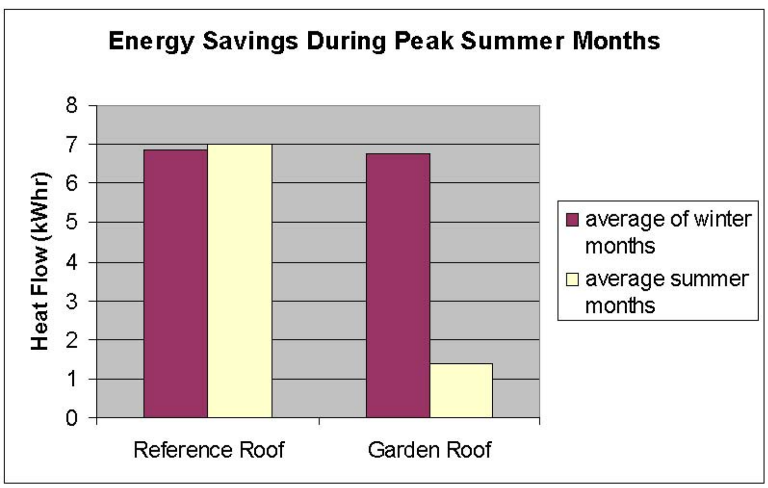


Fig. 11 Performance Benefit of Garden Roofs

The reduction in heat flow through the roof due to the cooler temperatures experienced is reflected in the lower energy demand in the summer. The nearly identical winter heat demand was seen because both the test and reference roof were snow covered. (Liu, 2002)

4 Conclusions

The scale of the opportunity for thermal management in buildings is immense. There are several proven technologies that can be implemented to address the needs. Rigid plastic extruded thermal insulation is proven to perform for many years in both interior and exterior applications. Additional benefits of external insulation are seen in enhanced modulation of outside temperatures through thermal mass. In areas where summer peak electricity needs exceed supply (or come alarmingly close), enhancements to thermal insulation exist to address peak load. In one example, a layer of phase change material can be placed within the insulation to absorb the peak heat and then be available to release it in the cooler night period. Incorporating active night cooling ensures complete peak heat management. By making use of the inert nature of plastic synthetic building materials to moisture, a garden or green roof structure can be implemented. Here, the peak thermal management through temperature control is enhanced by rain storm water management.

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THE EFFECTS OF SOFFIT VENT AND THERMAL INSULATION ON REDUCED HEAT GAIN IN HOUSES IN THAILAND

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Abstract

Many residential buildings in hot humid climate are designed to have soffit vent, so that it can reduce heat gain through roof. The objective of this research is to confirm whether the design of residential buildings using soffit vent is necessary and comparing its effect in reducing heat gain with thermal insulation alone without attic ventilation. The experiments were conducted in a real building, using two rooms on the top floor of three-storey building. The results shows that the soffit vent does not help in reducing room air temperature during daytime as most designers expect. When comparing its efficiency with using thermal insulation, fiberglass, it is found that using insulation can reducing room air temperature and ceiling surface temperature during daytime much better than using soffit vent. However, during nighttime the room air temperature of the building with soffit vent will be lower. The experiments also show that under air conditioning control the room with thermal insulation will use less electricity consumption, with economic internal rate of return higher than the acceptable rate, 9%, indicating feasible investment.

Keywords: Soffit Vent, Attic Ventilation, Thermal Insulation, Roof, Reducing Heat Gain, Fiberglass

1. Introduction

Traditionally, houses in Thailand are commonly designed to ventilate hot air from attic. This is with the believe that attic ventilation can reduce heat flux from the ceiling. However, research that confirms the efficiency of this practice in hot-humid climate of Thailand is scant. Design of attic venting in Thailand needs to take into account the problem of rain intrusion during storm events. Thus, the soffit vent is more widely use for residential building than gable and ridge vents. In addition, it needs to prevent the opportunity for insect and rodent infestation in the attics by installing insect screen at the vented area. This often causes blockage at the vents due to dirt and dust. Thus, the efficiency in reducing heat gain by attic ventilation is questionable. Nowadays, many types of insulation are available in the market at inexpensive price. In practice it was found that attic venting causes deterioration of air impermeable insulation, such as fiberglass because of high moisture level in the attics.

Parker (2005) from Florida Solar Energy Center conducted comprehensive literature review of the impact and need for the attic ventilation in Florida homes. This was to find the impacts of attic venting on cooling energy use and the rationale of most U.S building codes which require the ratio of the net free vent area to the attic area at least 1:300. It was concluded that the rationale of the vent area is to control moisture in the attic for cold climate to prevent ice dams. The justification for attic ventilation for moisture control in hot humid climates is not scientifically defensible. Ventilated attics allows moisture laden air into the attics. The author also concluded that attic ventilation can reduce space cooling energy in typical homes with conventional insulation by 5%. However, the air conditioning system used in Florida homes are mostly attic duct systems, in which energy use depends on duct system leakage. In Thailand, most houses use air-conditioning system without duct, such as wall type. Thus the result may not be directly applicable to house conditions in Thailand

The study by Hendron et al. (2003) conducted field test of vented and sealed attics in Las Vegas Nevada and Tucson Arizona was shown to produce negligible savings when the duct system was tight. Cooling energy savings were clearly seen when the duct was leaky. Under typical circumstances with 10% duct leakage, sealed attic reduced cooling energy by about 8%.

In the literature review by Rose and TenWolde (1999) concluded that attic ventilation is recommended only as a design option in hot humid climates. The attic ventilation does slightly reduce summer shingle temperatures, but the impacts of shingle color and geographic location are much larger. They also cited the research done by Burch and Treado , 1978 [5] that the performance of soffit vent without ridge vents was much like performance without ventilation and enhance ventilation (i.e., ridge vents, turbines or a power fan) in addition to soffit vents produced less than 3% reduction in daily cooling loads of test houses.

In contrast, some research support the effect of attic ventilation in reducing heat gain. Such as the study by Beal and Chandra, 1995 [7], cited by TenWolde and Rose (1999), found that the soffit vents were important in providing cooling to atticd. They found that a 1:230 attic vent ratio gave a 25% reduction in heat flow through the ceiling, but they did not indicate how much this would reduced the total cooling load of the building.

Thus, from the research review it seems unclear about the effect of attic ventilation in hot humid climates. Some research concluded that attic ventilation is only design option without any significant effect in reduce heat gain through roof, but some showed supportive. Therefore, it would be benefit to conduct the research in Thailand to find out the effect of attic ventilation, different from previous research in terms of climates and different research methods. This would contribute to the better understandings in architectural design about the necessity of soffit vent and to find out its efficiency in comparison with using fiberglass in sealed attic.

2. Research Objectives

(i) The research is aimed at investigating the reduction of room air temperatures when (a) using attic ventilation through roof and (b) using fiberglass insulation in sealed attic.

(ii) The cooling energy consumption between using attic ventilation and using fiberglass in sealed attic are compared.

(iii) The economic internal rate of return (EIRR) for fiberglass insulation in order to consider the suitability of investment for new houses and retrofitted houses.

3. Methods

3.1 Experimental Procedures

The research methods employed in this research are different from previous research, as they had used computer simulation or test cells. This research aims to investigate the effect of attic ventilation in real situation. Thus, two three-storey row houses in Bangkok were selected. The test rooms, 4x5 m each, were on the top floor. One house having wooden soffit vent. The net free area of the soffit vent to the attic is 1:25. The other room with sealed attic. The houses were located in medium density area in Bangkok. The test room faces west direction. No wind obstruction through the attic space due to the height of the buildings nearby. The houses adjacent to the test rooms were unoccupied, thus no effect from the air-conditioning usage from the adjacent houses. The attics of the two test rooms were separated by concrete block wall high up to the roof tiles. The air space above the soffit of each room was installed with 10 cm. expanded polystylene foam to prevent air flow above the soffit space of each house.

The study consisted of fifth experiments, conducted during May through June 2006. The outdoor air temperature, attic air temperatures, ceiling temperatures and indoor air temperature were recorded by thermocouples. The electricity consumptions of both rooms were recorded by watt-hour meters.

3.1.1 First Experiment: *Vented attic vs. sealed attic without insulation under air-conditioning control.*

This experiment was to compare between the test room with vented attic and the one with sealed attic under 24- hour air-conditioning control at 25^{o}C. It was found that the average attic temperatures of the vented attic was close to that of the sealed attic, 30.6 and 30.8 ^{o}C respectively. Although the vent area was large, 1:25 ratio, in comparison to that specified by the U.S code, 1:300, the attic temperatures of the vented and sealed soffits did not show substantial different. Thus, the soffit vent area was closely investigated. It was found the insect screen being blocked by dust behind vented soffit. This reflected the evidence of soffit vent blockage in real situation of most houses, no cleaning ever for vented soffit.

3.1.2 Second Experiment: *Vented attic vs. sealed attic without insulation no air-conditioning control.*

In this experiment the insect screens were then removed to observe the effect of attic ventilation to achieve the highest possible net free area of the existing soffit vent. It was found that without insect screen the maximum air temperature of the vented attic was noticeably reduced to be lower than that of the sealed attic about 2.7 ^oC., 40.6 ^oC for vented attic and 42.9 ^oC. for the sealed attic. It was noticed that the indoor air temperatures of the rooms with vented was not lower than that of the sealed attics in the afternoon. It should be noted that the vented attic can help lower the room air temperature during nighttime rather than daytime (Fig. 1).

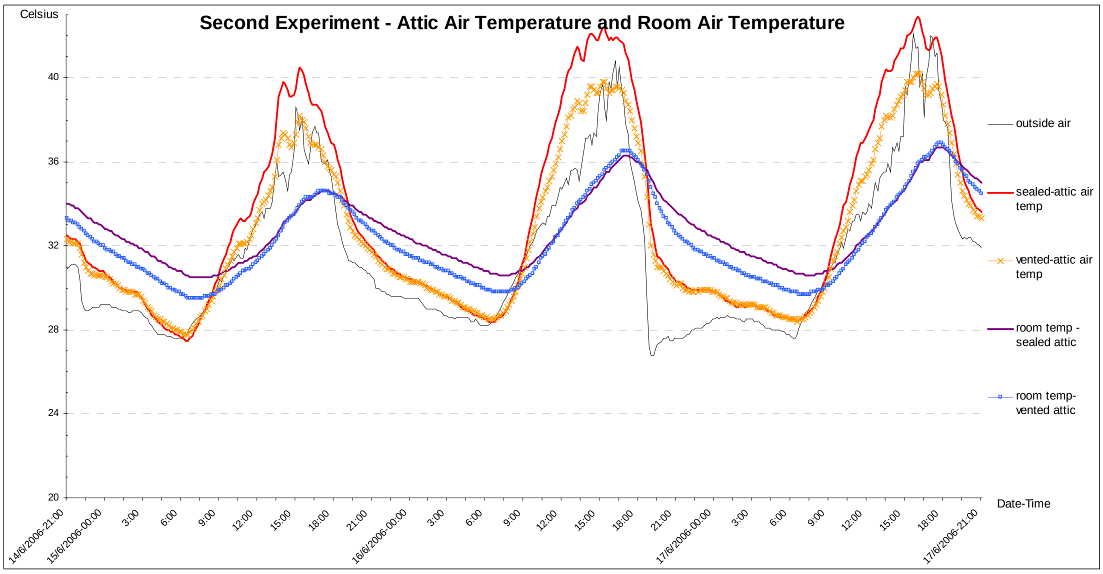

Fig.1 Attic air temperatures and room air temperatures with vented and sealed attics

3.1.3 Third Experiment: *Vented attic vs. sealed attic with fiberglass under air conditioning control at nightime*

In this experiment the three-inch thick fiberglass wrapped with aluminum foil (R=11.54 Hr ft^2 ^oF/Btu), was installed horizontally above the ceiling. Both rooms were controlled at 25 ^oC from 9 P.M to 6 A.M. for three nights. The result of the experiment clearly showed that ceiling surface temperature of the room with fiberglass insulation was closer to the room air temperature than that using attic ventilation alone, 0.4 ^oC higher compared to 1.5 ^oC higher of the room without insulation.

3.1.4 Fourth Experiment: *Vented attic vs sealed attic with fiberglass under air conditioning control during daytime.*

This experiment was similar to the third experiment but conducted from 9 A.M. to 6 P.M. under air conditioning control at 25 ^oC. It was shown that fiberglass insulation can substantially reduce the ceiling surface temperature. The ceiling surface temperature of the room with fiberglass was 0.4 C higher, while that without was 4.3 ^{o} C higher, indicating less heat flux to the conditioned room (Fig. 2).

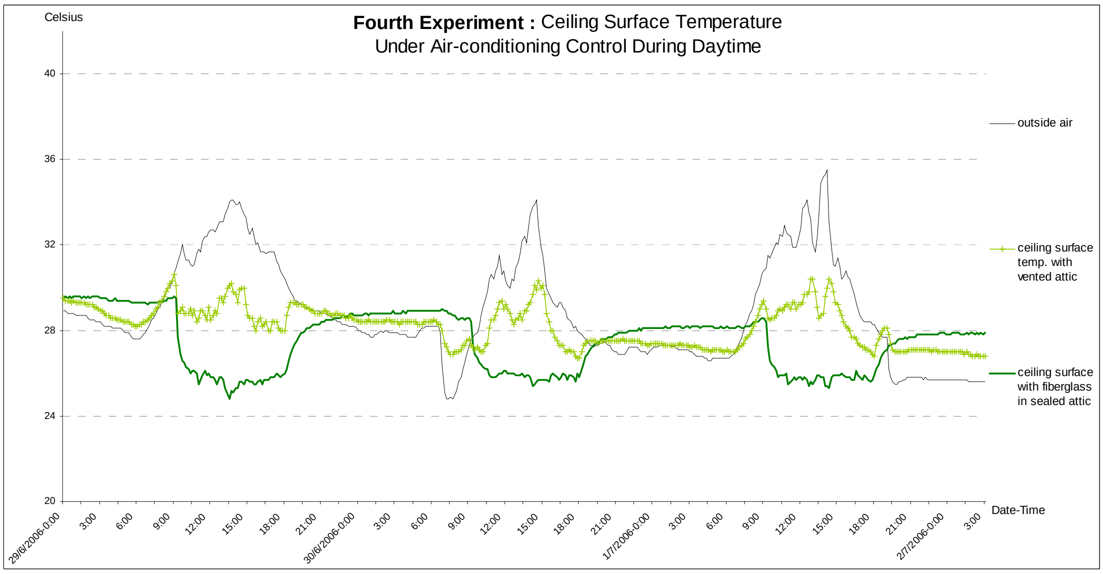

Fig. 2 Ceiling surface temperatures of the rooms with vented attic and sealed attic with fiberglass under air-conditioning control during daytime

3.1.5 Fifth Experiment: *Vented attic vs. vented attic with fiberglass under 24 hour natural ventilation*

It was found that during daytime room air temperature with vented attic was higher than the sealed attic with insulation about 1 ^{o}C, but lower during nighttime. However, it should be noted that the maximum ceiling surface temperature of the room with insulation was much lower, about 6 ^{o}C. As a result the mean radiant temperature of the room with insulation was lower, allowing better thermal comfort condition (Fig. 3).

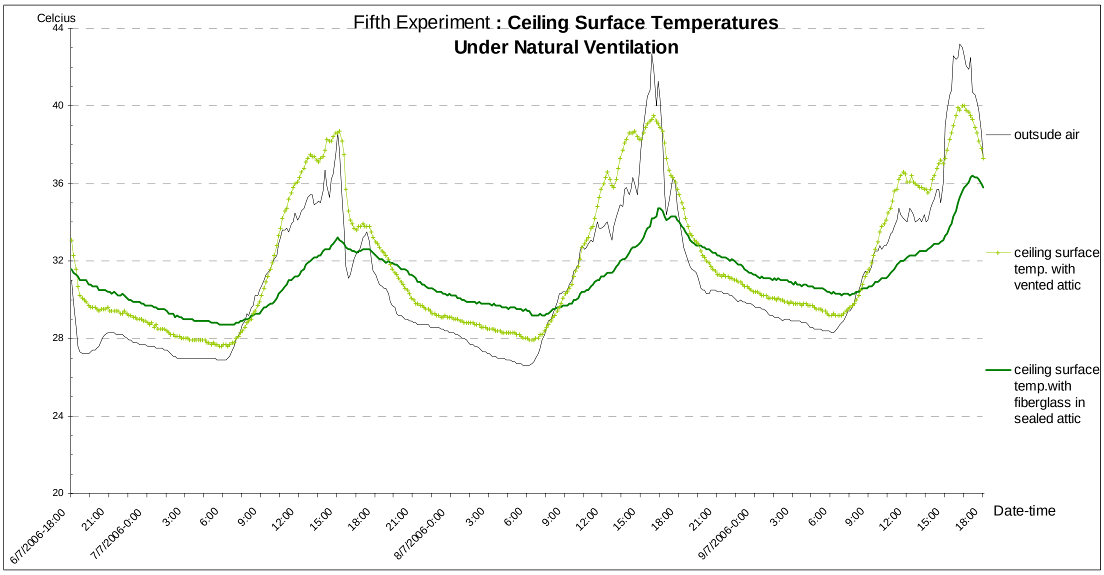

Fig. 3 Ceiling surface temperatures of the rooms with vented attic and sealed attics with fiberglass

4. Cooling Energy

It was obvious that the cooling energy of the room with fiberglass insulation in sealed attic was lower, during both nighttime and daytime operation. The hourly average electricity consumption during nighttime from 9 P.M to 6 A.M. was 0.32 kWh for vented attic and the 0.17 kWh for sealed attic. The hourly average during daytime,9 A.M. to 6 P.M., was 0.75 kWh for vented attic and 0.29 kWh for sealed attic.

5. Economic Internal Rate Of Return (Eirr)

Based on the cooling energy recorded, in the case of retrofit the existing building the EIRR when the using fiberglass was 12.7% with the payback period 6.75 year if conditioning the space during nighttime. The EIRR will increase upto 42% with the payback period 2.5 years for operating during daytime. Such values indicated that it is worthwhile for installing fiberglass to saving cooling energy. In addition, using fiberglass for the new building results in better investment. The EIRR was 16% with the payback period 6.2 years for nighttime. The EIRR will increase upto 49% with the payback period 2.3 years for daytime.

Discussion

The results from this research indicated that in real environment the attic venting has less efficiency in reducing heat gain in comparison to using insulation in sealed attic. The results also agreed with the conclusion of previous research by Parker (2005), indicating that the attic ventilation in hot humid climate had no significant effect in terms of reducing heat gain. Attic venting is only a design option.

The difference in cooling energy between both rooms some part may come from the different in room air temperature that were not exactly equal, even they were set at the same thermostat set point. In the experiments new and identical air conditioning systems were used for both rooms, and the refrigerant pressures were measured to be equal in order to eliminate the effect due unequal efficiency of the air conditioner.

In addition, the cooling energy recorded in this research was conducted under empty room conditions, without internal heat gain from people, lighting, and equipment. Therefore, the percentage of cooling energy reduction as compared between two test rooms may differ from the actual environment.

Conclusion

The research result indicated that the efficiency in reducing heat gain of the attic ventilation is lower than using fiberglass insulation in the sealed attic. Using insulation can substantially reduce room air temperature by about $1^{o}C$ under natural ventilation and reduce ceiling surface temperature by about $6^{o}C$ during peak in the afternoon, which in turn affecting mean radiant temperature and heat flux through ceiling. Using insulation can contribute more to thermal comfort than attic ventilation due to lower mean radiant temperature. In the building that use air-conditioning system, using insulation obviously saved cooling energy better than attic ventilation and worth investment.

Acknowledgement

The author thanks Chulalongkorn Institute of Energy Research, Thailand which funds this research and Silpakorn University for providing research instrument.

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ENERGY CONSUMPTION OF AIR CONDITIONING ROOMS WITH DOUBLE DOOR AND ELECTRICAL AIR CURTAIN

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Abstract

In Thailand, an electrical air curtain is extensively used in commercial buildings at theirs entrances as a means to save energy in operating air conditioning system. Electricity is used while the air curtain is in operation. The objective of this research is to demonstrate to the public in Thailand, as well as to others in hot and humid climate regions, that electricity expenses can be saved using the double door system. This study was conducted by constructing an experimental room with nine types of doors. The electrical consumptions of the experimental studies based on simulated normal usage were recorded and compared to investigate whether using double door system is effective in maintaining room temperature. The studies show that an air conditioning room with double door system can maintain its temperature while only conserving 63% of the electricity required to run an electrical air curtain for a single door, an air conditioning room can maintain its temperature when a double door system while consumes electricity approximately 63% of the same room which has a single door attached with the electrical air curtain.

Keywords: Double Door, Energy Consumption, Hot and Humid, Air Curtain.

1. Introduction

Energy conservation house minimizes the use of energy, while maintains temperature and relative humidity inside a comfort zone. It should have temperature between 22°C and 27°C, and relative humidity between 20% and 75% (Olgyay 1973). Air conditioning buildings in hot and humid climate allows air leakage creating considerable energy losses (Boonyatikarn 2002). Appropriate door layout designing is essential in order to prevent outside temperature and relative humidity, which are higher, entering into buildings. Energy consumption increases every year due to an economic growth in Thailand. Opening of numerous super stores and shopping malls in Thailand is a sign of the growth. Typically, at the entrances of these stores they usually install air curtains. They are designed to keep cold air generating by air conditioning system on the inside and prevent hot air on the outside getting into buildings. A laminar stream of air with sufficient quantity and speeds generating by several fans or air blowers is a main mechanism of this appliance. As a result, electricity is used in operating the appliance. The use of a double door system prevents loss of cold air from the inside. The system comprises of two series of doors with spaces in between them working as a mix temperature room and consumes no electricity. However, which layouts of double door systems should be installed and what percentage of the electricity could be saved are not known. As a result, there is a need for an experimental study to be conducted in order to determine what kind of double door system is appropriate for using in hot and humid climate.

The paper describes the comparison of energy consumption between systems using air curtain with single or double in maintaining temperature in the air conditioning room in hot and humid area.

Nine types of doors are attached with a standard room, which is equipped with a wall mounted air conditioning unit. During the data collection, room temperature is maintained at 25°C and the frequency of traffic using the doors are specified at 30 openings per hour.

2. Methodology

In this study, nine experiments are performed in an 18 square meter room, which is attached with a wall mounted air conditioning unit. It has a cooling capacity of 12,129 Btu/Hr or 3,555 Watts, and an energy efficiency rating (EER) of 3.19. Four sides of walls are drywall systems, which are a combination of 12 millimeter thick gypsum boards and galvanized steel studs. Ceiling is finished by a t-bar system, which is a combination of 9 millimeter thick gypsum boards and T shaped aluminum frame. Each experiment has specific characteristics and construction costs as presented in Table 1. The attached air curtain has a total input of 50 Watts and an air velocity of 8.8 meter per second. Fig 1 presents floor plans of experiments one to three for rooms equipped with air curtain and attached with single doors opening out, opening in, and sliding, respectively.

Table 1. Characteristic and Cost Information of Nine Experiments

Experiment	Characteristic of Each Experiment			Costs (Baht)		
	Single Door	**Double Door**	**Air Curtain**	**Door+Ceiling+Wall**	**Air Curtain**	**Total System**
1	Open Out	-	Yes	-	12,000	12,000
2	Open In	-	Yes	-	12,000	12,000
3	Slide	-	Yes	-	12,000	12,000
4	-	Parallel - Open Out	No	15,060	-	15,060
5	-	Parallel - Open In	No	15,060	-	15,060
6	-	Parallel - Slide	No	15,260	-	15,260
7	-	Perpendicular - Open Out	No	15,060	-	15,060
8	-	Perpendicular - Open In	No	15,060	-	15,060
9	-	Perpendicular - Slide	No	15,260	-	15,260

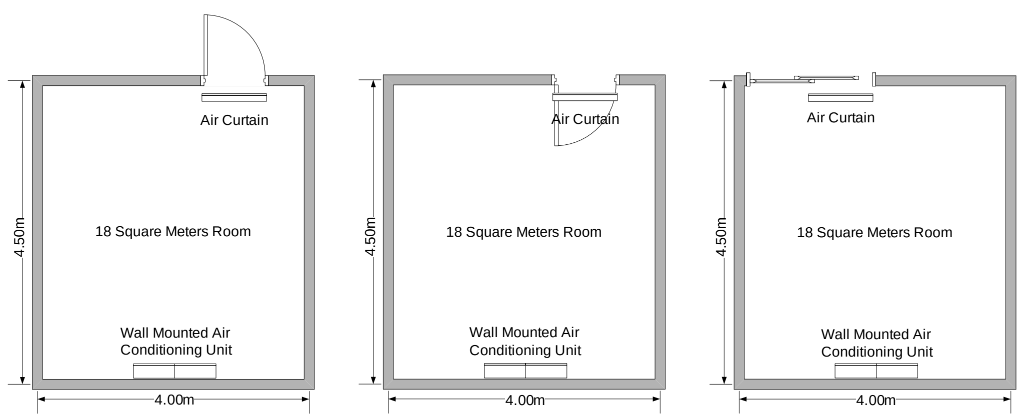

Fig. 1 Floor Plan of Experiments 1 – 3: A Single Door with Air Curtain

Fig. 2 presents floor plans of experiments four to six for rooms attached with parallel double doors opening out, opening in, and sliding, respectively.

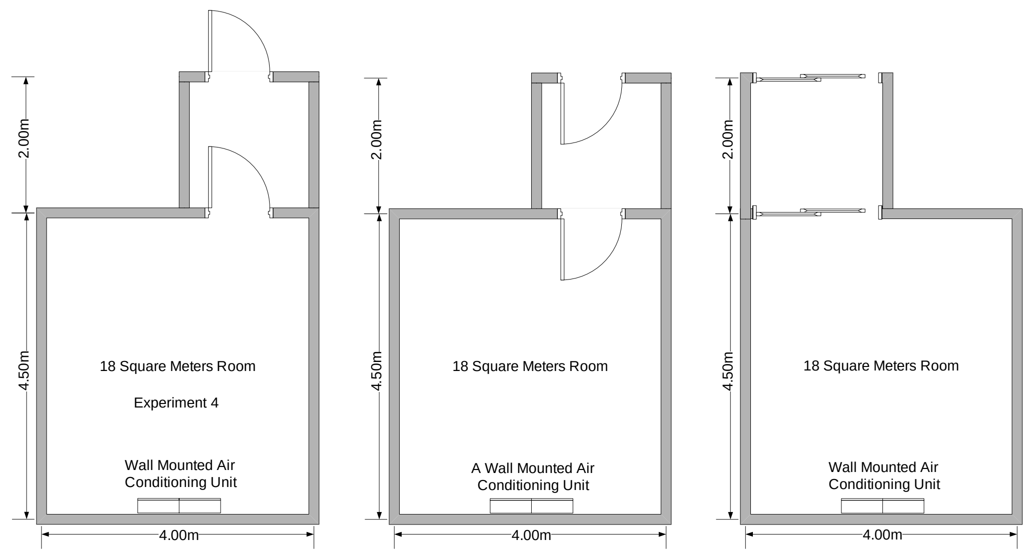

Fig. 2 Floor Plan of Experiments 4 – 6: A Double Parallel Door

Fig. 3 presents floor plans of experiments seven to nine for rooms attached with perpendicular double doors opening out, opening in, and sliding, respectively.

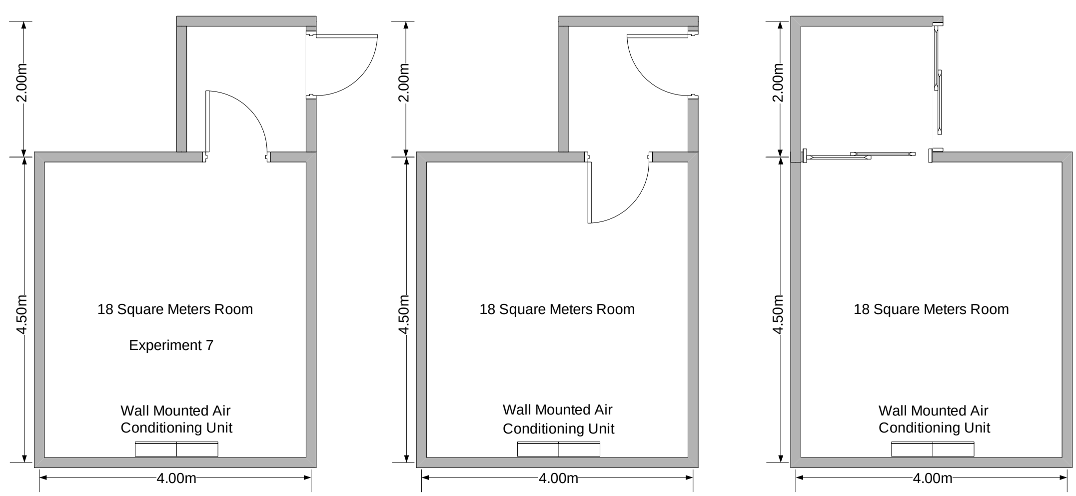

Fig. 3 Floor Plan of Experiments 7 – 9: A Double Perpendicular Door

Fig. 4 presents an exterior view of an experimental room which is air tight. Each experiment is performed for two days. In each day, the experiments are performed two times, which are between 6:00 to 8:00 and 18:00 to 20:00. The experiments start when an air conditioning is turned on and room temperature cool down to 25°C. Energy consumptions in kilo Watts (kW) are recorded during data collection using a digital electricity consumption reader which transfers data to a computer by a data logger software. Examples of recorded data for a period of two hours are presented in Figure 5. During the two hour experiment, there are 7,200 seconds as shown on the x-axis. The kilowatt-second is dropped from 0.31 to 0.03 kilowatt-second where the air compressor did not work. While the data is logged, a lab boy walks through the door by open it at full swing or slide for 60 times at 2 minutes interval during the two hours. Two thermocouples type K and two humidity transmitters are placed inside the room and outside the room in order to record room temperature and relative humidity and climate temperature and relative humidity. These tools are placed at the same position in every experiments. The temperature and relative humidity are read three times during the two hour period. The first time is recorded after the first opening; the second time is recorded after the 30th opening, and the last time after the 60th opening. These three values of the temperature and relative humidity are then averaged and presented in the forth and fifth columns of Tables 2 and 3 for the morning and afternoon periods, respectively. Due to impact of high relative humidity during raining, data collection was not permitted during raining and after raining for one hour, where the climate relative humidity is over 90%.

Fig. 4 An Experimental Room

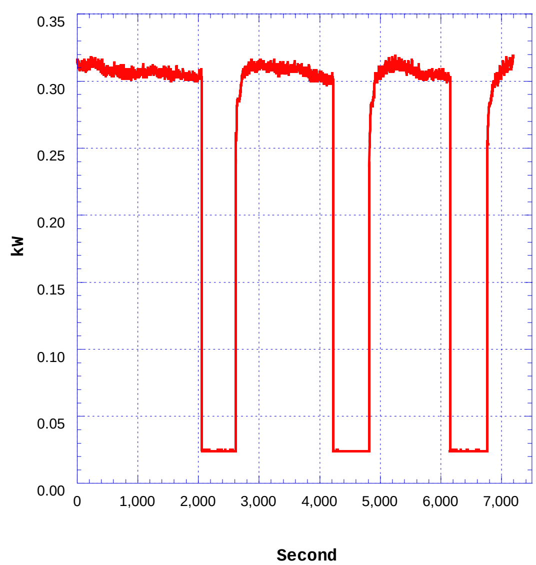

Fig. 5 An Example of a Kilo-Watt Profile During the Two Hour Experiment

3. Analysis

After completing data collection for nine experiments, the kilo Watt – Hours are determined by accumulating the kilo Watt – Seconds during the two hour period and divided with 3,600 seconds. Since we performed experiments for two consecutive days, therefore, the averaged kilo Watt – Hours for the morning and afternoon periods are calculated and presented separately in the last column of Table 2 and Table 3, respectively. Experiments one to three are considered as based alternatives, which are compared to experiments four to nine. Alternatives 4, 5, 7, and 8 require more installation costs than alternatives one to three for 3,060 Baht. Meanwhile, alternatives 6 and 9 require more installation costs than alternatives one to three for 3,260 Baht. The alternatives, moreover, require more spaces than the based alternatives for 4 square meters. Each experiment is performed individually at different times due to limited spaces and budget. As a result, certain inconsistency variables are expected such as different climate temperature and relative humidity varies throughout experimental programs.

Table 2. Incremental Costs, Extra Spaces, Average Temperature and Relative humidity of the Experiments for Morning Period

Experiment	Incremental Costs (Baht)	Extra Spaces Required (sq.m.)	Average Temperature	Average Humidity	Average kWH
1	-	0	27.50	82.00	0.34
2	-	0	27.50	83.50	0.44
3	-	0	28.50	86.00	0.35
4	3,060	4	29.50	85.00	0.36
5	3,060	4	30.00	72.00	0.32
6	3,260	4	27.50	76.00	0.17
7	3,060	4	28.00	76.50	0.16
8	3,060	4	28.00	77.00	0.20
9	3,260	4	29.50	77.00	0.20

Table 3. Incremental Costs, Extra Spaces, Average Temperature and Relative humidity of the Experiments for Afternoon Period

Experiment	Incremental Costs (Baht)	Extra Spaces Required (sq.m.)	Average Temperature	Average Humidity	Average kWH
1	-	0	25.00	81.00	0.47
2	-	0	28.00	84.00	0.51
3	-	0	27.00	84.00	0.48
4	3,060	4	28.50	73.50	0.38
5	3,060	4	25.50	70.00	0.22
6	3,260	4	29.00	83.00	0.39
7	3,060	4	28.00	73.50	0.29
8	3,060	4	27.50	72.00	0.28
9	3,260	4	27.50	70.50	0.30

4. Results

From the averaged kilo Watt – Hours shown in Tables 2 and 3, we can calculate monthly kilo Watt – Hours based on an operating assumption of 8 hours per day and 30 days per month as presented in the second column of Tables 4 and 5. The monthly kilo Watt – Hours shown in the second column are not rounded off. Monthly electricity expenses are calculated using combination of two unit rates, which are electricity costs of 1.8047 Baht/kW and FT Costs of 0.7584 Baht/kW. FT cost is varied based on energy price in the world market. Therefore, total monthly electricity expenses for morning and afternoon can be calculated as presented in the third columns of Tables 4 and 5, respectively.

Table 4. Monthly kW, Cost, and Annual Return of the Experiments for Morning Period

Experiment	Monthly kW	Total Monthly Electricity Expenses (Baht)	Monthly Saving (Baht)	Yearly Saving (Baht)	Annual Return %
1	82.03	210.25	-	-	-
2	104.77	268.53	-	-	-
3	84.04	215.41	-	-	-
4	86.24	221.05	10.35	124.16	4%
5	76.00	194.79	36.61	439.28	14%
6	41.49	106.34	125.06	1500.68	46%
7	38.97	99.87	131.53	1578.32	52%
8	47.19	120.96	110.44	1325.24	43%
9	47.64	122.12	109.28	1311.32	40%

Table 5. Monthly kW, Cost, and Annual Return of the Experiments for Afternoon Period

Experiment	Monthly kW	Total Monthly Electricity Expenses (Baht)	Monthly Saving (Baht)	Yearly Saving (Baht)	Annual Return %
1	113.26	290.30	-	-	-
2	122.71	314.52	-	-	-
3	114.88	294.45	-	-	-
4	90.31	231.48	68.28	819.32	27%
5	52.30	134.04	165.72	1988.60	65%
6	94.32	241.75	58.01	696.08	21%
7	70.40	180.45	119.31	1431.68	47%
8	67.04	171.83	127.93	1535.12	50%
9	71.68	183.71	116.05	1392.56	43%

Averaged monthly expenses of the first three experiments can be calculated as following:

$$\text{Average Monthly Expenses for Morning Period} = \frac{210.25 + 268.53 + 215.41}{3} = 231.40$$

$$\text{Average Monthly Expenses for Afternoon Period} = \frac{290.30 + 314.52 + 294.45}{3} = 299.76$$

These monthly expenses are averaged to compare with monthly expenses for experiments 4 to 9, and presented in terms of monthly cost saving and yearly cost saving as presented in Columns 4 and 5 of Tables 4 and 5. Annual return in percentage can be calculated by dividing yearly cost saving with incremental cost from Tables 2 and 3 for each experiment and presented in the last column of Tables 4 and 5. Therefore, the installation costs of double door system can be recovered in approximately between 1.5 to 5 years varying case by case.

Conclusions and Recommendations

Temperature, relative humidity, and electricity expense for single and double doors are grouped, averaged, and presented in Tables 6. It is obvious that averaging relative humidity of experiments 1 to 3 are higher than experiments 4 to 9 since experiments 1 to 3 are performed during the end of rainy season, while experiments 4 to 9 are performed during the beginning of summer season. Moreover, afternoon experiments use more energy power than morning experiments in maintaining room temperature at 25°C due to cumulative heat absorbed by a building during a day. As a result, yearly electricity expenses of afternoon experiments are higher than morning experiments. Yearly electricity expenses between single and double door systems are compared. It is found that the electricity expenses of the double door systems are 37.69% and 36.43% less than the single door systems for morning and afternoon experiment, respectively.

Table 6. Comparing Averaged Temperature, Relative humidity, and Electricity Expenses of Single VS Double Door Experiments

		Averaged Temperature	Averaged Humidity	Yearly Electricity Expenses(Baht)	% Saving
Morning	Experiment 1-3	27.83	83.83	2,776.76	-
	Experiment 4-9	28.75	77.25	1,730.26	37.69%
Afternoon	Experiment 1-3	26.67	83.00	3,597.08	-
	Experiment 4-9	27.67	73.75	2,286.52	36.43%

However, these saving percentages have not considered impacts from varying temperature and relative humidity. Temperature has more impact on electricity expenses than relative humidity since hot air decreases energy efficiency of air conditioning when entering its fan coil unit. Hot day require more energy in maintaining room temperature than rainy day based on data during experimental program. Morning data will be used to conclude these experimental studies in terms of door layouts and openings due to impacts from accumulated heat inside building. Table 7 summarizes yearly electrical expenses for different door layouts and openings which are calculated from monthly expenses from Table 4. Yearly electricity expenses for experiments 4 can be calculated as follows, while for other experiments can be calculated in the same manner.

Yearly electricity expenses for experiment 4 = 12 x 221.05 = 2,653 Baht

Table 7. Electricity Expenses of Double Door System for Morning Experiments

Types of Opening	Double Parallel Door		Double Perpendicular Door		Average Expenses
	Experiments	Yearly Expenses	Experiments	Yearly Expenses	
Open Out	4	2,653	7	1,198	1,926
Open In	5	2,337	8	1,452	1,895
Slide	6	1,276	9	1,465	1,371

Based on the average yearly electricity expenses shown in Table 7, a sliding double door is recommended to replace a single door attached with air curtain because they offer the lowest average electricity expenses at 1,371 Baht. The yearly electrical expenses of experiment 9 are higher than of experiment 6 due to higher temperature for 2°C and higher relative humidity for 1%. Sliding double doors require slightly more installation cost than double opening doors. However, they offer more energy saving than using opening out and in for 29% and 28%, respectively. The reasons why using sliding doors can save more energy than using opening doors because the air pressure generating when open and close the opening doors is higher than open and close the sliding doors. In conclusion, sliding double door is recommended for using in hot and humid climate temperature because it offers the most saving when compared to other types of doors. Relative humidity and temperature can be fluctuated rapidly in rainy season. Therefore, these two factors are direct impacts to result of this research. For better comparison results in the future, we recommend to perform data collection simultaneously for different room layouts and door openings in order to minimize impacts from such factors.

Acknowledgements

This research is funded by the Office of Policy and Energy Plan, Ministry of Energy, Royal Thai Government. The author is gratefully thank you for her support.

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ENERGY EFFICIENT DESIGN FOR ENVIRONMENTALLY SUSTAINABLE HOTEL INDUSTRY IN MALAYSIA

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Abstract

The shortage of natural resources and environmental pollutions are considered as signs of global warming and serious world climatic problems in the last few decades. Subsequently, environmental conservation has been of increased importance to all economic sectors of the countries. Although many tourism authorities abide to the world acclaimed standards of sustainable hotel design, very few Malaysian hotels were designed to address these issues. To curb the deteriorating situation the Malaysian government imposes a commercial electricity tariff to 12% with the hope to influence Malaysian industries to think 'green' and implement energy efficiency strategies. Environmentally sustainable hotel is the trend to go forward but questions as to what constitute a green hotel varies. This paper investigates the sustainability status of the Malaysian hotel industry as an attempt to produce an environmental checklist. Case studies of hotels from neighboring countries and local hotels are being compared

Keywords: thermal comfort, hotel design, green building

1.0 Introduction

Hotel industry all over the world is profitable depending on its location. However when overheads are high this business may not look interesting anymore. It helps to find ways to improve on reducing overheads without affecting tourism. Energy consumption can be predictable and unpredictable at the same time. It is predictable when the energy tariffs are fixed by the government. But the possibility of further increment by the government may create uneasiness among the hoteliers and therefore some predictable efforts to maintain profits would be taken by them. It was reported that in the hotel industry, it needs energy for maintaining comfort. Air conditioning has to be continuously switched on, otherwise discomfort would chase away the tourist. This item has to be tackled in order to make profit. While doing this it also saves the environment as researches have shown that one of the causes of global warming is the air conditioning. The condensers would blow away hot air to the environment thus adding to the heat island. Any slight leakage would release harmful gas to the atmosphere. It also takes a lot of electricity to operate and electricity comes from burning the fossil fuels which are found to be depleted very fast and the whole thing becomes a vicious circle. So any effort to reduce energy consumption in hotel industry would be very welcomed by the hotel management and this paper shows the possibility of environmental sustainability for Malaysian hotels.

2.0 Environmentally Sustainable Hotel

Hotels need to provide good facilities for recreation and tourist entertainment, but at the same time they also have a responsibility to conserve the environment that facilitates the tourism development in the first place (Canadian International Development Agency). Environmentally sustainable hotel, often called ‘green hotel’ is designed for environmentally friendly with both the hotel physical elements and conservation activities, such as recycle, reuse and reduce.

Various tourism authorities in other parts of the world have settled for environmental standards or guidelines to be considered as green hotels. By following with the generally accepted guidelines, hotels would be aware of the importance of environmental conservation. This would lead them to implement environmental management practices in order to get certified for recognition. This certification encourages hotel industry to develop the green concept in hotel management that would give them a value added component to attract additional foreign clientele who are inclined towards ecological consciousness (CIDA).

The Green Globe, originally developed by the World Travel & Tourism Council (WTTC) in 1993, is the global benchmarking, certification and environmental improvement system for sustainable travel and tourism. It aims to maintain good environmental and social benefits to all interested parties. In benchmarking Green Globe certifies four standards as checklist namely, (i) company, (ii) community (iii) international ecotourism (iv) design & construct. A new precinct has been under study and is being piloted, that is, planning and development standard. It is hoped that hotels in the world would be able to use this Green Globe which actively upgrades and update its activities and standards. Respective countries base its program entirely from the Green Globe standards or they adopt it as a reference and create their own. The most importance is that hotel industry has an environmental sustainable program. Any programs should contain consideration for major environmental, social and economical issues. Green Globe focused on the following; (a) greenhouse gas emissions (b) energy efficiency, conservation and management (c) management of freshwater resources (d) ecosystem conservation and management (d) management of social and cultural issues (e) land use planning and management (f) air quality protection and noise control (g) waste water management and (h) waste minimization, reuse and recycling.

Most interiors of hotels are air-conditioned and at least 70% of the monthly electricity bills go to paying for cooling purposes in summer condition. In Malaysian climate which is a tropical climate in order to feel thermally comfortable one has to experience constant air movement and be surrounded by cool environment. If one factor is absent there it would be highly unlikely that one would experience a comfortable environment. Therefore passive design elements for individual hotel sites should be studied before building up. According to Malik (2007), normal approach to green hotel design has four stages.

The *first stage* is to incorporate as many passive design elements in the building layout, fabric and envelope. Location, whether the hotel is in the urban or rural areas, on hilltops or at valleys or inland or by the sea, has a lot to do with the surrounding and immediate comfort for the occupants. Urban area will have to think about heat island and how to get rid of them in order to use less energy by using less of air-conditioning, whereas, this by the seaside can optimize the natural phenomenon of the land and sea breeze that can help to lessen the energy load for cooling.

Natural lighting means day-lighting and not direct sunlight. Whether this is optimized or not in hotel design is one good criterion. Also, natural ventilation is normally easier to design for where locations are by the sea or valley slopes because there is a quite predictable air velocity. Greening the walls by creepers and sun-shading are some of the ways and easier to implement to cool the building fabric so that the hard surfaces are not totally exposed to the sun where absorption of heat would warm up the interior by conduction and radiation. Choice of building materials also would help in reducing heat absorption. Exposed concrete is the worst form in tropical climate.

In the *second stage*, the energy efficient active systems (those that use electricity for power such as television, fans, air conditioners, water heater lighting, etc) should replace the obsolete and energy guzzling electrical equipment or appliances. This can either be done gradually so as not to burst the budget or can also be done during revamping.

For the *third stage* an energy management program and committee is to be formed to maintain effectiveness. The energy manager should report the energy consumption from time to time to the board of directors of the hotel management.

Only when budget allows apply the *fourth stage* which is using an alternative energy for power. Installing the photovoltaic system would be a wise move because of the several advantages in this technology. It is quiet in operation, it is almost maintenance free, the energy from the sun is free and also it is clean because there are no toxic gas emissions.

Unfortunately this awareness on the design of energy efficient hotel buildings has been received very little attention. Most tourism authorities overlooked the first strategy but concentrated more towards the active systems and employing best practices in energy consumption. In most case specific guidelines for passive building design is provided by individual accommodation groups, for example 'Six Senses Resorts & Spa' an acknowledged industry leader in environmental responsibility. Nearly forty resorts and spas belong to Six Senses in the world and they are guided in practical environmental hotel design.

It has been observed that successful example of green hotel management program (non passive building design) is often guided by a widely unified foundation. For example, in Thailand the environmental management program is conducted by a tourism authority known as the Green Leaf

Foundation with eighty green leaf hotels in its membership. Member hotels have an environmental committee and the Foundation committee monitors the hotel management. Guests and occupants are amicably informed of the program by well educated staff. This methodical transfer of responsibility is the key to developing a standard green hotel management. Most of member hotels of Green Leaf Foundation in Thailand have already achieved second and third stages of green hotel program.

3.0 A General Survey of Malaysian Hotels Pertaining to Sustainability

Questionnaires and field investigations were carried out to determine the present condition of Malaysian 'green' hotel management. From the questionnaires survey, fourteen respondents were chosen at random from all over Malaysia. About 50% of them are city hotels, 43% are resort hotels, and another 7% are from the suburbs or on top of hills. Entitled as 'The Survey on Malaysian Green Hotel – Sustainable management of energy consumption ', all questions were regarding the effective energy consumption in three categories namely (i) active system (ii) passive design and (iii) environmental management policies. A field investigation was taken at The Frangipani Langkawi Resort and Spa in Langkawi Island, Malaysia, because there was a newspaper review on it claiming to be the most comprehensively practiced in environmental program The resort has received the highest score as Responsible Tourist Award by Wild Asia, and is acknowledged as one of the best environmentally friendly resort in Malaysia.

According to the result of the questionnaire survey, in addition to the standards of environmental effort are not considered as world standards, surprisingly very little attention were given towards passive building design elements as part of green hotel assessment. In a passive design section, positive answers for environmental effort was less than 60% in all questions except for tree planting around the building. Though more than half respondents say they have energy efficient design in their hotels, these designs are not optimized. For example, 57% of respondents answer that their guestrooms are suitably designed for receiving natural cool wind but only 7% of respondents say they do not usually use air-conditioning for guestrooms. From the questionnaire survey most of the respondents did not show interest in minor passive building design elements like green wall or double skin for air-conditioned room.

As for active system, the lighting system was given more attention for effective energy consumption. 93% of respondents answered that they use energy efficient lamps. Another 7% are also in planning stage to change them. Automatic lighting on/off system is employed by all respondent hotels. Apart from changing to the more energy efficient light bulbs, other initiatives taken are the campaigns to create awareness. As expected, most of hotels provide thermal comfort by using air-conditioning especially at guestrooms and offices. The average temperature set for air-conditioning is 22.4C even though the researched findings for Malaysian thermal comfort would fall between the range of 24.5C to 28C (Malik, 1993). No photovoltaic system is implemented in any of the respondents as it was deemed too costly to recover the profits over a payback period of 25 years. Understandably, hotel industry needs to make profit returns immediately in order to sustain employment. This was considered as the priority than the environment though the advantages of photovoltaic were shown at many fields.

From the survey it was observed that environmental management has been ad hoc in nature in most of the hotel management. Only 50% of respondents have environmental management office or committee in their hotels. 20% of hotels have never held any environmental education for staff. Though 72% of hotels educate their staff, not all of them are trained by professionals. Interestingly, 79% of hotels ask their guests to cooperate energy saving program.

The field investigations have shown the possibility that introducing environmental management committee would be the easiest and inexpensive strategy for Malaysian hotel industry. The Frangipani Langkawi Resort & Spa, Langkawi Island, have been assertive on environmental management program thoroughly striving to meet acceptable standards in all areas, such as in since early 2007 it has implemented and succeeded in its recycling and reuse programs. The buildings are heavily landscaped as many as possible thus adopting the element of passive design. During daytime guest rooms receive sunlight through transparent eaves which is covered with palm leaves. Air-conditioned are switched on only for particular rooms in times of need. The environmental office section in Frangipani Langkawi has found that its energy consumption has been decreasing since it started the program of environmental

consciousness. The success of this environmental program is credited to the owner of Frangipani, Anthony Wong who has been appointed as the Subcommittee Chairman for Local Agenda 21 on the Environment.
From the survey environmentally sustainable issues in present day for Malaysian hotel industry are as listed below;

1. As in other parts of the world there seems to be either of little interest and knowledge or ignorance in passive building design elements. Probably this is due to the absence of any guidelines on this aspect as this approach needs professional advice.
2. Ineffective use of mechanical appliances and equipment especially in thermal control. Hotels should have knowledge of proper thermal comfort to reduce wasting of energy.
3. Lack of awareness as to the cause of global warming and therefore only few hotels have an environmental department in their management.

Thus to create some awareness starting off with the initiatives toward environmental management for Malaysian hotel industry, this paper set out to study one of the elements in the first strategy i.e. the passive building design. This paper would not be able to cover all the strategies required to reduce energy consumption without compromising of thermal comfort for occupants but would show that approaching the first strategy i.e. redesign and retrofitting with passive building elements. A template of passive building design for Malaysian hotel is proposed and a case study has been carried out to test the template.

4.0 Proposed Template for Passive Solar Building Design Elements for Malaysian Hotels

This proposed template is meant for either proposed building or existing, in tropical climates. Malaysia lies near the Equator and the temperature ranges between 21^0C to 32^0C in daytime. According to ASHRAE 55 (2004), comfort zone for summer condition is between 23^0C to 26^0C at 50% relative humidity and at 0.25m/s air velocity. However, in Malaysia an average is high at about 70-80% humidity with 0.4 to 0.5 m/s airflow (World Travel Guide, 2007). Based on Malaysian climate condition, Abdul Malik (1993) reviewed comfort zone proposed by ASHRAE (2004) and did his researched on Malaysians. It was found to be between 24.5^0C to 28^0C. The proposed template is created fully bearing in mind to achieve these comfort conditions as its benchmark (Fig. 2).

		Yes	No
Environmental Hotel Management > Resource Saving > Passive System			
Environmental Hotel Management > Resource Saving > Passive System > Location (Orientation)			
1.	Locating at place abundant in cool breeze		
2.	Locating at waterside such as the sea, pond or river		
3.	A lot of trees or green surrounding the site		
4.	Locating avoiding obstacle which shut out sunlight upon the building		
5.	Any environmental advantage at the site		
6.	East to west building orientation		
7.	Orienting considering receiving natural wind		
8.	Avoiding the sunlight from the west		
Environmental Hotel Management > Resource Saving > Passive System > Greening and Shading			
9.	Planting green on the building exterior wall		
10.	Covering roof with green		
11.	Surrounded with plentiful green		
Environmental Hotel Management > Resource Saving > Passive System > Material			
12.	Use of Exterior wall which does not easily absorb the radiant heat		
13.	Avoiding dark colored exterior wall		

			Lobby	Lounge	Restaurant	Kitchen	Shop	Guestroom	Office	Back Yard
Resource Saving > Passive System > Natural Lighting										
14.	Sufficient openings or skylight to receive sunlight	Yes								
		No								
15.	Use of sunlight instead of artificial lamp when possible	Yes								
		No								
16.	Reflective interior wall to diffuse sunlight	Yes								
		No								
17.	Double or triple window to avoid radiant heat receiving sunlight	Yes								
		No								
Environmental Hotel Management > Resource Saving > Passive System > Natural Ventilation										
18.	More than two openings or air vent in a room	Yes								
		No								
19.	Natural wind use more than electorical cooling equipment	Yes								
		No								
20.	Turning off air-conditioner or fun then take in natural wind when the temperature is less than 26°C	Yes								
		No								
21.	Adequate shading to avoid radiant heat receiving cool wind	Yes								
		No								
Environmental Hotel Management > Resource Saving > Passive System > Double skin and Insulation										
22.	Double skin for air-conditioned room	Yes or Not air-conditioned								
		No								
23.	Insulation for air-conditioned room	Yes or Not air-conditioned								
		No								

Fig. 1: Checklist for Passive Building Design Elements

5.0 A Case Study: A Beach Hotel at Tanjung Bungah, Penang

Objective:	To determine the average thermal condition when the hotel completely followed the template so that necessity and precision of the template would be found.
Study area:	Hotel lobby of beach hotel
Location:	Tanjung Bungah, Penang, Malaysia
Research:	Measuring air velocity, air temperature and relative humidity using BABUC environmental data logger.
Duration:	One week

In order to test the template, a case study has been carried out at a hotel lobby in Penang. The test limits itself to natural ventilation section in a template of passive building design. The tested hotel marked all 'yes' to the colored questions in above template; some questions about location and all questions about natural ventilation for a lobby.

Fig. 2 indicates natural ventilation in the tested beach hotel. The hotel lies beside the sea (Question 1&2) and the building opens itself toward the sea. This hotel opens the main entrance door most of the time (Question 18) so the land and sea breeze phenomenon can occur at the lobby. During daytime, the land being highly dense than the sea water is heated more rapidly. Heated air rises up and low pressure zone is created. This low pressure zone is filled up with relatively cooler air from above the sea, namely thermo-siphon. At night time reverse process occurs as dense land is cooled more rapidly than the sea.

In this beach hotel, the lobby is not designed with air-conditioning (Question 19&20). The measuring equipment, the BABUC environmental data logger, is placed at the lobby to measure the air temperature, the relative humidity and the wind speed under shaded condition. Readings of every fifteen minutes intervals were continuously taken for 24 hours for 8 days beginning from 2nd April to 9th April 2007.

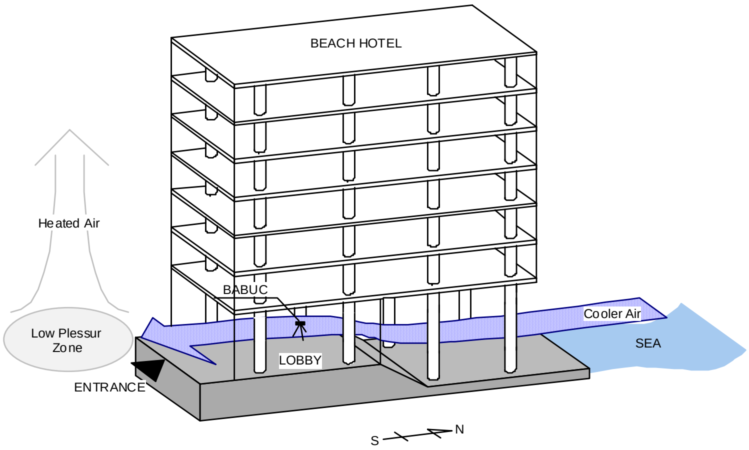

Fig. 2: Diagrammatic perspective and air movement of the hotel

Fig. 3 shows the averages of air temperature, relative humidity and air velocity at the beach hotel. It was observed that range of the air temperature at the hotel lobby was between 25^{0}C to 30^{0}C that averaged about 28^{0}C. The coolest time zone is between 6.00am to 9.00am and the temperature is about 26.5^{0}C at that time. Just after 8.00am, the air temperature starts to ascend and peaked between 3.30pm to 6.00pm at about 30.5^{0}C. A difference between coolest and warmest temperature is about 4C in a typical day. Though the temperature ascended from lowest to highest for 8 hours, the rate of descending is much more gradual (Fig. 3).

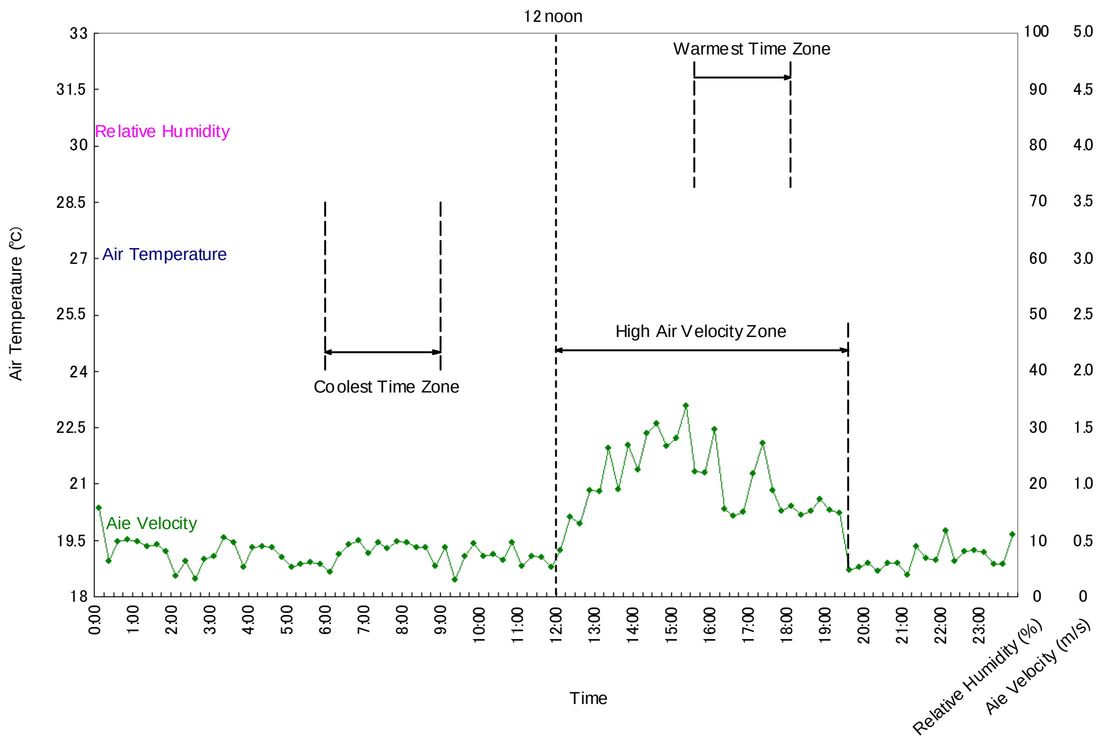

Fig. 3: Average of Air Temperature, Relative Humidity and Air Velocity at Hotel Lobby (2– 9/04/2007)

It was observed that the range of air velocity was between 0 m/s to 1.0 m/s beginning from 8.00pm to 12.00 noon. Between 12 noon to 7.30pm, air velocity is much higher. Range of high air velocities was between 0.5m/s to 3m/s and occasionally velocities of more than 3.5 m/s was recorded. It was also observed that the rate of ascending and descending are quite similar.

The Standard Effective Temperature (SET) is calculated by inputting the recorded data of the three climatic elements using the software Thermal Comfort Program created by ASHRAE. It is the interaction among these three climatic elements that would give us the thermal sensation feeling of the skin. Fig. 4 shows the SET at a metabolic rate of 1.0met and clothing level of 0.6clo. The most noticeable difference between the air temperature and SET is that the SET shows three peaks in a day as compared to the performance by air temperature alone which has only one peak. Each peak is at 2.00am, 12.30pm and 6.30pm and then a gradual descend for 3 to 4.5 hours. An shaded zone in the Fig. 5 is a comfort zone for Malaysia. According to Fig. 5, SET is almost in comfort zone between 3.00am to 10.00am (zone 2) and 1.00pm to 4.00pm (zone 4). When there were higher air velocities the percentage of relative humidity shows gradual declining and it caused reduction in SET was seen between 1.00pm to 4.00pm.

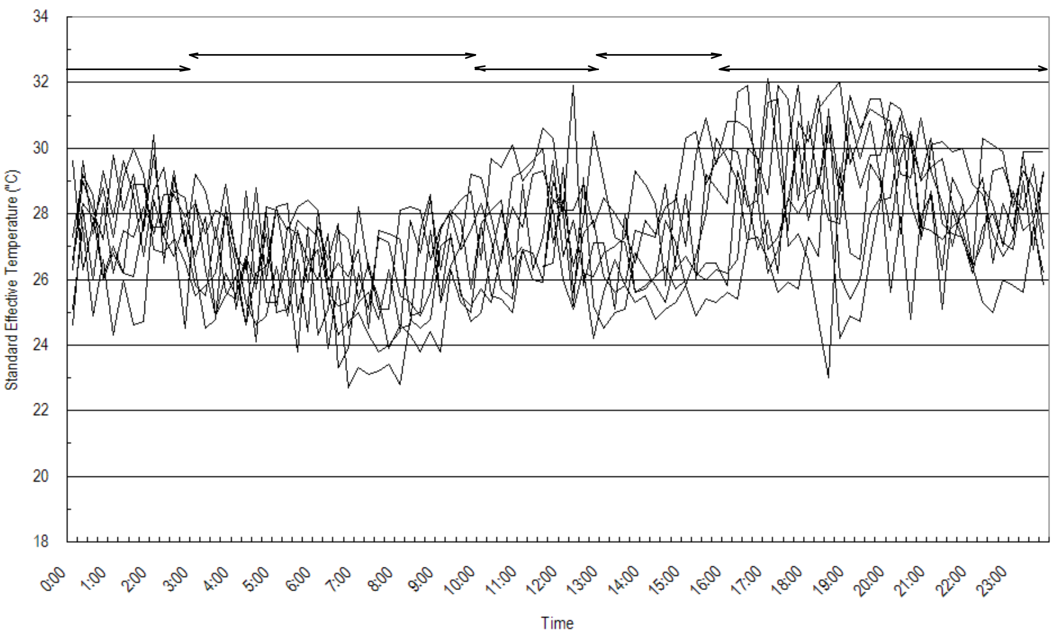

Fig. 4: Standard Effective Temperature at Hotel Lobby (2– 9/04/2007)

6.0 Discussion and Conclusion

There are many passive building design elements that can be utilized to help alleviate the heating problems of the building fabric in tropical climate. It depends largely on the location. Normally buildings by the seaside are premium for hotel industry because of the beaches. The land and sea breeze phenomenon is then the most predominant passive design elements for the location. The above experiment shows this land and sea breeze can help reduce the dependence on electricity to cool the hotel lobby, thus a significance savings without compromising thermal comfort. Therefore the template of passive building design is an essential tool to propose practical green hotel guidelines. This study was done to propose the template through a case study.

Most hotel lobbies in Malaysia are cooled by air-conditioning throughout a day. As a result of that, hotel management is uneasy with the high tariff of 12% charges on electricity for air-conditioning which takes up about 70 percent of entirely electricity bill. An observation in most hotel lobbies show that air conditioned hotel lobbies are normally set at the temperature of less than 22^0C which is much below the stipulated 24^0C. The bigger the difference of inside and outside air temperatures would consume more electrical power. The rule is to narrow the difference and savings can be obtained.

Suggestions from this study would be as follows:

1. When beach hotels follow the proposed template and adopt land and sea breeze ventilation, it would be provide comfortable thermal condition for at least 10 hours a day without any electrical equipment. Considering that there are not many people in the lobby at midnight, there is comfort environment for about 60 percent of a day without energy consumption.

2. Instead of 24 hours air-conditioning, the lobby can be designed to use air-conditioned only during the times when there is air temperature equilibrium, i.e. the air temperature inside and outside are almost the same. When they are almost the same no wind can be present, as wind occurs only when there is a temperature difference. Referring to Graph 4, the possible strategy to take is that air-conditioning may only be used when the SET is not in comfort zone i.e. from 4.00pm to 3.00am and 10.00am to 1.00pm.

3. And as an alternative, for those existing beach hotels, renovation by opening up the lobby would be recommended, but if not possible then increasing the temperature from 22^0C to 24.5^0C is suggested. A 2.5^0C can save a significant amount of energy.

4. For further improvement of energy saving and to give more comfort for the occupants or tourists, fans are proposed to be installed instead of air-conditioning during those times where equilibrium of air temperatures are experienced (i.e. when there is no wind). Though they also consume electricity, the amount of consumption is much lower than for air-conditioners.

A growing number of hotels in the United States are registering for green certification. According to Bill Connors, the executive director of the National Business Travel Association in the USA, environmental issues are becoming one of the in-thing and hottest concerns within the travel and tourism industry right now. Thailand hotels are also going towards this direction and have become quite established in this South East Asian region. Malaysian Hotels Association should take heed by having a concerted effort and not leave individual hotels to fend themselves. There should be greater awareness by working together with other associations like the Malaysian Energy Center (MEC), the Ministry of Energy, Water & Communications (MEWC) and also with the Center for Education and Training of Renewable Energy and Energy Efficiency (CETREE). So hotels are not only rated as 3, 4 or 5 stars for its services but also on its environmental friendly programs as well, for example in hotels in Thailand being rated as one to five green leaves. In many cases, environmental friendly programs are also business friendly as well. Since the cost of fuel is gradually rising as time goes on, these programs are considered smart investments.

Acknowledgement

The authors would like to thank the Univerisiti Sains Malaysia for the grant given to make the research a success. This measurement has never been attempted before and the findings do help to contribute to the knowledge on passive design elements especially for the microclimatic conditions.

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News Straits Times, Friday, June 29, 2007

A CHINESE VISION FOR SUSTAINABLE CITIES: COMPACT CITY, LIFESTYLE, AND PERSONAL ASPIRATION

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Abstract

The paper discusses challenges, issues and opportunities confronting the city planners of Contemporary China. It was the late Deng Xiaoping's Post-Marxist Reform of the late Seventies that opened the door for Capitalism for the Socialist state and transformed a nation with 1.3 billion mouths. Overnight, every Chinese is bewildered by the unimaginably diversity of irresistible temptations of materialistic proficiency, and with it the pride of achievement and more importantly elevated self-esteem at an individual and national level. On the other hand, the phenomenon growth in finance, economics and transformation of city images ignite a neo-class struggle because of disparity of wealth, and dismays of the enormous underprivileged. The facelift of physical facilities and outlook of cities prompted a horrifying rate of urbanization and demography -- influx of population from rural to urban. All of these give rise to a revolutionary change in the social structure and personal values.

The prevailing urban form that infested the 700 or so Chinese cities is the compact mixed land use city model, better described as high-density and even high-rise city in contrary to the western model of a sprawl city. What then are the pros and cons of the compact city model? What are the challenges and solutions that Chinese planners have resolved? The paper analyzes the success and failing of the mixed land use planning approach based on a sustainability framework (comprising social, economics and environmental criteria) explained by selected case studies such as Hong Kong and Guangzhou which have been instrumental for many of the mainland cities at the eve of the Open Door Reform. Finally, the discussion is concluded by a reference to the new vision for sustainable urban form by the case study of Beijing, Shanghai, and Hangzhou to illustrate the new approaches for Chinese cities.

1. Introduction

The 1978 'Open-door' policy jump-started the economic and social reform of Chinese cities. The backbone of the policy is based upon an ideological mind-shift from a Stalinist-Socialistic doctrine to the Deng Xiaoping doctrine of Socialistic Capitalism. Deng's interpretation of a new doctrine in 1982 provided a unique framework for changes. His vision motivated the State and individuals to engage in a pursuit for economic advancement of the nation as an entity. In the short run, Hong Kong and Macau's return to the Chinese sovereignty in 1997 and 1999 respectively provided a booster for the Chinese reform by way of the two capitalistic economies' fusion with the motherland cities via the formation of the Pearl River Delta – PRD economic region in 2005, a thirteen-cities economic network that unites Hong Kong, Macau and adjacent cities in the Guangdong province; and the further expansion of the PRD into a province-based economic network in 2006 (known as the Greater Pan Pearl River Delta network or GPRD) that unites Hong Kong, Macau and nine other provinces in the South-western China (the so-called 9+2). In the long run, China's successful inclusion in the World Trade Organization WTO in 2001 paved a progressional economic reform towards an open market. Today, China experiences a phenomenon economic growth rate in her domestic market: 7.1% for 1999, 8.0% for 2000, 7.5% for 2001, 8.3% for 2002, and 9.29% for 2003 (the World Development Indicators). In this economic revolution, the thirteen billion population that comprises 56 ethnic groups bear witness to a complete change of personal and institutional attitudes, and priorities that in turn shape urbanite's vision for the 667 cities (http://www.chinaculture.org, the Ministry of Culture, China). Essentially, the changes may be summarized by an ultra growth in economical, societal as well as physical entities of the cities. Firstly, the city as an economic powerhouse continues to draw in population from the rural and country areas. As a result, it is not surprising to find that the rate of urbanization in China has grown to 42.99% in 2005, threatening the existence of the rural and suburban settlements (http://society.people.com.cn/GB/1063/4622522.html). On the downside, the concentration of population in the urban areas constitutes a number of near unsolvable problems for the city managers – for example, shortage of housing and infrastructural facilities (transport, education, medical and social support, etc.), rise in crimes and social friction due to economic disparity in the society – for instance, the issue of deprived social status versus the economic contribution of migrant workforce (majority came from the less developed countryside) is not a unique Chinese problem but a global occurrence and concern for urban managers and policymakers.

Secondly, the change in the physical realm of the city brought about irreversible changes of the character and identity of the city. For example the Pudong New District in Shanghai which started the economic transformation in 1990 was successful to inject a new image of China in the world arena (www.china.org.cn/chinese/2005/Apr/841219.htm). In this example, the emergence of high-rise office and sky-reaching residential buildings, rings and rings of elevated highways that encircle the city like a womb is being praised as an instant 'facelift' that symbolizes a modernized nation. The invitation of world renowned architects and planners to re-planning the expanding city and designing new buildings appeals to city administrators as a quick-fix method to achieve a city facelift (the same belief has been practiced in many other cities such as Berlin, Barcelona, Singapore and others). But the underlying fact is that the quick-fix might not be a desirable remedy in the long run. Take Guangdong and Shenzhen as an example, the twin cities who have topped the nation in GNP for 13 consecutive years since 1993 are well known to be suffering from a striking rate of deforestation, deterioration of water, air quality and the lose of arid land. The irony to this paradoxical economic achievement is that economic supremacy has a high price to pay if no heeds are given to the concern for urban sustainability. In this case, the two cities have been threatened as a livable city because of severe environmental pollution for there is hardly any balanced growth in terms of sustainable development. Fortunately, recent evidences shown that the cities have begun measures to mitigate serious environmental deterioration. Attempts are made by the local governments to arouse the awareness of stakeholders such as real estate developers, industrialists and others to include sustainability as an agenda in building and construction activities.

The Ministry of Construction has recently (July 2006) implemented a series of planning control measures that are targeted to lower the risk of an economic bubble burst due to an overheated property market nationwide. One of the new checking measures are the prohibiting of the supply of deluxe houses, and the restriction of large size apartments (above ninety square meters) for new projects. (Source: http://www.gov.cn/zwgk/2006-05/29/content_294450.htm) Besides, the Ministry also advocated the incorporation of sustainability as a design agenda for new developments. (http://www.cin.gov.cn/green/file/05062302.htm) Real estate developers are encouraged to embrace sustainability in their new projects -- a recent wave that brought a collage of green demonstration projects all over the nation.

As noted by Huston Eubank CEO of the World Green Building Council WGBC at the closing of a green building conference in Taiwan (2006), the government-led, top-down approach seems to be a typical way for effective enforcement of policies and actions for most Asian nations such as China, Singapore and others. For instance, in the area of greening of buildings, the NGO-led initiatives in Hong Kong have brought a mere 200 certified green buildings in the twelve years of introducing a green building labeling system despite an active property and construction sector. On the other hand, the Taiwanese government led initiatives have achieved in the successful renovation of 600 or more public buildings for the green building label in a mere 5 years. In 2005, a number of Japanese city governments introduced mandatory enforcement of their green building label scheme.

2. Future Vision- an Event City

"For a better urban living" is the vision of the Shanghai Expo 2010 that could be used to illuminate one of the Chinese visions. The realization of the cited vision is echoed by a wave of urban enhancement of the Chinese cities. An example may be the resumption of occupied land and turning them into green spaces and parks in the inner city of Shanghai. With the increasing awareness of the positive effect of vegetation on the urban environment, the Administration of Shanghai has set out a green campaign in order to build Shanghai into a "garden city". Till year 2003, the green ratio, the green coverage and the public green area per citizen of Shanghai has reached 34.51%, 35.72%, and 9.20m2, respectively.

The formation of the Green Land Corporation, for instance, is a Shanghai government owned company set up to oversee the land use conversion process- turning public or private land into amenity space for the city dwellers.

Private developments also responded to the new vision by creating handsome amenity space for public usage such as publicly accessible water-theme parks connecting existing communities and new developments. This man-made oasis approach is a common planning feature in the new towns.

Besides upgrading city living with green spaces and parks, recent years saw major operatives in the upgrading of the city's infrastructure such as airports, intra and intercity transportation – airports, high-speed trains, subways, road networks, hospitals and education facilities.

Besides these huge infrastructure programmes, perhaps the most debatable initiative is the central government's decision to encourage private car ownership for all, especially, the big cities, one of which is Beijing that represents the tragic scenario of an ill-fated automobile-city. A popular joke was made of the air pollution caused by cars, which tells of the presence of a ring of thick, bad smog in the sky circulating over Beijing used by air pilots as a navigation beacon. In actual fact, the land transporter would find traffic jam an unbearable nuisance and a time killer besides air pollution and those heart-breaking episodes of traffic accidents on highways that might be attributed by the rapidly increase of cars on the roads. What is worst is when Beijing's model for a car-city has been copied by many other cities; Shanghai, Guangzhou and Shenzhen, to name those obvious ones, have all been infested with the bad consequence of a frantic attachment to car-city as a symbol for economic success. So the vision for a future city based on cars is a debatable vision.

Finally, a vision for the future Chinese cities may be seen in the central government's strategic grouping of 'city belt or corridor'. Three major economic corridors are being proposed based on the geographical localities of the Chinese mother-rivers. To the north, there is the ' Tianjin-Beijing' group with Beijing as the lead city. To the Southeast, there is the Changjiang group with Shanghai, Hangzhou and Nanjing as the lead cities.

In the South, there is the Zhujiang cities corridor with Hong Kong and Guangzhou as the economic, financial and

vindustrial leaders. The objective is to achieve a balanced economic growth for the cities of China in the long run by means of naming the leaders respectively and in so doing neutralize and eliminate any hostile competitions among the strong ones. For instance, there was a sense of hostility when Hong Kong reunited with its motherland in 1997, her future role for China as the financial hub-city was challenged by Shanghai; and Hong Kong as a container port was threatened by many such as neighboring Guangzhou.

3. Choices of an Urban Form

One of the major characteristics of Chinese cities and their new towns is the predominance of a vertical urban form. In contrary with the Western doctrine that disfavors high-rise living, the towers are a common sight of budding cities. The high-rise building is a provider for office, industrial (light industry), residential, recreational and ancillary activities, and perhaps more significantly, a symbol for modernization and economic achievement. Typically, it is home to hundreds of families, as a thirty-storey tower would house 200 families or a population of 600. So broadly speaking, a single tower could be translated into a vertical village in a European context. In fact for a lot of the Asian cities such as Seoul and Singapore besides the Chinese cities, everywhere one goes, one is in touch with the high-rise building syndrome. For instance in Shanghai, over 1,800 new high-rise buildings have been constructed in the new district of Pudong (east of River Huangpu) alone in its 16 years of urbanization[1],

[1] http://www.stats-sh.gov.cn/2003shtj/tjnj/nj06.htm?d1=2006tjnj/C1107.htm

known to some critics as an 'instant' city! The race for a vertical skyline goes on as well on the west side of the River Huangpu known as the Puxi district where the old town situated. The Shanghai skyline today parallels that of Manhattan's and projected an eye-struck image of 'our city of future is the vertical city of today' for its visitors.

Another characteristic of the Chinese cities and new towns besides verticality is density. Hong Kong is an extremity in this regard for it possesses as much as 50,000 inhabitants per square kilometer, and an average density of 6,300 inhabitants/square kilometers. Other cities like Macau and Shanghai share the same degree of hyper-density (16,000[2] and 2,145[3] [including the suburb area of Shanghai] average density respectively). Several questions may be asked of the density issue: What are the explanations of hyper-density? Is density refers to population per building area or population density per land area? How does the population react to the density issue? What are the implications of a density city from a socio-cultural perspective, or from a health perspective? These questions are answered in the following paragraphs and sections.

An understanding of a hyper-density urban form may be derived from those statutory provisions that dictate the direction of an urban form. Among the Chinese cities, Hong Kong is the first to embrace high-density whilst under British rule (1840 to 1997). It was her planning regulations of the 1970s that advocated a high-density, high-rise approach by proposing a very high floor-area ratio (FAR) or plot ratio (PR) of 8 for residential re-development and 15 for other land use relative to building height (Buildings Ordinance, 1970). The planning regulations were in effect a reaction towards an unpredicted outbreak of Chinese immigrants into Hong Kong in the era of the Cultural Revolution when the colony was flocked with exodus of immigrants over a very short period of time. Shortage of resources (land, economics and infrastructure, etc.) that could not cope with an unexpected demand for housing prompted the high-density approach. The high floor-area ratio prescribed by the planning regulations ended up in a concentration of tall and mixed use building in the built-up area of the city, producing a unique urban form that was subsequently adopted and copied in the Chinese cities during the Open-door era. In those days, Hong Kong real estate developers as investors are major players in the booming Chinese cities and towns welcomed by the central government's policy of oversea-local joint venture developments. Shortly afterwards, governments of municipalities or new towns saw the high-density land conversion facility as a quick and easy means to generating fast and huge revenue from land sales in an effort to acquire economic strength. Thus the total submission to the high-density and high-rise urban form was met without any idealistic or formalistic questioning.

There is another explanation of the vertical city -- cities such as Pudong was destined to be a high-rise city on day-one for it was the Central Government's motive to showcase the national economic achievement that offers a promising business attraction for oversea investors by means of the creation of an 'instant' city. The choice of a vertical urban form in this latter example might explain why and how an urban form comes into being, from a political rather than a basic need from the population, one might argue.

4. Choices of a Lifestyle

Recently, urban designers and researchers began to be interested in how city inhabitants think about the high-density approach to city form; they examine the constituents of urban forms by deploying theories and investigation techniques from the disciplines of sociology and anthropology. Most studies focus on the subjective responses of the city dwellers – trying to qualify perception and preferences for a particular way of city living. For instance, a survey in 2002 (Lau, 2002) interviewed 100 families who used to stay in high-rise towers provided favorable support for high-rise living.

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[2] http://www.chinaasean.org/news/2005/11/08/42929278930578.html
[3] http://www.stats-sh.gov.cn/2003shtj/tjnj/nj06.htm?d1=2006tjnj/C0302.htm

5. Advantages of high-rise living

84% of the user-residents think that view is the main advantage of living in a high-rise apartment. Apart from view from the apartment, a lot of people considering quiet environment (47%) and fresh air (44%) important advantages of high-rise living as well.

6. Preferable Housing Types

77% of the user-residents prefer high-rise living. Most of the others (16%) prefer houses; only 7% of families questioned prefer low-rise living

The trade-off for an otherwise better living such as a single house is an overwhelming favoritism for convenience, efficiency and proximity to workplace. This single reply signifies a fundamental cultural difference and attitude for a particular urban form. Most of the families interviewed prefer to reside in high-rise towers despite an increase in economic status in a hypothetical question posed to them by the interviewer. Similar field research in Shanghai (Wang, 2006) interviewed members of an emerging social class, the white collars.

Referred to as 'young professionals' (university graduates who are trained in finance, computer or building designers, etc.), it is observed that the majority of this group live an urban-centered life-style with equal linkages with work, recreation, entertainment and home. The study is thought to be significant since the young professional's view of the city might well determine what the future urban form might be in a market supply-demand situation. The same observation could perhaps be applied to the 'young professionals' living and working in other cities such as Beijing, home to the famous SOHO project designed by Steven Holl and Riken Yamamoto respectively (Phase 1 and 2), an apartment-office-entertainment development geared for the young professionals' aspiration to a home office, small office vision.

7. What is the Future City?

The following are selected examples of representative new towns and cities of China that shed light into the search for a better future urban living.

7.1. Hong Kong – Pondering Over a Sky City or a Culture City

Hong Kong is known to many as a high-rise city filled with thousands of skyscrapers. In the heart of Hong Kong lies the CBD district within close reach to the romantic views of the Victoria Harbor. There, over a hundred buildings are connected by a network of sky-bridges for 24 hours use by the inhabitants. The worm-like pedestrian network extends to the mountainous terrain where many of the population settled for best orientation and views in multi-story apartment buildings. In many parts of the city, the sky-walks (for it is commonly called) are a generator of urban form that connects buildings of different functions; they connect people from all walks of daily life; and provide users with protection from weather and traffic. The uniqueness of the Hong Kong urban living is expressed by the connectivity of activities that precludes distances and localities. The acceptance of connectivity as a planning tool for urban form is derived from the users' perceived benefit brought by convenience and efficiency. (Compact, connectivity, convenience, conservation) The urbanized areas of the small city of Hong Kong (about 1,100 sq km scattered in over 200 islands, including the main island of Hong Kong, the Kowloon peninsula and the vast hinterland New Territories) is covered by webs of subway trains, short and long circuit commuter buses, electric trams, roadway and different kinds of ferries.

The entire city, new towns and the countryside is well covered by a 60 minute commuting network to qualify Hong Kong to be one of the most convenient cities for live, work and leisure. In recent years, the concept of connectivity continues to nourish a swift lifestyle. It has extended the physical and economic links between Hong Kong and the cities and towns in the neighboring Mainland China by means of a rapid train and high speed ferries to facilitate inter-region mobility for leisure and economic ties soon after Hong Kong reunites with the Motherland in July 1997. In conclusion, the interview with 100 families (Lau, 2002) who live in the high-rise towers all their lives have overwhelmingly supported the vertical city and praised the attractiveness and dynamism of a swift lifestyle. Compromises were inevitable with regards to the infringement of privacy, open spaces, obstruction of views, insufficient daylight, etc. due to the adjacency of one tower on another. Recent efforts see the local government's strong initiates in commissioning environmental studies to tackle concerns such as ventilation, air, water pollution and noise from traffic in the urban canyon as an immediate response to the health threat caused by SARS in 2003. Otherwise, Hong Kong seems to be happy with her quest for a Sky City into the new Millennium as residents continue to reside in the latest generation of skyscraper apartment buildings of 60 to 70 stories! (280 meters above ground)

But besides the quest for verticality, recent events in Hong Kong points to a new direction for the search for a world city status! There was a year-long public debate and civic actions for and against huge investments from both public and private sector to invest in the building of a culture city! The government intended to turn a prominent piece of reclaimed land adjacent the harbor into a deluxe multi-performing and arts complex, a park and quality housing, hoping to change the image for Hong Kong from a financial center into a culture city! But the huge investment and operative costs became a civic concern. After rounds of public forum and consultation, the government had given in by suspending the project, hence putting the dream for a culture city on hold!

7.2. Guangzhou (Guangdong) – the Zhujiang New Town

Another example for the search for an idealized living environment is drawn from Guangzhou: recent trends saw the preoccupation by quite a few developers and home-buyers in a vernacular architectural expression. There are ample examples to suggest a revival of a traditional Chinese architecture language in the construction of new residential buildings. For instance, there is a development known as the "Yun Shan Shi Yi" or "the living wisdom of Orient" (www.yunshanshiyi.com), which is a gated community of low and medium rise apartment buildings (5 to 17-story) with ancillary facilities and well provided landscaped gardens in the outskirts of urban Guangzhou. The 'living wisdom' is manifested in the deliberate borrowing of the well-known Fei-style traditional architecture, a peculiar expression of village houses found in the rural villages of Huizhou, in the province of Anhui (Southern China). It is interesting to see the deployment of black and white washed gable walls in a modern tower, suggesting a subconscious desire to return to nature, as well as a quest for a spiritual harmony between man and environment via the romantic architectural style of the past, to take us to the future. It is interesting, however, to see that there is a limit to the nostalgia – the interior space planning of the residential units remains to be modern by all standards!

7.3. Hangzhou – a Leisure City

The final example is the charming city of Hangzhou that is famous for its natural beauty, historical and cultural heritages. Besides being the capital of Zhejiang province, it is the political, economic and cultural center of the province. Hangzhou is located on the low reaches of the Qiantang River in southeast China, with a distance of 180 kilometers to Shanghai. Covering a total area of 16,596 square kilometers, Hangzhou has a population of 6.08 million, including 683 square kilometers of city area and a city population of 1.69 million.

Hangzhou is famous to be one of the seven ancient Chinese capitals, famous for its historical and cultural heritages. As a famous scenic city in China, Hangzhou attracts more than 20 million domestic and foreign tourists every year. Hangzhou is known for its natural beauty of West Lake worldwide. In the Yuan Dynasty, the famous Italian traveler Marco Polo described this city as "the finest and most splendid city in the world."

In the 1990s, Hangzhou has built many museums representing the Chinese culture: for instance, China Silk Museum, China Tea Museum, Hu Qinyu Tang Traditional Chinese Medicine Museum, Southern Song Porcelain Museum, Zhang Xiaoquan Scissors Museum, Liangzhu Culture Museum,etc. The places like Linyin Temple, Yue Fei Temple, Six Harmonies Pogoda, Huagang Park and the Running Tiger Spring are world-famous scenic and historical sites. The Qiantang Tidal Bore is the famous sight for viewing seasonal tide waves, which can be equaled to the sight of Amazon River. According to official statistics, the total number of foreign tourists approximates to half a million while domestic visitors amounted to 21 million. A recent visit by the author to Hangzhou in 2006 brought a wonderful memoir of the charms and tranquility of an ancient Chinese city as well as a resort city!

Hangzhou has continued to rank very high in the national listing for the best city overall tells us many things about the merit and necessity for a leisure city – for relaxation and peace of mind!

8. Conclusion

The paper made a quick scan of the development of Chinese cities in an era of phenomenon economic developments that brought acute societal changes and shifts in individual preferences over lifestyles; last but not least is the incredible physical transformation of the cities. The development of the Asian cities is unique since a lot of them encountered colonization prior to the advent of globalization. One could argue that these cities exhibit a rich mix and assimilating of differing values, beliefs and cultures. Examples are drawn from a number of selected cases and cities (Hong Kong, Shanghai, Guangzhou and Hangzhou) to illustrate the complexities and contradictions faced by individuals, society and government in the collective search for a better community and a livable city! The problems and challenges that confronted these cities are not new issues but merely signifiers for a price to be paid on the way to triumph –achieving a balanced growth while maintaining a harmonious co-existence of man and environment. The views expressed in the paper are personal and should be taken as a reflection for those who share a similar goal in the search for a better city!

Acknowledgement

Thanks are due to Mr. Yang Feng, M.Arch., B.Arch., Doctoral researcher; Miss Wu Xiaoling, B.Arch. M.Phil. and Miss Poon Hoiling, M.Arch. researcher at the University of Hong Kong.

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INTEGRATION AND SUSTAINABILITY OF CITIES – THE CASE OF KUALA LUMPUR

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Abstract

Cities are nothing more than people, their activities, the spaces that people and their activities occupies, or better known as land uses, and the systems that allows them to interact, generically termed as transportation. Cities are deemed to be efficient when its components are in harmonious interaction with one another.

More often than not, cities are plagued with numerous problems. Unemployment, crime, traffic congestion, squatters and overcrowding, pollution, etc are common in cities the world over. City components are not only internally disaggregated, but are often in conflict with one another. Indiscriminate utilization of land, the competition for survival and existence, results in neglect of the environment, affecting the sustainability of cities. Kuala Lumpur is no exception.
In anticipation of the pressure for growth and development, the need to provide for human needs, the elimination of problems and the creation of a more livable city for its future generation, Kuala Lumpur embarked on its Kuala Lumpur Structure Plan Review 2020.

The Kuala Lumpur Plan 2020 formulated 182 different policies to cover 13 different aspects of the plan, covering areas such as economic base and employment, income and quality of life, infrastructure and quality of life, commerce and industry, tourism, housing and squatters, urban design and landscapes, environment, etc. Playing the role of a premier city of the nation, Kuala Lumpur believes that it must contribute strongly to the attainment of the ideal embodied within the country's Vision 2020. Kuala Lumpur set to become a world class city by 2020 in the areas of Living Environment, Working Environment, Business Environment and City Governance.

This paper presents the findings and recommendations of the Kuala Lumpur Plan to secure the short term and the long term growth and sustainable development of Kuala Lumpur. It will summarize the issues and policies of different sectors. Particular attention will be given to the issue of *integration of the key components* of the plan, particularly, housing, commerce and industry and, traffic and transportation, in a bit to secure sustainability.

Keywords: Integration, Sustainability, Sustainable city growth, Sustainable development.

1. Introduction

Sustainability can be achieved through various means. In city planning, planners have the opportunity to shape the form and function of cities, to plan for the location of uses, amenities and facilities in order to maximize benefits, while reducing disbenefits for the inhabitants. Planners have the means to better manage cities, to break away from the present trend of development, and to pave the way for a better community.

This paper discusses the organic effect of growth on cities, namely suburbanization, and examines the policies outlined in the Kuala Lumpur Structure Plan 2020 that relate integration and sustainability. It is based on the hypothesis that integration, particularly, land use and transportation is an efficient ingredient for sustainability.

2. The Living City

Cities essentially, are made up of three major components, namely, its people, the land uses they so generate for their existence and well being, and the transportation system that link all these uses and activities. The larger the population size, the more diverse will be their needs leading to the growth of the city to include diversified establishments and institutions. In more recent times, it is common to have cities with more than 10 million people, as in Mexico City, New York, Tokyo, New Delhi, etc. Kuala Lumpur however, has 1.2 million people. Its daytime population is about 1.6 million.

The density of population in cities increases with the increase in population. As such we have modern high rise cities like Hong Kong with 37,000 inhabitants per sq kilometer, Singapore, 9,000 inhabitants per sq kilometer, and New Delhi, 11,000 inhabitants per sq kilometer, and so on.

The basic needs for survival i.e. for food, education, health, recreation, housing and employment is enormous. Translated into land uses, it means more land will be used up for these purposes. Cities grow in size and needs. They are alive. The speed of city growth or urbanization has been greatest during the last 50 years, and now more than 50% of the world's population lives in cities. Continued urbanization put pressure on resources. The desire for sophisticated comfortable places to live and work, and the typical features of modern life styles, also multiplies the resource usage, waste production, and pollution generated in urban areas. There is no doubt that cities are effective in terms of their wealth creation and cultural promotion; but not without cost.

3. City Growth and Suburbanization

Suburbanization refers to the movement and developments eating into the country side as the urban areas become too dense and saturated. For the affluent, it's a way of life. For some, it's a legitimate search for cleaner air and green pasture and a different style of living. For the working population, it's a search for cheaper land and property, pushed out by higher rent and cost of living in the urban centers. For the developers it's a new frontier of development, to try out new housing designs, and a new market to ride on. Proponents of new urbanism and smart growth movements that subscribe to the idea of sustainability respond to these concerns with calls for creating more livable communities. Developments that are designed to maintain and enhance the existing neighborhoods, as well as environmental and natural resources conservation were prescribed.

Douglas R Porter (2006) believed that market demands are changing in the direction of more sustainable form of development. He noted a sizeable niche market of consumers apparently values compact, mixed-use development that frees them from maintaining large houses and gardens and depending on the automobiles. This may be true in some developed economies. It is unclear if the same can be said of this region, where success and achievement are often portrayed in the size of one's property, the high parameter walls and the electric gate, where cottages in the countryside are rural retreats or weekend hideouts. It is a sought-after lifestyle.

It was also noted that developers respond well to the so-called advocates of sustainable and smart growth. As a result, we see pockets of smart sustainable rural like development taking place around the urban areas. In Malaysia, Tanarimba in Janda Baik, in the state of Pahang is an example. But these are exclusive communities designed for a certain target group. It was never meant for the man on the street. They cannot afford it.

It was noted that the result of growth, overspill, sprawl and suburbanization is that both the city and the suburbs are now locked in a mutually negating evolution towards loss of community, human scale and nature. This pattern of growth has created unnecessary congestion, pollution, isolation, seclusion, slums and division of community. This pattern of growth have become more and more dysfunctional and problem cumulative. It separates the very community the planner dream of integrating. Lewis Mumford (1956) noted that metropolitan growth is fast absorbing the rural hinterland and threatening to wipe out many of the natural elements favourable to life.

Suburban sprawl increases travel demand, pollution and generate enormous cost, particularly to the taxpayers and the environment. Sprawling land use patterns compel us to drive our cars, and with growth in family size, we add more cars to our house, and this led to greater fuel consumption. It was noted that, in the last 20 years, the population of California increased by 40%, while vehicle miles traveled have increased 100%. We drive more (Peter Calthorpe, 1993).

4. Integration and Sustainability

Westerman (1998) define integration as implying "a concern with the whole; agreement on the kind of outcomes we wish to achieve; having the means of achieving them; and a collective commitment to make it happen.

The concept of sustainability is worth a brief examination. The U.N. Bruntland commission in 1990 defined sustainability as "meeting the needs of the present generation without compromising the ability of future generations to meet their own needs." The Oregon Progress Board (2000) defines sustainability as "using, developing and protecting resources at a rate and in a manner that enables people to meet their current needs and also provides that future generations can meet their own needs" … through "simultaneously meeting environmental, economic and community (social) needs". The achievement of the sustainability outcome simultaneous with meeting of needs implies integration. Other than that, sustainability refers to the ability to maintain and continue that which sustains us, and that we find sustaining. It is a multi-dimensional concept that has environmental, social, political, economic, cultural and spiritual dimensions. Sustainability acknowledges that evolution occurs within limits that prevent continuous and unceasing growth (Puttnam, 2000).

5. Land Use and Transport Integration

Greiving and Kemper (1999) link land use and transport planning together by defining the desired outcome for land use planning as "reducing the need for travel" and for transport planning "making the remaining traffic (travel) sustainable". The Western Australian Planning Commission (1996) identified the desired land use planning outcome as an orderly planning process that achieves regional wealth, conserves and enhances the environment and builds dynamic and safe communities. Based on this view, reducing the need for travel, or "accessibility by proximity", is the desired outcome for land use and transport integration rather than land use. Curtis (1999) describes the desired outcome of integration as achieving a better balance in the use of transport modes. The suggested integration outcome for land use and transport, separate from land use and transport outcomes on their own, is presented in Figure 1.

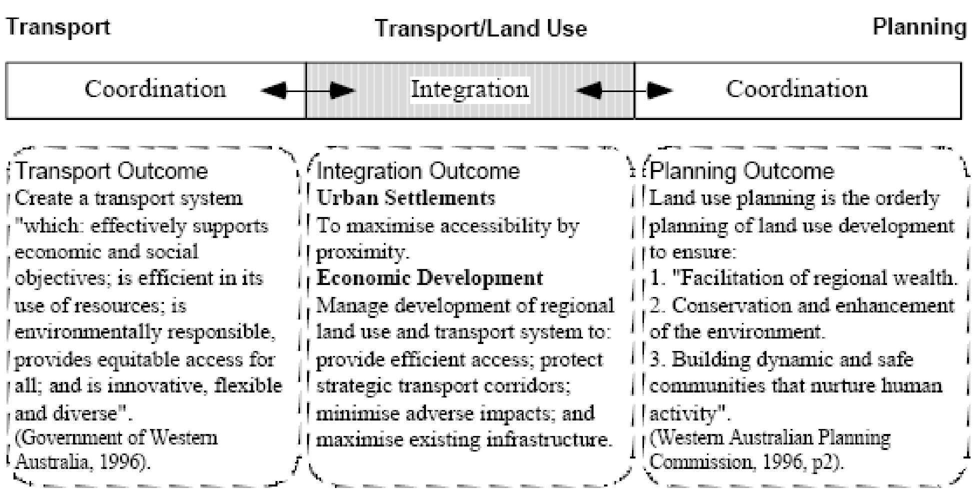

Figure 1: Land use and Transport integration desired outcomes

The location of land uses has a major influence the demand for travel. Conversely, the provision of transport infrastructure and services can influence land use and development patterns. The integration of land use and transport planning is critical for reducing demand for travel by private car. Key initiatives that address this situation are: employment self containment, mixed use development, higher density development around public transport nodes, concentration of major traffic generating land uses in areas well serviced by public transport, viable local centres, limiting car access in congested areas, parking constraints, encouraging higher vehicle occupancies, provision and protection of routes for cycling, walking and public transport and requiring transport impact statements for major development.

6. Elements for Integration and Sustainability

6.1 Density

The density of development plays an important role toward ensuring sustainability. With high density development, meaning a larger number of people over a given area, with amenities and facilities planned around it, one will eventually need to travel less. It is economically viable, as the density provides the threshold population to support the goods and commodities sold. It is also with high density that an efficient public transportation system can be set to work. Urban planners have an important role to play, especially in promoting higher density development at strategic locations and in planning for higher density living that is attractive to a wider range of population. There is a need to reverse the trend of urban growth from one of low density sprawling land use to that of higher density mix development.

Some of the newly planned settlements in Kuala Lumpur have a much higher density. They are built close to the main commercial and shopping areas, and more importantly within walking distance of the main public transport corridor. Apartments at these locations are in good demand and fetch higher rental value. Commuters gradually realize that it is to their advantage to live in such apartments as transportation will not be a problem. The train guarantees smooth uninterrupted rides, always. Perhaps the electric powered train should replace all petrol powered vehicles in the city!

6.2 Accessibilty

When distance between land uses and buildings increases, it **create** the needs to travel. When cities grow in size, and both population and uses get dispersed over a wider area, planning for public transport become difficult. The automobile consequently become the automatic choice for ease of movement. It is also not feasible to provide for public transport when density is low and the population sparsely distributed across the landscape.

Urban planners should strive for accessibility needs, high degree of accessibility from residential quarters to work places, to education and recreational areas. Community office development providing employment should be planned to have easy access to community hubs and local centers with public transport links and facilities.

Accessibility is not about building more highways, or adding more lanes to our roadways, or continuous intersection upgrading. Of course they ease the flow of traffic considerably, but only temporary. Solving congestion by building more infrastructures is ineffective. It does nothing to reduce trips. Indeed, it invites more sprawls and paves the way for more auto use. It is self defeating.

6.3 Mix Use Development

Mix use development refers to the different land uses, such as commercial, educational, recreational, administrative, etc, located in close proximity to one another. Mix use development reduces the need to travel as all facilities and services are available close by. Some argued that local facilities become more viable due to increased local demand from the local work force as local residents and community spirit is encouraged.

6.4 Public Transport

It has been accepted worldwide that the key to improving the environmental performance of a city is by the reduction of private auto use. The urban sprawl common to most cities, Kuala Lumpur is no exception, calls for the provision and encouragement to use the public transport system. The commuter train in Kuala Lumpur serves the main urban hub with the suburban areas and surrounding towns. The network is expanding into new areas where travel demand warrants such a service.

In Hong Kong, major infrastructure providers such as the bus or the MRT, are given land rights over their stations for property development. The cost of constructing new lines comes from the profit made on these developments while the fares merely cover the operational cost. As such, there is a good relationship between a station and its surrounding buildings and uses. Land use and transport integration is at its best when it is convenient and safe to walk from one's house, board a train, and arrive at the office without having to cross a single road.

6.5 Transit Oriented Development

TOD is a concept that promotes public transport usage. Land use and the transit systems must be planned together. The two cannot be disconnected. Transit system will not work if the density of land uses is inappropriate. Similarly, if the land uses immediately surrounding transit station are thoroughly developed with the right mix and density, the result is more beneficial environmentally and physically. Some even argued for transit station to be the neighborhood or the community's focal point. It will encourage ridership of the public transport. High density mix uses around a transit core promotes environmentally friendly walk-and-ride rather than park-and-ride which again is auto dependent. TOD discourages auto usage.

7. Integrating Land Use, Town and Transport Planning : Singapore

Land use planning plays a key role in creating a sustainable transport network. Planning can influence the need for travel, even the mode of travel. Singapore has done well in integrating their land use and transport planning. For example, they decentralized the population by building HDB towns away from the city centre but connected them by an efficient system of roads, expressway and public transport. Besides that, they decentralize commercial and other economic activities through the development of regional, sub-regional, fringe centres at MRT stations. This has resulted in better utilization of the MRT network in both directions during peak hours. They also planned to reduce the need for people to travel by locating employment centres like industrial estates, business parks and commercial centres near residential areas.

Figure 2(a)

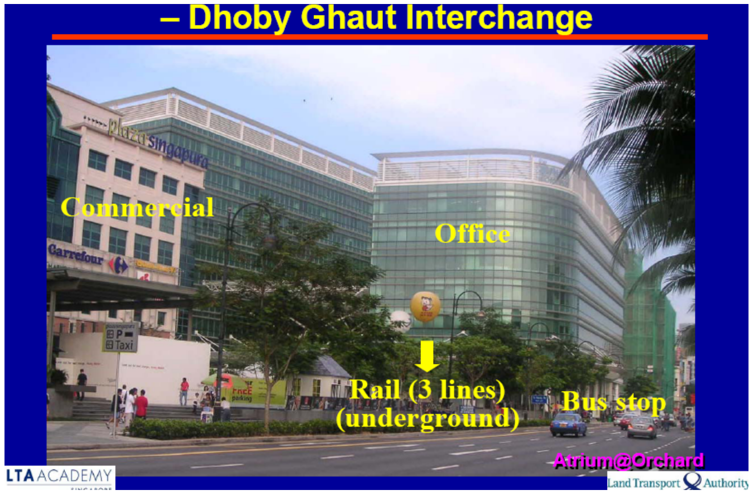

Figure 2(b)

Figure 2 : Land Use and Transport Integration, Singapore

Singapore also planned for a proper mix of residential, industrial and even institutional developments with the highest plot ratios at and around MRT stations as in Toa Payoh where the bus interchange was developed into commercial cum residential hub. The purpose is to improve accessibility to the bus interchange, the Toa Payoh MRT station and residential and commercial developments nearby (Figure 2(a) and Figure 2(b)).

Intensifying developments around MRT station alone is not sufficient to ensure good accessibility. They also fully integrate MRT stations with building developments and other transport modes. For example, at the new Woodlands MRT Station, other transport facilities like bus interchange and taxi and car drop-off points are well integrated with the station. Commuters can interchange easily, in comfort even in poor weather.

The fundamental principle of integration was extended to HDB estates. For example, the configuration of LRTs should maximize accessibility for residents. In some instances it may be better for the LRT to hug the road reserve rather than sit astride the road divider. Such a configuration could greatly shorten the walk to the LRT station and provide residents and the local community with significant usable space under the viaducts.

8. Suburban Living – Kuala Lumpur

There has been a reversal in net in migration of about 9,000 persons per annum between 1975 to 1980 to a net out-migration of about 4,280 persons per annum for the period 1991 to 1997 (Figure 3). The out-migration is clearly not a result of lack of employment opportunities but is partly due to the shortage of affordable housing. Kuala Lumpur has experienced a movement of people to the suburbs and outlying towns such as Klang, Rawang, Petaling Jaya, Bandar Baru Bangi and even Seremban, who, nonetheless, commute daily back into the City to work (Table 1). They can easily use the highways or public transportation such as bus, taxi, and the commuter train to commute daily to the city. While the suburbs grew rapidly, the City itself experienced a slower population growth.

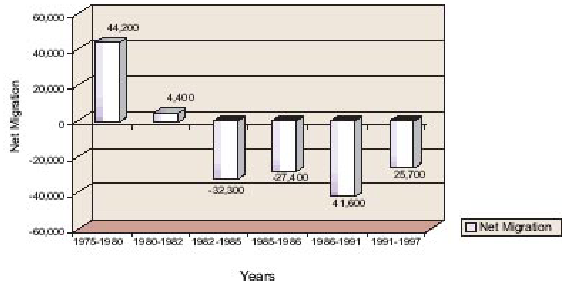

Figure 3: Net Migration in Kuala Lumpur, 1975 to 1997

Suburbs	Distance from Kuala Lumpur City
Klang	32 km
Rawang	30 km
Petaling Jaya	8 km
Bandar Baru Bangi	33 km
Seremban	67 km

Table 1: Distance from Kuala Lumpur City

In parallel with the decline of the City Centre residential population, there has been a commensurate drop in residential land area from 523 hectares in 1980 to 288 hectares in 2000. Residential land and buildings left vacant have high commercial value and are thus quickly taken over by commercial uses. In addition to the areas of dilapidated housing in the City Centre, there are many older, low density housing areas occupying land which also has high potential commercial value. Pressures will remain on these remaining pockets of residential land to convert to more profitable land use, which, in turn, could lead to a further reduction in the inner city residential population.

8.1 Travel Demand – Kuala Lumpur

Figure 1.5 shows the demand for travel in Kuala Lumpur in 1997, 2000 and 2020. The projections takes into account the population and land use increase as well as the present trend in auto use and travel pattern in Kuala Lumpur.

The modal split for Kuala Lumpur in 1997 was 81:19, in favour of the automobile. This put tremendous pressure on the roadway. The arterial roadways leading into the city are jammed up at least two hours before office begins. The evening peak is even worse stretching to up to 8.00 pm in most cases.
From the graph it can be seen that the capacity of roadways in the Central Planning Area remain almost constant till 2020. Travel demand instead, increases close to about 100%. The city is choking by its own traffic, and also by its own doing. This is a by-product of urbanization, and dependency and faith that mankind placed on the automobiles to provide for all their transportation needs. What this implies is that, for Kuala Lumpur to move, there must be a change in the modal split, meaning that trips will have to be made via public transport; an uphill task, looks difficult, yet unavoidable. Many changes will have to be made i.e., travel pattern, the frequency of trip making, land use distribution, the way we do things, including that of life style.

Because cities cannot be allowed to grow as it pleases due to the role of the state toward its citizens and other social contracts and obligations, it is therefore necessary to monitor and regulate the development process. There must be some control for orderly development and city growth. Urban planners for instance, may have to revisit the concept that encourages sprawl, suburban living and continued suburbanization.

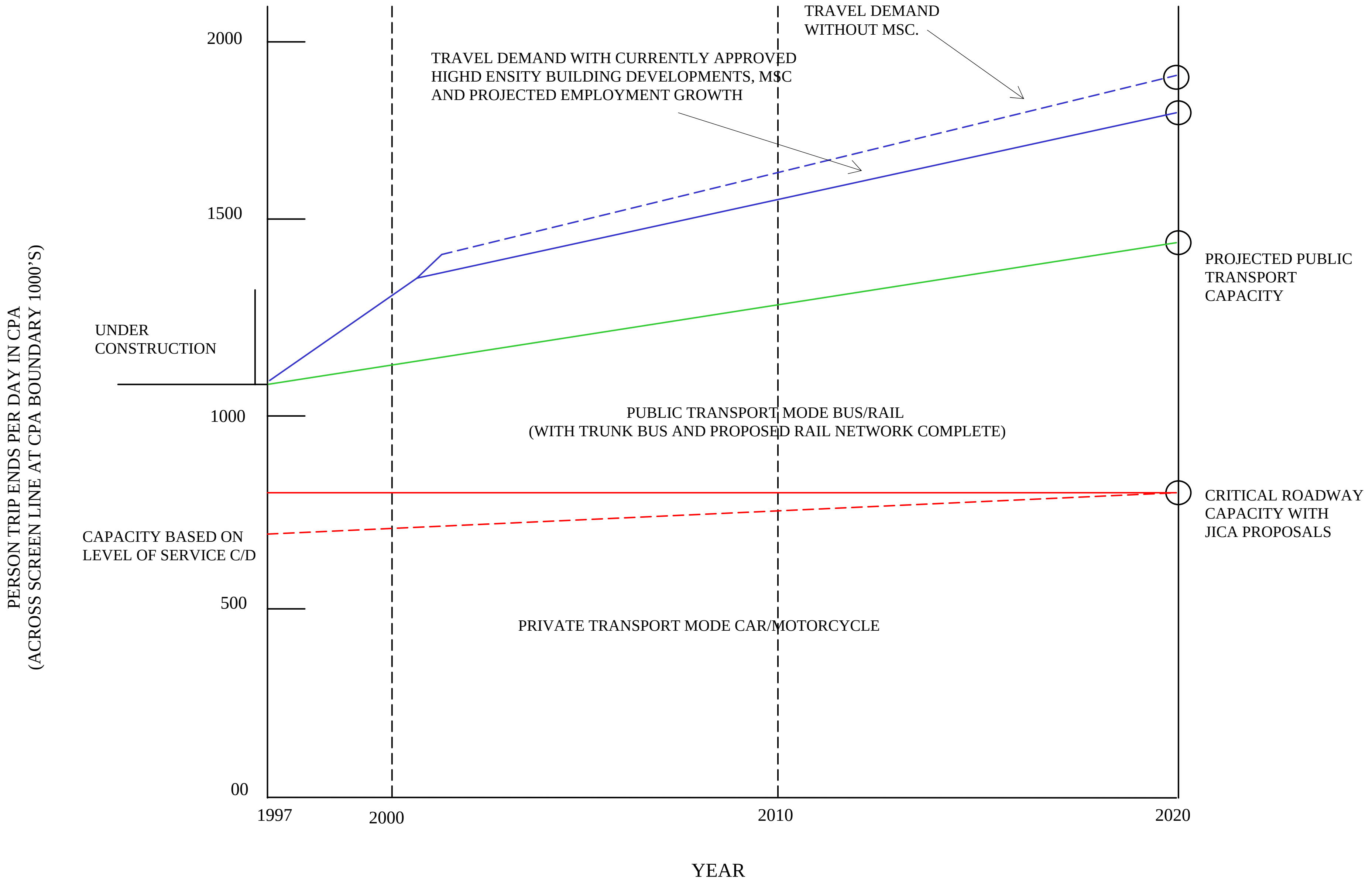

Fig 1.5: KUALA LUMPUR CENTRAL PLANNING AREA PRELIMINARY PROJECTED TRANSPORTATION CAPACITY

8.2 Integration Policies: Kuala Lumpur Structure Plan 2020

In order for Kuala Lumpur to achieve sustainable development, 12 policies have been identified in Kuala Lumpur Structure Plan 2020 where the integration is the key component of the plan can be found in four major sectors, they are housing, commerce, industry and transportation.

8.2.1 Housing

The residential population of a city is its most important resource and its greatest responsibility. The well being of Kuala Lumpur's inhabitants is the overriding concern of the city authorities and for that reason, housing has always been an item high on its agenda. The emphasis focuses on improving the quality of housing and the housing environment.

H01 – CHKL shall encourage responsible parties in the housing sector to develop good quality housing and living environment.

Good quality housing is a combination of many aspects of housing development. Design and layout, environmental responsiveness, the quality of workmanship and materials, the provision of utilities and facilities, landscaping, maintenance and upgrading, all play a part in the total housing environment. City Hall Kuala Lumpur (CHKL) shall encourage and work with the private sector to raise overall standards of housing in all of these areas so as to produce housing of the highest quality.

8.2.2 Commerce

An integral part of the vision to make Kuala Lumpur into A World-Class City is to enhance its position as international commercial and financial centers. Commerce is the driving force behind a city's economy. It is the creator of wealth, the principal provider of jobs as well as a primary impetus for development and renewal.

C03 – CHKL shall encourage the development of home-office business.

The technologies associated with the K-Economy are leading to a growth in home-office businesses. There are many benefits for individuals, businesses, administrative bodies in this trend as overheads are lower, and demands on the City's infrastructure, particularly the transportation network are reduced.

C07 – CHKL shall ensure that there is adequate provision of commercial apartments with convenient access to the main business areas.

As the number of international business locating in Kuala Lumpur increases, sufficient service apartments must be provided in convenient locations to cater for the needs of expatriate businessmen.

8.2.3 Industry

The industrial sector now in Kuala Lumpur plays a relatively minor role in the economy of the City compared to the commercial sector, an industrial component will be necessary to service the population of Kuala Lumpur and provide support services to commercial enterprises in the City.

IN9 – CHKL shall ensure that all designated industrial areas are provided with adequate public facilities including parking for heavy good vehicles.

Measures shall be implemented to provide all industrial areas with proper basic infrastructure, services and facilities including wider roads, improved loading and unloading facilities, better drainage systems, parking and public transport facilities as well as suitable commercial enterprises, banking facilities, food courts and recreational areas.

IN10 – CHKL shall encourage the development of new industrial areas and the redevelopment of older industrial areas which are near to transit facilities.

Transit oriented development is a cornerstone of the development strategy. Development policies shall aim to ensure that residential areas, services and commercial facilities shall, as far as is possible, have easy access to transit facilities. Where appropriate this strategy shall also include industrial areas particularly those where there is high employment. Feeder bus services in these industrial areas shall link to the rail-based public transport system.

8.2.4 Transportation

Comprehensive and efficient transportation system networks with good inter and intra urban linkages are essential enabling factors to ensure Kuala Lumpur's position as an International Commercial and Financial Centre. For the residents of Kuala Lumpur, the City must be able to provide an efficient and equitable city structure that, as far as possible, allows all members of the community equal accessibility to all areas and facilities so that everyone may enjoy the maximum benefits of city living.

TT4 – CHKL shall establish a Transit Planning Zone to facilitate intensification of transit oriented residential, commercial and mixed-use development around rail stations.

A principle objective of the transportation sector is the integration of land use and transportation and the development of a Transit Oriented Development strategy. This strategy will promote intensified development along the rail network. Any planned extension to the rail network must, therefore complement this policy by ensuring that rail stations serve designated urban centers.

TT6 – CHKL shall ensure that public transport principally comprises a fully integrated system of bus transport and rail-based services with common ticketing and complementing route scheduling and major multi-modal interchanges located at strategic locations.

TT7 – CHKL shall ensure that multi-modal interchanges and terminals incorporate park-and-ride facilities and facilities for pedestrians and bicycles.

TT8 – CHKL shall coordinate with the relevant authorities to provide efficient feeder bus services to the rail-based public transport network.

The emphasis will be on providing an integrated, flexible, wide ranging and efficient public transport system orientated towards passenger accessibility and convenience. Central to this approach is the integration of public transport modes with each other and with private transport so that, with streamlined inter modal transfer facilities and integrated ticketing, passenger trips become as convenient and seamless as possible.

In order to avoid traffic congestion occurring on local streets, major bus/rail and park and ride interchange facilities will be located at the points of intersection of the rail stations and major roads.

TT11 – CHKL shall implement a bus terminal network for inter and intra urban bus services.

CHKL will also implement measures to create a network of bus terminals on the periphery of Kuala Lumpur for buses and coaches serving separate regional and inter-urban services. These terminals will be integrated with the rail system via multi-modal interchanges to enable easy access to the City Centre and other areas of the City.

TT16 – CHKL shall ensure that proposed and committed major roads are considered in the broader context of public transport services, freight movement and impact upon the community and environment.

New roads, if any, must be examined in the context of CHKL's general transportation policies. However, any new roads that may be deemed necessary should support CHKL's policies to promote public transportation by making provision for high-occupancy vehicles and/or trunk bus routes. The reserves of these roads should be clearly demarcated to prevent urban encroachment on the right of way. Privatization bids on arterial roads must also conform to the network proposed in the Structure and Local Plans and not be conceived independently.

TT19 – CHKL shall develop specific guidelines and standards to provide for the needs of the aged and handicapped to be applied to pedestrian networks, new public transport terminuses and stations as well as multi-modal interchanges.

A pedestrian friendly environment will be created throughout the City with particular emphasis on the City Centre and other urban centres. Pedestrian networks in the City Centre will emphasize linking public transport facilities and will incorporate urban design elements. Special attention is to be given to areas around main transport interchanges to ensure that they incorporate facilities to make them fully accessible to the handicapped.

9. Conclusion

"We control air pollution with tailpipe emissions, fuel consumption with more efficient engines and congestion with more freeways, rather than making cities and towns in which people are less auto dependent". We treat the problem as we see it, piece by piece. We subscribe to segmentation in our approach, in the way we analyse and recommend solutions. As a result, we become shortsighted and uncoordinated.

Planning of roads, rail, housing, commercial and other land uses at both local and regional levels must reflect efficient and sustainable community development. They must be coordinated and integrated. Policy makers must realize that sustainable community development cannot be achieved by piecemeal, localized growth management measures. Investment decisions large or small must be guided by the existing approved plans, not otherwise. The Kuala Lumpur experience has shown that in spite of the shortfalls, the Structure Plan 2020 was able to assemble an array of policies designed towards a more sustainable community through integration.

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THE SUSTAINABLE DEVELOPMENT OF YANGON CHANGING FROM CENTRAL PLANNING TO MARKET ECONOMY, THE STRATEGIC PLAN APPROACH

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Abstract

This case study presents the findings, analysis and recommendations in charting the future long-term growth and sustainable development of Yangon, the premier and capital city of Myanmar, in line with the vision and aspiration of the Myanmar Government and the Yangon City Development Committee.

A number of key sectors have been studied, in particular highlighting the current issues and the carrying out of technical analysis and projections with a view to formulating a strategic plan that will serve as a planning instrument to guide the future growth and expansion of the city.

A general understanding of the country's socio-economic development, relevant economic indicators at both the national and division levels are imperative. At the regional or city level, the spatial dimension had analysed important parameters such as landuse changes and development trend, urban settlement and hierarchy and linkages.

The existing scenarios of the primary productive sectors, their contribution and challenges have been addressed. These form the economic fundamentals essential for the sustainable growth of Yangon City, which is very much conditioned by the country's economy and socio-political stability. Future infrastructure and utility services also need to be put in place to provide efficient, reliable and safe delivery of essential city services.

In the process, priority project initiatives and policies need to be formulated to complement the various reform measures that have been promulgated by the government. In essence, the economic sustainability of the city can be expected on conditions of a stable macro-economic environment, the implementation of proper policy instrument and market-friendly government intervention. A stable macro-economic environment will provide a conducive setting for business to prosper and to endeavor important matters related to buildings, including sustainable construction.

Keywords: market economy, sustainable city development, macro-economic sustainability, development parameters, priority project initiatives.

1. BACKGROUND

The Yangon Strategic Development Plan study has been undertaken under the auspices of the Economic Planning Unit, Prime Minister's Department, under the Malaysian Technical Cooperation Programme (MTCP). The initiative forms part of the Malaysian Government's Strategy and Commitment to the promotion of technical cooperation among developing countries, the strengthening of Regional Corporation and nurturing collection self-reliance among these countries.

2. UNION OF MYANMAR'S NATIONAL COURSES AND OBJECTIVES

The State Law Order and Restoration Council (SLORC) in September 1988 committed itself to the national causes on non-disintegration of the Union, non-disintegration of national solidarity and consolidation of national sovereignty. SLORC gave priority to the restoration of law and order, the improvement of communications and the uplift of people's livelihood. It moved away from the centrally planned economy of the Burma Socialist Programme Party (BSPP) period towards a market-oriented economy, relaxing the former restrictions on private industry and trade and offering incentives to attract foreign investment.

The SLORC in endeavouring the modernization and progress of the Union also embarked on the 12 point political, economic and social objectives as follows:

(a) Political Objectives

i. Stability of the State, Community peace and tranquillity, prevalence of law and order;
ii. National reconsolidation;
iii. Emergence of a new enduring State Constitution; and
iv. Building of a new modern developed nation in accordance with the new State Constitution.

(b) Economic Objectives

i. Development of agriculture as the base and all-round development of other sectors of the economy as well;
ii. Proper evolution of the market-oriented economic system;
iii. Development of the economy inviting participation in terms of technical know-how and investments from sources inside the country and abroad; and
iv. The initiative to shape the national economy must be kept in the hands of the State and the national peoples.

(c) Social Objectives

i. Uplift of the morale and morality of the entire nation;
ii. Uplift of national prestige and integrity and preservation and safe-guarding of cultural heritage and national character;
iii. Uplift of dynamism of patriotic spirit; and
iv. Uplift of health, fitness and education standards of the entire nation.

3. PLAN OBJECTIVES

The objectives of the Yangon Strategic Development Plan are: To serve as a planning instrument to guide the future long term growth and development of Yangon City; to promote private sector participation and investment, local and abroad through the identification of Project Identification Briefs and priority strategic projects that will facilitate the attainment of an accelerated, balanced and sustainable development of the Yangon City Region.

With this in focus, the study comprises the following:

i) Establishing the macro, spatial, sectoral and support services framework, sectoral review, analysis and projection; and

ii) Formulation of the policies and strategies, identification of priority projects, preparation of project identification briefs and recommendation of an implementation framework.

iii) The conceptualisation of the Strategic Development Plan, taking into the sectoral issues, potentials and aspirations of the City of Yangon.

Nett available land for the future development of Yangon City stands at 26,970 hectares (35 per cent of the total Yangon City Area). This non-built-up area includes agricultural and forest land. Most of these lands are found in the Dagon Extension Area, Mingalardon, Hlaingthayar and Dagon Myothit East. Some of these may be constrained where much of the lands are within the water catchment area. In light of the available lands and growth trend, future development within the planned period is likely to focus in the north-east (Dagon), near airport area in the mid-north (Mingalardon), to the west (Hlaingthayar) and in Dala Township to the south.

4. KEY ISSUES

i) Regional Framework

The regional development framework provides an overview of Myanmar in the context of a wider regional perspective, specially within ASEAN. A general understanding of the country's socio-economic development, relevant economic indicators at both the national and division levels are imperative.

Significant observations:-

- Economic fundamentals have been adversely affected by the US sanctions, disrupting trade and productions, causing inflation and unemployment;
- The Consumer Price Index (CPI) rose by about 20 times between 86/87 and 99/20 financial years. This was the direct and indirect results of the large budget deficits financed by increase in money supply;
- Myanmar maintains a multiple exchange rate policy. There has been a market depreciation of the Kyat in the parallel 'free market' while the official rate remains overvalued;
- Declining Foreign Direct Investment, especially after the Asian Financial Crisis and the ban on new US investments;
- The country's import grows at a rate faster than export; affecting the balance of trade and payments;

- The development in manufacturing and the service industries have made little progress due to energy shortages expensive telecommunication services, and other infrastructural support; and
- Yangon Division has the highest concentration of urban population. This contributes to the primacy of Yangon city and high in-migration into the city.

ii) <u>Spatial Framework</u>

This spatial development framework relates to the spatial dimension of the Development Plan analyzing such parameters as land use changes and development trend, urban settlement hierarchy and linkages. The essence of this sector is to highlight future spatial strategies deemed appropriate for the Development Plan.

The following shortcomings have been identified:

- Land suitable for development within the Inner City Are;
- Clear hierarchy of urban centres;
- Clear definition of town centres with corresponding social facilities within the township;
- Clear hierarchy and structure of roads, especially the east west links and the ring roads; and
- Clear definition of heritage and conservation zones, protection of nature areas such as wetland and river reserves, and definition of district open spaces and parks.

iii) <u>Productive Sectors</u>

The Study primarily highlight the overall existing scenario of the primary Productive Sectors of Myanmar which for this study are confined to agriculture, livestock, fisheries, forestry and mining, its contribution to Myanmar and their future challenges. The study also provides a deeper insight into the manufacturing sector, an important catalyst for the growth of Myanmar.

Major issues in the productive sectors are:-

- Acute water shortages facing paddy farmers;
- Difficulty of water control and, management during the main seasons;
- Crop yield, such as, paddy yield is comparatively low;
- Farm income are generally much lower than non-farm income;
- Average farm holdings are small and unorganised;
- Information is often incomplete and inconsistent and the marketing system requires improvement;
- The support infrastructure is lacking;

- Large resource based industries are currently located outside the dedicated industrial zones such as close to the rivers, and relocation is a tedious and difficult exercise;
- Most small and medium size industries especially the food and wood based sectors are fragmented, lacking in support infrastructure, quality product branding, market linkages and effective networking;
- The industrial and manufacturing sectors suffer from inadequate power supply, affecting production.

iv) <u>Infrastructure and Utilities</u>

This chapter analyses the existing infrastructure and utility services with a view to providing efficient, reliable and safe delivery of essential city services for the future.

Major issues noted:

- There is a lack of central sewerage treatment facilities in Yangon. Untreated discharge of waste water contributes to pollution;
- Drainage channels in Yangon are left in their natural states and are exposed to erosion during heavy rain. Siltation affects the flow area, resulting in constriction and flooding;
- Most drainage channels are not properly maintained, reducing channel capacity and aggravating channel condition;
- All the 22 channels are under the influence of tidal regime, causing the inflow of water from rivers to flow into drainage channels during high tide. This often causes flooding;
- Squatters and illegal settlements along drainage channels create problems on the channels themselves, and often a cause of flooding;
- Yangon lacks sewerage facilities. Only the CBD area is connected by the main sewer network. The rest are not. Only one sewerage treatment plant was constructed in 2005 to receive discharge from the CBD area (capacity 300,000 PE);
- There is a high rate of leakage in the water mains due to old pipes that are more than 50 or 100 years old, contributing to 50% non-revenue water;
- Demand for electricity exceeds its supply. Currently, there is insufficient power supply to service Yangon City. With the increase in population and land uses, consumption will increase, thus aggravating the problem further; and
- The telecommunication industry is currently under-developed and does not encourage widespread use.

v) <u>Transport</u>

This sector addresses the existing transportation system including urban road network, operational characteristic of traffic, volumetric counts and the urban public transport, ascertains future transportation requirements and develops medium and long-term action plan.

Significant highlights include:-

- Yangon has a fairly comprehensive road network, but lacking in hierarchy and function. The east west connection is not well developed, and ring roads are not a common feature; and
- The public transport serves its purpose well, particularly for the locals. The public transport vehicles particularly the buses, however, are in poor physical conditions. The same can be said of the train's rolling stock and service characteristics.

5. POLICY AND STRATEGY FORMULATION

Two major closely linked components are necessary, i.e., the economic development strategy incorporating policy directions; and the physical development strategy providing the essential impetus and foundation for guiding the Yangon City development.

The overall policy objective is aimed at developing Yangon as the Premier City of Myanmar through accelerated economic growth and planned physical development besides maintaining its lush greenery and preserving its heritage. In harmony with this overall thrust, the development strategies proposed are directed towards:

(a) Enhancement of the Economic Environment

This can be achieved by ensuring conducive environment for investment as postulated by the Government's reform policies. The provision of adequate and reliable facilities are essential for production economic activities. Other efforts include promoting the development of commercialized agriculture, livestock and fisheries activities, strengthening of the manufacturing activities and intensifying the tourism industry.

(b) Enhancement of the Quality of Life in the City

The enhancement of the quality of life in the Yangon City will commensurate with the present and future role of the Yangon as the capital and premier city of the Union of Myanmar. Among others, it is imperative to improve and upgrade the transportation system, the quality of public transport, efficient circulation system and adequate and orderly parking facilities especially in the CBD. The upgrading of the city's infrastructure and utility system including telecommunication services are of paramount importance to meet its future population growth target of 6.8 million by 2020.

(c) Enhancement of the Quality of Urban Environment

Besides efficient, adequate and reliable infrastructure, the improvement of other social amenities, enhancement of the city' image and character are to be given due attention towards creating an aesthetically pleasing environment and identity such as through the preservation and conservation of the heritage precincts and landscaping. Yangon City has a preponderance of water bodies, parks and architecturally significant colonial buildings that provide the basic criteria to create its own unique identity.

(d) Enhancement of the City's Physical Growth

It is also imperative to enhance the city's physical growth by ensuring orderly development via planned urban programmes. Efforts towards integrating the development of townships outside the City Centre would be desirable with a view to improve the physical and economic linkages.

(e) Enhancement of Human Resource Skills

In preparation of manpower for the future progress towards industrialization and market economy, more manpower training is expected in the relevant skills especially in the field of engineering and applied science. There is a need to provide for the development of more technical and skills training facilities. Manpower training in other service sector, such as business and finance is also important as Myanmar integrates further with the global economy.

6. PRIORITY PROJECT INITIATIVES

To complement the strategic policy, immediate, short and long term projects and programmes are proposed that will address both the existing citywide issues and harnessing the potentials of the premier city. Such projects are expected to provide the necessary impetus to the city's future growth and development. These have been specifically identified within the domain of the productive economic sectors, land use and spatial development, transportation, infrastructure and utility services. A summary of the priority projects implementable within the early action plan period are described as follows:

a) Spatial Development Framework

Development of New Government Administrative Centre in East Dagon.

- To facilitate the decentralization of city functions to the East of Yangon and providing development impetus to this area.

Upgrading Insein Town Centre with a District Centre.

- One of the two new district centres proposed for YCDC area.

Development of Metropolitan Park in Dagon Myothit Area.

- This is a fast growing suburban district where the development of a Regional /Metropolitan Park will be appropriate and serve to prevent urban encroachment.

Establishment of a Heritage and Conservation Zone in Downtown Area.

- The Downtown area is an important historical area which houses some of the most significant heritage buildings in Yangon.

Redevelopment of Waterfront Promenade along Seikkan Port Area.

- This project complements the establishment of a Heritage and Conservation Zone in Downtown Yangon as the waterfront is considered a public asset.

Feasibility Study on the Application of Land Readjustment in Yangon.

- The land readjustment scheme provides an opportunity to achieve comprehensive urban development without having resort to land acquisition.

Draft City Planning and Development Law.

- An urgent needs to establish a comprehensive city planning and urban development land and its supporting rules and guidelines.

Preparation of a City Urban Development Plan.

- This plan is expected to provide the planning instrument to achieve the proper development of Yangon City to be supplemented by an overall Infrastructure Master Plan.

Capacity Building in Town Planning.

- Capacity building in town planning as part of the overall human resource development is necessary to support a competitive and efficient running of local government and businesses.

b) <u>Productive Economic Sector</u>

Integrated Grading, Packing and Chilling Agriculture Products Centre in Yangon.

- To reduce post harvest losses, improve product sorting and packaging that would assist in the marketing process of agriculture products.

In-situ Breeding Improvement Programme.

- As part of a collaborative venture of the Ministry of Livestock & Fisheries.

Recreational Sports Fisheries, Lake Cruising and Yachting in Lake Inya.

- Is to be developed as part of a greater package of agro-tourism and sports tourism.

Integrated Agro-Health home stay facilities in western and eastern Yangon.

- This is to be developed as part of a greater package of agro-health tourism.

New Industrial Zone for Export Market in North-East Yangon.

- To further expand the utilisation of local resources and promote labour intensive industries.

New Industrial Zone for ship building, ship repairs and services in Thilawa.

- To establish strong ship related industries to compliment and enhance the new port's activities

MICE facilities in Yangon.

- The national capital as well as being the most important gateway into the Myanmar, the city should also serve as a MICE destination.

Waterfront development along the Strand Road, Yangon.

- To emulate and develop a well-landscaped and beautified riverfront, blended with locally designed architectural walkways and greeneries together with a fishermen's wharf.

c) <u>Infrastructure and Utilities</u>

Upgrading work for Kunitplin Chaung, Nat Chaung, Meomakan Chaung and Aungmingalar Chaung and other related structures.

- Involves upgrading of 10km on existing channels, construct 3 nos. of tidal gates and improving 6 nos. of drainage crossing.

Upgrading work for Yoegyi Chaung, Thamang Chaung, Aungthaikdi Chaung, Padauk Chaung and Kamayut Chaung and other related structures

- Upgrading 7 km of existing channels from earth section to concrete section, improves 7 nos. of drainage crossings.

Upgrading work for Ywama Chaung, Kathwe Chaung and Pauktaw Chaung and other related structures.

- Upgrading of 2.5km on existing channels from earth section to concrete, constructing 3 nos. of tidal gates and Improving 12 nos. of drainage crossing.

Improvement work for Zwenzon Chaung, Shwehle Chaung, Thunandar Chaung and Danityoe Chaung and other related structures.

- Improvement of 8 km an existing channels, Constructing 4 nos. tidal gates, Improving 8 nos. drainage crossing.

Upgrading work for Kyaiksan Chaung, Semyaung Chaung, Yeipauk-Kyi Chaung and other related structures.

- Upgrading of 12.4 km on existing channels, constructing 2 nos. tidal gates, improving 8 nos. drainage crossings.

Construction of Sewage Treatment Plant (300,000 PE) complete with ancillary works.

- Construction of a treatment plant at each township with the following scope of works – Earthworks, Foundation, Structural, Drainage, Road and Fencing, and Mechanical and Electrical Works.

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Construction of Sewage Treatment Plant (300,000 PE) complete with ancillary works.

- Construction of a treatment plant at each township with following scope of works – Earthworks, Foundation, Structural, Drainage, Road and Fencing Works and Mechanical and Electrical Works.

Solid Waste Disposal and Treatment Site Using Sanitary Landfill for Zone ‘A’ (Eastern)

- Construction of landfill civil works and structures, administration and workshop buildings. Provision of adequate machineries including collection vehicles, compactors and lorries.

Solid Waste Disposal and Treatment Site Using Sanitary Landfill for Zone ‘C’ (Northern)

- Construction of landfill civil works and structures, administration and workshop buildings. Provision of adequate machineries including collection vehicles such as compactors and lorries.

Inventory of Plant and Equipment Modernisation Programme.

- Increase in number of collection vehicles. Compactors are to be introduced or increased. Provision of support services. Promotion of recycling habit.

Construction of main raw water pipelines and pumping station from Ngamoeyik Reservoir to Yangon Central Reservoir.

- Involves construction of Pumping Station, 1800 mm diameter pipelines. Mechanical and electrical works inclusive of pumps and accessories.

Hlaing River Intake and Water Treatment Plant and Pipelines.

- Construction of pipelines to the reservoirs, Construction of the treatment plant at Gwendanshe, installation of M&E Services.

Preparation of Water Supply Zoning Master Plan.

- Master Plan Study, Water Reservoir Study, Demand Projection.

Replacement and Relining of Old Water Mains in Yangon.

- Replacement of old leaking pipes at identified locations, relining where appropriate of old pipes and carrying out of associated civil and M&E works.

Increasing the Capacity of Main Intake Sub-Stations.

- Sub-Station Structure, Equipment installation and associated M&E works.

Construction of new Main Intakes in new development areas.

- Main Intake structure and civil works, installation of new plant and equipment and associated M&E works.

Construction of Sub-Stations for Low Voltage Distribution in existing and new areas.

- Sub-Station Structures and Civil Works, Installation of new equipments and associated M&E works.

Fibre Optic Cabling Works in Yangon City.

- Installation of fibre optic cables and associated infrastructure.

Provision of Broadband System for Internet Services.

- Improve and upgrade current internet system with new equipments and cabling.

Installation and Connection of Fixed Lines.

- Review of current fixed lines system, study of revenue and cost of plant, services, etc.

Promoting Use of Natural Gas as Fuel in Public Transport System.

- Natural Gas Stations, Fuelling Equipment, Vehicles to be fitted with gas tanks.

Construction of Gas Fired Power Plants.

- Installation of turbines and related plants, associated civil, building, and M&E works, transmission and distribution network.

7. The Way Forward

The implementation of the Yangon Strategic Development Plan therefore cannot be seen in isolation from the relevant Government's policy context and national development planning. It must be supported by a policy framework that will enable the various projects and programmes to be implemented. The context of implementation shall be within an overall framework of sound economic condition, a political commitment to realize its objectives and a dynamic institutional framework that will respond to the various challenges and opportunities in the City and its hinterland region.

The adoption of a market oriented policy sine 1988 was therefore a significant change in terms of this overall policy framework as the initial starting point for endeavouring these initiatives. The current policy on the participation of foreign countries provided under Myanmar's Economic Objectives is aptly described as 'Development of the economy inviting participation in terms of technical know-how and investments from sources inside the country and abroad'. Foreign Investment Law was introduced to induce and boost foreign direct investment (FDI).

It can be expected that the response of the private sector to the government's liberization policies can be further enhanced, and complemented by YCDC's proactive stance. Such problems that have been entrenched in the economy because of wrong economic policies and strategies and poor governance are to be regarded as matters of the past. Uncertain investment environment and cumbersome administrative procedures will only prevent the inflow of FDI. The right environment is required for focus and efficient markets to work and flourish.

More investments can be expected on conditions of a stable macro-economic environment, implementation of proper policy instrument and market-friendly government intervention. Given the right condition, Myanmar will develop to become **'a new modern developed nation'.** In this process lessons can be learnt from the experiences of the High Performing Asian Economies (HPAEs). In the context of regional cooperation, the current ASEAN's **'constructive engagement approach'** to the Myanmar issue is expected to continue to facilitate the process.

SUSTAINABLE DEVELOPMENT MASTERPLAN – IMPLEMENTATION OF THE ECES© MODEL IN COLLABORATION WITH GOVERNMENT, INITIATIVES AND PARTNERSHIPS

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Abstract

The rapid rise of the world population and its advancing technologies have put pressure on the building industry to provide and implement measures to ensure the ecological balance of the environment and the provision of sensitive development to accommodate the rising need for housing and increased development. The fine balance of these two elemental issues could be seen as the driving force of the phrase "sustainable development'.

The idea and effective implementation of the concept of 'Sustainable Development' is crucial to the continued existence of this balance but notwithstanding, the key to sustainable development need also to take into account the economic and cultural elements of each community as can be illustrated in the more comprehensive definition.

The Brundtland Report vigorously promotes the idea of sustainable development, which it defines definitions in formal terms; "Sustainable development is development result in the various concepts of that meets the needs of future generations sustainability not being achieved; without compromising the ability of future generations to meet their own needs" (WCED 1987, p43)

"...economic growth, the alleviation of poverty, and sound environmental management are in many cases mutually consistent objectives." (World Bank: 1988, p1)

Thus it can be suggested that Government has to be an active partner in the process of sustainability to be sustainable. A collaborative Partnership in ensuring in that it is the public's active participation in the process of evolution from the roots level in the industry rather than from the top down.

The Government's role is to provide land for competitive tender for large scale best practice projects. The outcome will be a shift in the mind set of the industry, the development of skills, technology procedures and buyer preference in a positive framework. The greater health and amenity of a sustainable project will then become a force in the market place bringing about economic adjustment to land vendors economic expectation through active application of sustainable feasibilities. This will bring about the broader comprehension within the industry to facilitate the work of regulators.

The ECES© is based on first principles in which a model was developed by the authors to ensure the implementation of "Sustainable Development' . The ECES© model is a synergy of the combined elements of the four primary elements of development which consists of the Economic, Cultural, Ecological and Social fundamentals through a methodology and mapping analysis with input from specialist experts to derive a sustainable outcome.

The combination of the elements in a balanced state at the centre will ensure the most productive outcome for all parties involved and will be discussed in further detail based on the best practice model of the proposed development of a 57 hectare parcel of land in Sydney, Australia, with specific reference to the case study of the Newington Sydney Olympic Village, the masterplan and built form concept of the author[1]. These masterplanned developments have proven to be a precedent to enhancing and refining the ECES model in the best practice application for a masterplanned development of land in Belrose, New South Wales Australia.

As a result, out of this need for sustainability emerge both challenges and opportunities. This paper highlights the call for members of the built environment to continue to pursue higher levels of understanding of sustainable development in the context of a holistic approach to the design of the built environment, and this contributes indicators on how to move forward in the context of this forum's goals.

1. Introduction

There exists in this day and age, a significant shift and realizations within the development industry of the value and social consciousness when creating a sustainable built environment which range from governing global commitments to the overriding social consciousness in the way an individual lives and consumes within the built environment.

With the new treatises and agreement on the climate change in the recent APEC summit, there is an emphasis to be placed in the way the built environment responds to this call.

It is the need for Cooperation and Partnerships for the Implementation of Sustainable Development between the public and private sectors that will ensure better and more effective outcomes.

For instance the use of government land for best practice sustainable projects will ensure that developers and architects adopt ESD principles . This in turn will force up-skilling and education, a greater awareness in consumers of what is available in the market.

For that reason, it can be suggested that the collaborative partnership of Government Initiatives and the Implementation of the ECES© model encompasses and fundamentally implements the following sustainable development objectives.

The application of the ECES principles facilitate the following objectives;

(a) Create a “mile stone” or “flagship” development in environmental terms
(b) To provide the Developer with an image of a quality developer caring for the environment and the community and provides job opportunities for members of the Developer in respect of the Project;
(c) Utilise the Land efficiently for its most productive use, a development that Enhances and connects with the environment in doing so achieves ecologically sustainable development ;
(d) Conserves and educates significant cultural and archaeological items to the community
(e) Is commercially viable and responds to the market to maximise the commercial potential of the Land and returns to the Parties.
(f) Is in accordance with accepted standards of development and environmental responsibility;

2. Applications of ECES principles

The following sections outline the ECES principles when applied to these 2 developments as mentioned in this paper result in the sustainability of built environment.

2.1 Details of Projects

The following snapshots background the following 2 projects by the authors to be discussed herein.

2.1.1 Newington Olympic Village, New South Wales, Australia

- 86 Ha site
- $750M project cost
- The world’s largest solar village
- 629 permanent homes, 1380 home units and up to 500 specially designed relocate-able modular dwellings
- Sustainable Millenium Park additions
- The “Living Centre” interpretive centre
- The Village in the Park open space
- Retention of the elements of heritage in the masterplan as part of a comprehensive strategy
- Ameliorate and enhance the built environment and the public realm
- Ensure that public transport focuses on maximizing and the use of private vehicular transport is minimized

2.1.2 Belrose, New South Wales Australia Project Snapshot

- The Lizard Rock project is on a 57 hectare site adjacent to Forest Way, Belrose.
- $250m total project cost.
- The development focuses on environmental excellence and sensitivity, with Metropolitan Local Aboriginal Land Council's (MLALC) vision to create a flagship development.

- Proceeds from the Lizard Rock development will go towards providing;
  -Home ownership for MLALC members
  -Long term economic benefi ts to MLALC
  -Youth scholarships
  -Jobs, education and training

- Team of leading environmental experts have determined;
  - Bushfire protection is improved at a local and regional level
  - There are no endangered ecological communities present – the study was undertaken over a 24 month period. 1500 mature canopy trees survey will be retained
  - The water quality exiting the site will actually be improved and there will be a nil increase in runoff to Narrabeen Lagoon as a result of the development.
  - Best practice of monitoring sediment controls during construction
  - Final traffic levels will be manageable -Sewage capacity issues are resolvable by MLALC providing a new sewer main
- Protection of significant Aboriginal rock carvings on site that are currently being vandalised.
- No impact on natural character from Wakehurst Parkway or Narrabeen Lagoon.
- Provide affordable housing
- The site is an extension of the existing urban fabric.
- Provides good logical use of infrastructure already in place.

3. The ECES principles and Government Initiatives–Creating a Milestone or flagship Development in Environmental terms

3.1 Case Study Using ECES Principles to Assess Sustainability Outcomes – Newington Olympic Village

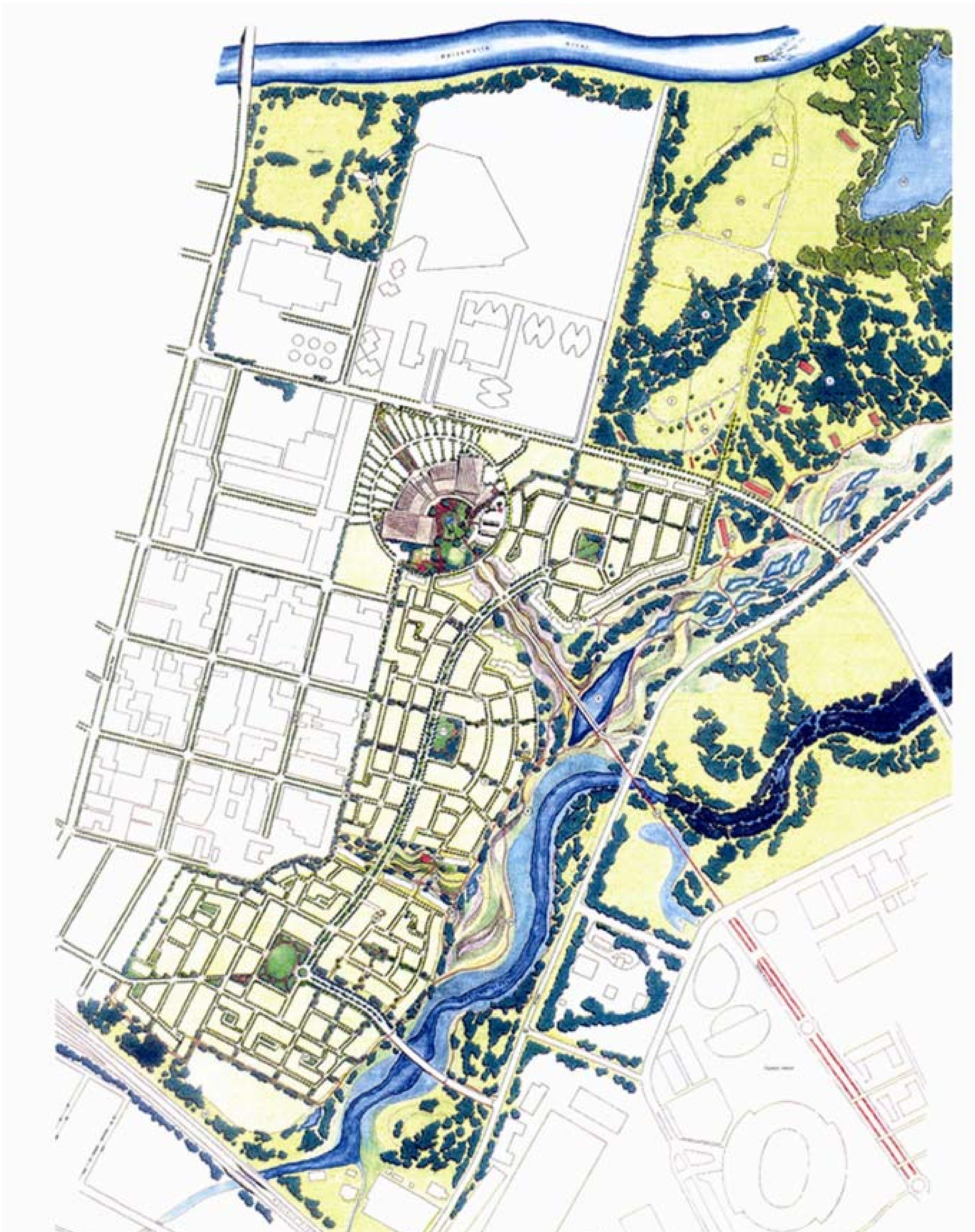
The Newington Village represents an **exceptional opportunity to establish a best practice example of sustainable urban development**, building on world class initiatives in energy management, water management, green building design, ecological management and the healthy lifestyle offered by the Park's wide array of sporting facilities and 425-hectares of urban parkland.

The Sydney 2000 Olympic Games incorporated an athlete's village, as an overlay to a larger new residential development called Newington, aimed at creating a practical example of more sustainable living for the 21st century.

Newington has a range of environmental features including solar hot water, solar photovoltaics, energy efficient design and water recycling for irrigation and toilets. Each home will have 1 kW (peak) of roof integrated PV connected to the grid via an inverter system.. The Newington development demonstrates that using today's technology through a high concentration of solar power that is readily integrated into a residential development with benefits to all participants.

In most parts of the world, strikingly small amounts of turnover in the building and construction industry (BCI) are used for R&D as compared to other industries. Despite the apparent difficulties with introducing new technologies in the construction sector, there are success stories as well. One of these concerns the introduction of solar energy systems in the Sydney Olympic Village, which represents a remarkable case of network knowledge renewal, involving competence development among a range of actors in the industry. Selection of technologies with proven track records, careful network configuration and management and a strong emphasis on knowledge dissemination are important factors for mobilising resources and convincing actors to adopt new recipes for construction (Journal of Business Research Volume 57, Issue 4, April 2004, Pages 351-360)

Thus is can be suggested that this is one of the examples in which the government's goal is of providing a practical opportunity for developers to competitively participate in delivery of best practice design filters through to the grass roots level of work practice, material supply, technology and waste management. Furthermore, the role of government in setting targets for sustainable performance actively participates in upskilling industry rather that forcing performance through repressive regulation.



Stephen Bowers Principal of Sdmasterplan worked in HPA on this Project as Managing Director responsible for concept and project delivery

Fig. 1- The masterplan concept for the Newington Olympic Village

Fig. 2- The example of the ECES principles when applied to the development

3.2 The ECES principles and Government Initiatives – Creating a milestone or flagship development in environmental terms

BEST PRACTICE – BELROSE

Fig. 3- The Belrose Masterplan

MLALC is a significant owner of land assets in the Sydney Basin and is the recognized custodian of Aboriginal land in the local government area. The MLALC was conscious of the need to prudently and proactively manage their assets for the future benefits of all their members

The Metropolitan Land Council (MLALC) is a semi government body whose primary objectives are "to improve, protect and foster the best interests of all Aboriginal persons within the council area and other persons who are members of the council. (MLALC Section 51 of the New South Wales Aboriginal Land Rights Act)

Thus this parcel of land was identified as being suitable for innovative and environmentally sensitive development. The project is named Lizard Rock and 432 lots are proposed with a development value of $250 Million.

The authors and a group of 15 specialist consultants were appointed over a 4 year period to develop the concept plan for this site. The process undertaken was to brief numerous Government bodies in regards to the concept plan during the concept planning stage to illustrate and explain how this land was a significant development which undertook and embraced the principles of sustainable development.

As this land is one that is of a sensitive nature, a thorough assessment of how to insert the footprint of development whilst conserving the site's natural features and maximizing yield. The constraints and opportunities diagram based on the ECES principles the tool used to facilitate this process. The proposal is one which is deemed to be the right approach to the land and is seen as progressing the creation of a healthy environment to live in and implements the government's objectives in relation to this land.

Fig. 4- Mapping identifies development zones

Fig 4 & 5 - The mapping process showing a thorough assessment of how to insert the footprint of development whilst conserving the site's natural features and maximizing yield

4. The ECES Principles and Government Initiatives – To provide the Developer with an Image of a Quality Developer Caring for the Environment and the Community

4.1 Case Study Newington Olympic Village

In the case of the Newington Village the collaborative nature of a government in implementing best practice standards to the development of their land ensured that the developer's objective to be recognised as a leader in best practice development principles were met. The developer and his consortium's vision was to create a project that demonstrates design excellence and environmental sensitivity.

In the preparation of the masterplan and design of the built environment, the developer had to carefully consider all issues such as cultural heritage, flora and fauna issues, bushfire protection, impact in existing waterways, traffic, sewage capacity and maintaining the preservation of natural character of the area and to come up with a solution that is an example of the best practice requisite.

To exemplify this process , in 1996 the New South Wales (NSW) state government called for expressions of interest in design and construction of a village to house the athletes during the Sydney Olympic Games in the year 2000, a group consisting of Mirvac Lend Lease Village Industry Consortium. The group put together an innovative bid to build an internationally significant solar powered suburb named `Newington, incorporating grid connected solar photovoltaic systems, solar thermal hot water heating and energy efficient design. The bid was successful and the construction of Newington was commenced in late 1997 and completed in 2000. The village consists of up to 629 permanent homes, 1380 home units and up to 500 specially designed relocate-able modular dwellings (which will only be used for the period of the games). The result is a very attractive new suburb for Sydney which incorporates many aspects of sustainable development. (Morphett, Watt, Grunwald, Zacharias :2000:p.2)

The Newington Village received several awards for 2000 Architecture Awards - NSW Chapter, Single and Multiple Housing Design Award, "Newington, NSW" From Urban Development Institute of Australia: and the developer had greatly 2001 National Excellence Awards, Presidents Awards, "Newington, NSW.

Thus the success and benchmarking of the high quality sustainable development provides a basis in which the developer, government and community and social awareness all benefit from this process.

Therefore it can be suggested that with the growing community concern regarding greenhouse gases and carbon footprint are leading to purchasers, house owners seeking housing that will reduce these impacts. Therefore developers who are environmentally branded yet offering product at competitive prices will have a larger market and therefore benefit from being recognised as a developer of best practice sustainable development.

4.2 Best Practice Application – Belrose

To provide the Developer with an Image of a Quality developer Caring for the environment and the Community

Whilst the case study provides low risk economic return to government, Belrose provides low risk and economic return to alleviate hardship and improved housing standards of living and education for members of the landowner's community.

For instance, a significant contribution will be made from the development of the land at Belrose to upgrading and providing housing and facilities within established urban areas preferred by the Community such as the upgrade of the Red Square, a redevelopment of the housing project at Redfern. It is stated that the vision of this Red Square redevelopment is to provide a clean, healthy and safe environment in which the next generation of Aboriginal children can live harmoniously and grow to achieve the quality of life, standard of living and well being. (Pemulwuy Housing Project : 2006 : p.2)

The funding that results from the development of the land will result in social, financial and environmental stability by providing a built environment that provides high quality and culturally appropriate affordable housing.

Proceeds from the Lizard Rock development will go towards providing, home ownership for MLALC members long term economic benefits to MLALC , youth scholarships, jobs, education and training

Thus it is suggested that the social benefits that are derived from this application of the ECES principles brings great social benefit to the community contributing in the through an integrated social and renewal approach.

5. Utilises The Land for most Productive Use and a Development That Enhances and Connects With The Environment.

5.1 Case Study Newington Olympic Village

The Newington masterplan identified opportunities for location of density of dwelling types, a school, a town centre and various warehousing and office opportunities within the framework of adjoining land uses and retained natural and heritage features.

This was the most productive use because commercial retail and recreation facilities were centrally located to serve not only the local community but the broader community while areas of highest density was located to the edges of conserved and introduced open spaces. Thus the underlying need for range of housing types is accommodated in such a manner that each home embraces the highest level of residential amenity.

Open space areas within the development are linked to the conserved environmental access and used to facilitate water sensitive urban design principles. Thus the resource, by being retained, rehabilitated and protected to mitigate the environmental impacts of the development.

5.2 Best Practice Application – Belrose

The Belrose Project within its regional context retains habitat and riparian vegetation along with the introduction of measures to clean up the water entering the site from the upstream environment so that regionally significant vegetation is retained and water quality leaving the site is significantly improved. In the local context significant canopy trees and natural features such as rock shelves and drainage lines are retained within this regional local context a diverse range whre housing is sited at its highest density where they will have least impact thus achieving a highest level of productive use.

Water Sensitive Urban Design is implemented to ensure that infrastructure and housing will have NIL impact on conserved areas within the site and beyond in its downstream environment.

Fig 6-Illustrates the primary areas of significant vegetation types retained within the site to maintain the site's key within its regional context

6. Conserves and Educates Significant Cultural and Archaeological Relics to the Community

6.1 Case Study Newington Olympic Village

Newington site analysis identified areas of heritage items of significant cultural heritage. These areas were predominantly excluded from the developable area and have subsequently been conserved and open to the public within the regenerated woodland site as a destination for tourism and recreational opportunities.

An interpretive centre incorporates the significance of the disused armaments depot with the biodiversity of the remnant regionally significant woodland estuarine habitats.

6.2 Best Practice Application – Belrose

The Belrose site incorporates a sense of archaelogically significant pre European sites incorporating Aboriginal Rock engravings between 3000-5000 years old. These sites are conserved within open space and provided with appropriate curtilllage to ensure adjoining development does not encroach on interpretation of the site. To supplement the objects of heritage an interpretive centre for education purposes are recorded within the proposed neighbourhood centre as is illustrated in Fig. 7 and 8 below.

Fig 7 & 8 - Retention of Archaeological Heritage

7. Is Commercially Viable and Responds to the Market and Maximizes the Commercial Potential of the Land and Return to the Parties

7.1 Case Study Newington Olympic Village

The Newington site was firstly considered within the context of the housing type for which there is highest demand and supplemented with further housing types such as residential flat buildings and townhouses to increase densities whilst retaining a low scale environment beneficial to the most desired housing type, further locating housing into neighbourhood precincts within close proximity to facilities to ensure that opportunity for commercial return is maximized.

This is exemplified in the Mirvac Stock Exchange Report in 2001 " Over 1000 sales at Newington, The Olympic Village; The various sales successes achieved over the past 3 years is a testament to our increasing brand awareness and rapidly growing customer loyalty to Mirvac". (Media and Stock Exchange Report: 2001: p.1)

7.2 Best Practice Application – Belrose

Belrose is a 'disbursed development model' achieves best practice in commercial potential by incorporating natural features possible within a low density framework which has a significant reduction in site preparation cost. However, high densities are achieved through placement within the masterplan of multi unit buildings and townhouses overlooking conservation areas. The returns to the landowner are thereby optimized within the conventional development profit parameters.

8. Is in Accordance with Accepted standards of Development and Environmental Responsibility

8.1 Case Study Newington Olympic Village

In addition to these technological innovations, materials selected for using construction were based on low energy embodiment and low emission of noxious gases and selection from renewable resources. Dwelling layouts were managed to incorporate climate control and mimimise energy consumption. Landscaping species were chosen to reduce the need for horticultural assistance whilst regional transport networks were incorporated into the masterplan to enhance the likelihood of use of public transport facilities.

8.2 Best Practice Application – Belrose

Belrose seeks to further the response to sustainable development standards by incorporating the latest thinking in relation to reduced water consumption through the retention of facilities and contribution to reduction of the carbon footprint.

9. Conclusion

In conclusion, it can be suggested that the combination of the implementation of the ECES principles as a guide to bring sustainable development alongside with the cooperation and partnerships for the implementation of sustainable Development between the public and private sectors that will ensure better and more effective outcomes.

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CURRENT PRACTICES IN SELECTED SOUTHEAST ASIAN COUNTRIES ON MANAGING CONSTRUCTION AND DEMOLITION WASTE

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Abstract

This paper presents part of the results from a research recently conducted to compile information on the current practices of construction and demolition (C & D) waste in relation to the practice of 3R (Reduce, Reuse, Recycle) principle. Some cases from different countries have been selected and included in this paper to discuss current practices within Southeast Asia context. The findings provide baseline information to stakeholders and at the same time aid in understanding the C & D waste management in the sub-region. The information can also be used to assist the decision making process in the formulation and implementation of policy interventions relating to C & D waste based on challenges, opportunities and constraints of the compiled cases which are also discussed in this paper.

Keywords: 3R Practices, Construction and Demolition Waste, Southeast Asia.

1. Introduction

Annually billions of tons of material are mined and processed to produce building materials around the world. The amount of material removed and refined immeasurably surpasses the quantity of finished building material produced. The volume of material moved and wasted during the production of a building material contributes to its environmental burden (Graham, 2003: 68). Holm (2001, cited in Kulatunga et al., 2006) stated that approximately 40% of the generated waste portion globally originates from construction and demolition (C & D) of buildings. In general, C & D waste is bulky, heavy and is mostly unsuitable for disposal, e.g., incineration or composting. This poses to environmental burdens related to waste management problems particularly in urban environmental management.

C&D waste is waste material produced in the process of construction, renovation, or demolition of structures. These structures include buildings of all types in residential and nonresidential as well as roads and bridges. Components of C&D waste are typically concrete, asphalt, wood, metals, gypsum wallboard, and roofing (Franklin Associates, 1998). Burgeoning urbanization and economic development in the Southeast Asian could be manifested with the built environment. The growing construction, renovation, and demolition activities of this built environment cause C & D waste; this contributes to one of the major environmental burdens to cities in Southeast Asian sub-region. For instance in Malaysia, the source of construction waste at the project site includes materials such as soil and sand, brick and blocks, concrete and aggregate, wood, metal products, roofing materials, plastic materials and packaging of products. The composition of total waste generation is shown in Fig. 1, which is percentage by weight. Concrete and aggregate is the largest component with 65.8% followed by soil and sand (27%), 5% from wood based materials such as timber, lumber, etc., 1.6% from brick and block, 1% from metal products, 0.2% from roofing materials and 0.05% from plastic and packaging products such as papers, cardboards, etc (Begum et al., 2005).

The principle of reducing waste, reusing and recycling resources and products is often called the "3Rs." Reducing means choosing to use things with care to reduce the amount of waste generated. Reusing involves the repeated use of items or parts of items which still have usable aspects. Recycling means the use of waste itself as resources. Waste minimization can be achieved in an efficient way by focusing primarily on the first of the 3Rs, "reduce," followed by "reuse" and then "recycle" (MoEJ, 2005). Coventry et al. (2001) highlighted opportunities of C & D waste related to 3Rs principle e.g. will help reduce environmental impacts. Further, Addis (2006) highlighted that the dominant reason for reusing or recycling materials and goods is to reduce our society's impact on the environment.

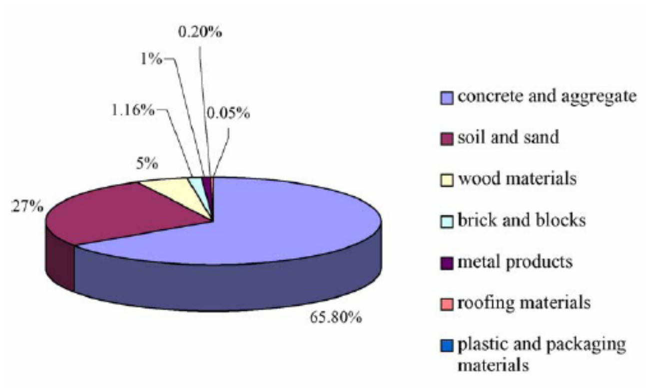

Fig. 1: Composition of total waste generation (Source: Begum et al., 2005).

Furthermore, the international community has come up with initiatives for cooperation to mitigate environmental pollution on waste management and tackle the environmental burden. In 2004, the G8 Sea Island Summit adopted the Reduce, Reuse, and Recycle (3R) action plan and progress of implementation on Science and Technology for Sustainable Development. In the following year, the 3R initiative was formally launched at the Ministerial Conference in Japan.

The recycling of C & D waste is routinely carried out in many countries around the world including the United States, Japan, Republic of Korea, Australia and many countries in Europe. Moreover, good practices on C & D waste management in relation to 3R principle have been carried out by OECD member countries. This can be manifested in countries like Japan and Germany, among others.

Southeast Asian countries have their own definition of C & D waste in terms of the components of C & D waste in the construction industry. In some countries particularly in urban centers, the 3R principles have already been practiced in most C&D waste management. Also, awareness raising on C & D waste management is practiced in some C & D industries of these countries.

2. Methodology

Compilation of the current C & D waste management practices in SEA focused on collecting information on generation rate and characteristics, technology, management and partnerships. The information in this study has been compiled from international journals, reports and proceedings of various waste management organizations. Certain information was also received through communications by electronic mail and incorporated in the compilation of this paper. The selection and comparison of compiled practices are based from the geographical area reflecting C & D waste management policy measures in SEA region (e.g. regulation that is registered); actual change that contributes positively to improvement in the C & D waste management; involvement of actors in C & D waste management and indicators at some visible or measurable change relative to C & D activities.

3. Overview of C & D waste management Practices

Table 1 illustrates the current status of C & D waste management in some SEA countries - relative to 3R practices. The practices focus on technology, management and key partners involved in the C & D waste management. In terms of technology on C & D waste, SEA countries are still in the process of development.

SEA countries like Singapore and Malaysia are two of the leading countries of technology on C & D waste practices. Other countries like Indonesia and Vietnam practices such as reuse of C & D waste, particularly concrete which is utilized as filling.

Table 1: Current Status of C & D waste practices in SEA relative to 3R principle

Country	Annual C & D waste	Technology	Management	Key Partners
Indonesia (Alwi et al., 2002)	No Data Available	Adopt Dry-Masonry Brick House System an environmentally-friendly cycle that covers 3R scheme (Khamidi et al., 2004)	- Improvement of construction industry coordination among project participants - Adopted own in-house quality systems - 52% of construction industry has ISO 9000 compliance - DEBRI: demonstrate a waste management mechanism	Demonstrating Environmentally Sound Technologies for Building waste Reduction in Indonesia (DEBRI):: Ministry of Environment (MOE) or Kementrian, Lingkungan Hidup (KLH) - Indonesia, International Solid Waste Association – Denmark and UNEP
Malaysia (Begum et al., 2006)	28.34% (including industrial waste)	- Reuse and recycle of concrete and aggregates - Recycled Construction Wood Waste Products Developed by FRIM	- reusing materials are the most practiced waste minimization - practice of economic instruments in some construction industry for waste minimization	Board of Malaysia, Institute for Environment (CIDB) and Development (LESTARI) of University Kebangsaan Malaysia and the Forest Research Institute of Malaysia (FRIM)
Singapore (NEA, 2005)	422,900 tons (as of 2003)	- recycle concrete waste from concrete batching plants - use recycled aggregates for non-structural pre-cast concrete products	- Most of contractors gained Environmental Management System ISO 14000 series certification - Building and Construction Authority promote adoption of pre-fabricated concrete components - National Environment Agency (NEA) established regulations on control of noise at Construction Sites	- Waste recycling company, BCA, NEA and construction industry - NEA reviewed the regulation for construction nuisance in consultation with various government agencies and industry partners, and the public
Thailand (Carden, 2005)	No Data Available	- Immediate reuse of undamaged construction elements for building temporary shelters - Recycling as aggregate for structural concrete	- Recycling and Reuse of Debris from the Tsunami Disaster and Technical guideline developed for C & D waste management - International Cooperation: C and D waste program for recycling and reuse	Academe, Overseas Funding agency and the Pollution Control Department
Vietnam (VEM 2002, cited in Vietnam Environment: Monitor, 2004)	Proportion of Construction waste is about 9% of municipal waste	- Monitoring Mobile station for TSP used on large construction projects - Reuse of C & D waste	- Decree passed to reduce waste by introducing charge/fine to construction industry directly for waste handling or disposal - Construction waste is normally used for back filling	Ministry of Natural Resources and Environment, Ministry of Construction, Municipal Peoples Committees and Public Urban Environment Company (URENCO)

In terms of management aspects, most of the construction and demolition activities in Singapore and Malaysia have demonstrated good practices on 3Rs. Thailand, Indonesia, Vietnam and Philippines are in the process of formulating guidelines and procedures to apply appropriate management measures on C & D waste management. Singapore is encouraging most of the construction industry to obtain EMS using ISO 14000 series. Currently, 25 constructors obtained ISO certification and some of the others are in the process of certification approval. 52% of construction industry in Indonesia have complied ISO 9000. Further, NEA Singapore and Vietnam implemented regulatory measures on C & D waste management and other initiatives which are effectively enforced and implemented such as awareness raising and campaign, among others. Partnerships on C & D waste management initiated in SEA countries like Singapore, Malaysia, Indonesia and Thailand.

4. Selected cases in Southeast Asia

4.1 Case 1: Waste management guidelines and regulation for construction sector in Vietnam

Construction waste is one of the five types of solid waste that exist in Vietnam's MSW. Existing legislation on waste management, particularly addressing to the construction sector, is established. These guidelines include regulations and environmental protection applied for the space planning of the siting, construction, and operation of landfills (Inter-ministerial circular of 2001); preparation of Environmental Impact Assessment reports for the planning of construction projects, including solid waste management during and after construction (Inter-ministerial circular of 2000); and regulation on environmental protection in the construction sector which establishes the requirements for environmental management (Inter-ministerial circular of 1999)(VEM, 2004). In 2005, a degree was passed by the Hanoi's People Committee requiring individuals and organizations involved in construction and waste disposal activities to ensure that the waste handling and transport of construction materials does not cause dust pollution. Disincentives e.g. charge or fine was introduced to reduce waste from construction industry directly for waste handling or disposal (ADB, 2006).

4.2 Case 2: Reuse and recycle of concrete and aggregate and construction wood waste in Malaysia

Malaysian construction industry generates a lot of construction waste which cause significant impacts on the environment and increasing public concern in the local community. The country's construction industry in terms of the availability of data is limited, data may include the current structure of construction waste flows by the source of generation, type of waste, intermediate and final disposal and the amount of waste reduced at source, reused or recycled on-site or off-site. According to Begum et al. (2005) extra construction materials are usually planned due to the lack of considerations given to waste reduction during planning and design stage to minimize the generation of waste. The excessive wastage of raw materials, improper waste management and low awareness of the need for waste reduction are common in the local construction sites. The 3R principles have been promoted and encouraged in the construction industry due to the most significant wastes generated in terms of volume.

A study done by Begum et al. (2006) of the project sites in Malaysia, construction waste materials contain a large percentage of reusable and recyclables. Estimated 73% of the waste materials in the project site is reused and recycled. Table 2 shows the amount of reused and recycled waste materials on the site. The highest amount of reused and recycled materials is concrete and aggregate, comprising 67.64% of the total reused and recycled material. It is followed by soil and sand, wood, brick and block, metal products and roofing materials. The practice reuse and recycling of construction waste materials is common on the site of one of the project sites. Furthermore, reuse and recycling of waste have been promoted in order to reduce waste and protect the environment (Begum, 2005).

Table 2: Amount of reused and recycled construction waste materials on the site.

Construction waste material	Amount of reused and recycled	
	Tonnage	Percentage
Soil and sand	5400	27.33
Brick and block	126	0.64
Concrete and aggregate	13365	67.64
Wood	810	4.0
Metal products	54	0.27
Roofing materials (tiles)	5.4	0.03
Total	19760.4	100

Source: Begum et al., 2006

Forest Research Institute of Malaysia (FRIM) has developed recycled construction wood waste products. These recycled construction wood waste (Fig. 3) are wood cement block, particle board, among others. Wood Cement Block is made from saw dust or wood particles and mixed with special cement under high pressure and controlled heat. The recycled construction wood waste is commonly used in the construction industry for outer walls, dividing walls and ceilings. Particle board made from saw dust or wood particles but mixed with glue. The product is popular in the making of furniture, for example cupboards, cabinets, kitchen cabinets, tables and chairs.

Fig. 5: Wood cement block and particle board made from C & D waste.
Source: LESTARI - http://www.lestari.ukm.my/wmrpcm/research.htm.

The Construction Industry Development Board of Malaysia (CIDB) has granted a research fund to the Institute for Environment and Development (LESTARI) and Forest Research Institute Malaysia (FRIM) on Waste Minimization and Recycling Potential in the Construction Industry of which recycled construction wood waste is one of the researches. Various key stakeholders from the environmental and socio-economic disciplines are involved in the project. The research aims to produce standards and guideline documents as well as examples of good practices to minimize and recycle construction waste (Source: http://www.lestari.ukm.my/wmrpcm/index.htm).

4.3 Case 3: Initiatives on 3Rs for C & D waste in Singapore

NEA has been actively promoting the recycling of the waste outputs. Waste concrete is the principal component of C&D waste and is typically recycled by crushing and sieving it for reuse as aggregate material in concrete products. Recycling centers like Tri-Mix has invested in a concrete waste recycling plant that sifts through leftover concrete waste brought back by concrete trucks. The separated components of sand, coarse aggregates as well as the filtered water can be reused (NEA, 2002).

Ofori (2000) cited that construction site waste is a major problem owing to the scarcity of land. Ministry of the Environment put only "construction debris" in a separate category, and shows that 5% of the total amount of waste. The Ministry encourages more responsible practices and disposal charges have been raised. Further, Environmental Public Health (Amendment) Act 1999 has tightened its legislation, with stiffer penalties, to discourage illegal dumping of wastes which the authority put it as construction companies are among the main culprits.

Table 3 depicts how C & D waste output in parallel with the recycling rate has increased in Singapore since 1997 to 2003. Hence, recycling practices prove to be the best solution to get rid of construction waste in Singapore (Wong, et al., 2006).

Table 3: Construction and demolition waste output and recycling statistics in Singapore.

Year	Amount disposed of (tonne)	Amount recycled (tonne)	Total waste output (tonne)	Recycling rate (%)
1997	126,000	188,000	314,000	59.9
1998	127,900	136,600	264,500	51.6
1999	125,700	288,500	414,200	69.7
2000	125,300	193,700	319,000	60.7
2001	51,524	299,764	351,288	85.3
2002	39,400	367,200	406,600	90.3
2003	24,600	398,300	422,900	94.0

Source: Wong, et al., 2006.

National Environment Agency (NEA) is encouraging the establishing of facilities to recycle construction and demolition waste. Building and Construction Authority has also supported a study done by Hock Chuan Hong Waste Management Pte. Ltd to use recycled aggregates for non-structural pre-cast concrete products. The company has successfully used recycled aggregates to manufacture pre-cast concrete drain slabs, and with help from NEA, other agencies and institution and key stakeholders in construction industry, the company has embarked on a pilot project to lay a stretch of pre-cast concrete drains in Singapore (NEA, 2002).

4.4 Case 4: Partnerships on 3Rs for C & D waste in Malaysia, Thailand and Singapore

Public Private Partnerships and awareness raising on waste minimization and recycling were among the initiatives undertaken by the authority in Singapore with the participation of various citizens. In Indonesia, a project on Demonstrating Environmentally Sound Technologies for Building waste Reduction in Indonesia (DEBRI): demonstrate a waste management mechanism where partners involve Ministry of Environment, International Solid Waste Association – Denmark and UNEP. Moreover, Thailand has built partnership between GTZ (Deutsche Gesellschaft für Technische Zusammenarbeit) and the Pollution Control Department for the development of technical guidelines on C & D waste program for recycling and reuse.

5. Discussion

C & D waste is a major component of the solid waste stream, which should be recognized as a valuable resource as large quantities of it could either be reused or recycled. C&D waste has been overlooked in the efforts to reduce waste sent to landfill, with the emphasis being placed on domestic reuse and recycling. With this view, SEA countries have a problem of disposal sites of which C & D waste largely account to it. Environmental issues such as increase in volume and type of waste, resource depletion, shortage of landfill and illegal dumping, among others are evident in countries in this sub-region. Furthermore, the SEA countries have limited or no available data on C & D waste and the management aspects of it particularly with regards to their C & D waste generation and composition; practices and policy, stakeholders' participation and available technology related to 3Rs.

The challenges that most SEA countries encountered include: the unavailability of data and information of C & D waste management, lack of participation between national authorities and construction industries in the formulation of C & D waste policy measures, lack of awareness campaign on C & D waste management, limited institutional arrangement between various government agencies and C & D sector, and inadequate resources including technologies e.g. recycling facilities, waste storage and handling.

Opportunities of SEA member countries that could be considered include: strengthen information exchange in C & D waste management, usage of 3R principle, enhance Public-Private Partnerships, formulation, development and implementation of 3R policies, develop institutional arrangement and improve participation and cooperation among key stakeholders relative to the practice of 3R principle on C & D waste management.

Constraints of C & D sector in SEA countries is that most of the countries like Philippines, Myanmar, Cambodia, Vietnam and Thailand do not have or have limited compilation of data on C & D waste management. Most of the data included in the MSW. Lack of awareness of the influence of C & D waste and its management to construction industry performance and environmental impact is still evident. No legislations exist that directly address C & D waste management issues in most SEA countries.

6. Conclusions

Most of the countries in Southeast Asia address more on municipal solid waste management, and do not recognize C & D waste as a pressing issue. Programs and initiatives on C & D waste management have not been a focus of the sub-region. Such initiatives should be addressed and practiced in the C & D sector, particularly in SEA urban areas, for better management of C & D waste. Considering that urbanization is manifested in its built environment parallel with the economic development, environmental burden of this sub-region may continue. Also, no available or limited data exist in this sector, particularly related to the practices of the 3R principle in the waste management. C & D waste management practices are evident in countries of Singapore, Malaysia and Indonesia, while some SEA countries where C & D waste data and information are still developing and emerging are found. .

Access and availability of having baseline data and information on C & D waste generation and waste management in SEA countries should be studied and explored. Also, as most of the SEA countries have poor data availability, compilation of C & D waste and waste management in this sector should be strengthened. Key stakeholders in this sector specifically, the national government in different SEA countries should look for an opportunity to formulate strategies and policy measures to mitigate the environmental impact and burden of C & D waste. Awareness raising and capacity building in construction industry should be developed and effectively enforced. Partnerships and cooperation of various stakeholders in C & D sector should be enhanced for the provision of resources for an effective implementation of the 3Rs.

Acknowledgements

This paper is part of Master Thesis for Urban Environmental Management Field of Study in AIT under the auspices of Canadian International Development Agency (CIDA) Grant. Also, this paper is part of 3R Knowledge Hub (3RKH) project jointly established by partners, Asian Development Bank (ADB), Asian Institute of Technology (AIT), United Nations Environment Programme (UNEP) and United Nations Economic and Social Commission for Asia and Pacific (UNESCAP).

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A CONSTRUCTION WASTE STUDY FOR RESIDENTIAL PROJECTS IN MIRI, SARAWAK

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Abstract

The construction industry is a major consumer of new materials. Given that material production for construction work accounts for a significant percentage of all energy consumed nationally in newly developing countries, it becomes vital that the construction industry strives to reduce waste at all stages of construction. However, the importance of these construction wastes in terms of types and sources have yet to be identified. Established systems to record quantitative data for the generation of construction waste are still lacking across much of Europe. Although categorisation of waste assists segregation of construction waste arisings and increases the potential for reuse and recycling, little progress has been made in Sarawak. Thus, this pilot study is carried out as the logical first step towards construction waste management in Sarawak by categorisation of construction waste at residential construction projects. Through this study, useful information concerning waste assessment data necessary to achieve a better understanding of construction waste is obtained. Case studies involving quantification and classification of construction waste for several on-going residential construction projects in Miri, Sarawak are presented. A database of information concerning the quantification of local construction waste was developed, together with current construction waste management practices.

Keywords: Construction waste, Waste quantification, Composition.

1. Introduction

The construction industry has been regarded as one of the major contributors of negative impact to the environment, due to the high amount of waste generated from construction, demolition, renovation and activities associated with construction. The construction industry plays a significant role in Malaysia's development both in the infrastructure and economic sectors. After some decades of extensive "use and throw away" philosophy, it has now been recognized that this uninhibited use of natural resources and pollution of the world is unsustainable (Chong, Tang & Larsen 2001). Therefore, it is essential to raise the awareness and revise previous common practices within the construction industry.
Construction waste generally refers to waste resulting from construction, demolition, renovation, real estate development, infrastructure development, earthworks and land clearing operation (US EPA 1998, Tang, Soon & Larsen 2003). It consists of, but is not limited to, wood, concrete, metal, brick, drywall, roofing, material packaging, plastics, papers, cardboard and others. Categorisation of construction waste is a study into the composition and amount of construction waste generation, as well as enhancing understanding of the sources and causes of waste generation. Associated information is usually obtained via construction waste assessment, such as quantification of construction waste, field surveys and site observations. The definition of construction waste varies and depends significantly on the type of construction and practices where the sampling is performed (US EPA 1998, Begum et al. 2006). In this study, construction waste is defined as the solid waste resulting solely from construction activities, in which waste subjected to demolition, renovation, earthworks and land clearing operation is excluded from the scope. Typical components of construction waste generated from residential construction sites include wood, concrete, metals, drywall, brick, roofing and others (US EPA 1998, Tang & Larsen 2004).

Currently, The Ministry of Housing and Local Government of Malaysia (2005a) has implemented policies and provided incentives to build low and medium-cost housing for the lower-income group of society. In recent years, the numbers of housing projects have increased dramatically due to the financial support from the federal government. In addition, accessibility to housing has increased for lower income groups as 'housing loan schemes', a government funded loan, have been made available to them, which came into effect in 1976 (Ministry of Housing and Local Government 2005b). As a result, it is expected that construction waste generation within the country will increase significantly in the future if the trend continues (Tang & Larsen 2004). In recent studies conducted regarding the breakdown of waste in the central and southern region of Malaysia, 28.34% of the total waste generated was contributed by construction and industrial waste (Hassan et al., cited in Begum et al. 2006). Consequently, the minimization of construction waste has been brought to the forefront of the society as an important issue. It can be argued that an organized construction waste management system should be developed for all residential projects in order to regulate and reduce the generation of construction waste on construction sites. In order to set up a proper waste management system for the construction industry, a set of data concerning the current structure of construction waste generation should be made available (Begum et al. 2006, Bossink & Brouwers 1996, Tang & Larsen 2004). Currently in Malaysia, there is not much research being conducted on the issue of construction waste (Begum et al. 2006, Tang & Larsen 2004, Tang, Soon & Larsen 2003). Hence, there are very few data available on the current structure of construction waste flows by the source of generation, type of waste, amount of waste generated and disposed, and the amount of waste reduced, reused or recycled (Begum et al. 2006, Tang & Larsen 2004). Secondary research conducted here finds no comprehensive data–available regarding the amount and composition of construction waste generation for residential projects in Sarawak.

2. Construction Waste Management Practice In Sarawak

The are a few regulating bodies in Sarawak dealing with construction waste management, namely Local Authorities Ordinance (LAO), Local Authorities Cleanliness Bylaw (LAC), Natural Resources and Environment Ordinance (NREO).These existing regulations are concerned with waste flow: generation, transportation and disposal. There are a number of provisions that available to regulate the management of construction waste in Sarawak. According to surveys performed by NREB, the existing provisions are currently not put into good use due to the fact that no consistent strategy and system for the desired management was in place (Tang & Larsen 2004, Chong, Tang & Larsen 2001).

At present, there is no coherent waste management system being established in Sarawak (Chong, Tang & Larsen 2001). For the case of the construction industry in Sarawak, it is very common that local contractors and developers do not have proper construction waste management systems, or registrations of waste on site (Tang & Larsen 2004).

According to Natural Resources and Environmental Board (NREB, 2005), there are 45 existing landfills in Sarawak, in which 40 of them were visited by the NREB regularly. The total area allocated for the dumping of municipal solid waste is around 80 hectares in which about 370,000 metric tonnes of solid waste are disposed at these sites per annum.

A study was conducted by Tang, Soon and Larsen (2003) to investigate the collection and transport of construction waste in Kuching. The disposal of construction waste generated from construction activities is the responsibility of the developer or contractor. In most cases, construction waste is normally transported by private contractors, in which the construction waste usually ends up at their own premises or reallocated within the construction site for landfilling or future construction purposes. However, the waste transported from small scale construction or renovation works is believed to be disposed of at illegal dump sites. This statement is supported by illegal dump site field surveys (Tang, Soon & Larsen 2003).

Based on the survey conducted by NREB and Danish International Development Agency (DANIDA), it is estimated that about 50% of the construction waste does not leave the site. It is either used for the preparation of site, dumped on site, or even open burnt. It was found out that some of the waste was disposed at informal dumpsites on private land and some was illegally dumped at road reserves or idle land. Scrap metal is usually collected for recycling due to its high resell value at present date (Tang & Larsen 2004). Thus, only a small amount of construction waste was actually dumped into public landfills.

Currently, there are no official facilities in Kuching for the treatment of construction waste. Based on surveys, it is anticipated that a majority of the construction waste generated is informally landfilled, with some being dumped illegally at rural spots, road reserves or landfilled on private land (Tang, Soon & Larsen 2003)

3. Methodology

The selected project pilot-study sites should provide a fundamental representation of the current structure of construction waste for residential projects in Miri therefore the locations chosen for construction waste assessment were based on the following criteria;

(i) The location and builder, where the construction sites covers different locations within Miri, with the condition that permissions were granted by the respective developers and contractors. The selected sites involved different developers and contractors.
(ii) Types of activities: the construction sites chosen are new residential developments in Miri. In addition, the sites selected comprise of different types of residential development, such as low cost/affordable housing. All of the residential pilot-study projects involved reinforced concrete construction.
(iii) Construction stage and duration: most of the studied sites selected reached practical completion within the research period.
The three main pilot-study sites selected are located at Desa Senadin Housing Estate, Promin Jaya Development and Piasau Residential Development. They are labeled as Site A, B and C respectively. In addition, two other on-going residential sites, located at Desa Senadin Housing Estate and Promin Jaya Development, were selected for monitoring purposes. They are labeled as Site D and E. The studied sites selected reached practical completion within the study period.

Three methods outlined below are used to obtain the composition, generation and sources of construction waste from residential construction sites.

3.1 Quantification by Estimation

The layouts of the construction waste generated on the construction site were divided into four forms: stockpiled, gathered, scattered and stacked. Quantities of the construction waste generated, in terms of weight, for a particular layout were determined through the product of its respective estimated volume and estimated unit weight. For stockpiled waste, it was assumed to stay in the form of rectangular base pyramidal shape (Fig. 1). The volume (V_s) of a stockpiled waste was taken as the volume of a rectangular base pyramidal shape, where $V_s = 1/3\ (B \times L \times H)$. For gathered waste, it was assumed to stay in the form of rectangular prism (Fig. 2) on the ground surface. The volume of gathered waste (V_g) was taken as the volume of rectangular shape, where $V_g = L \times B \times H$.

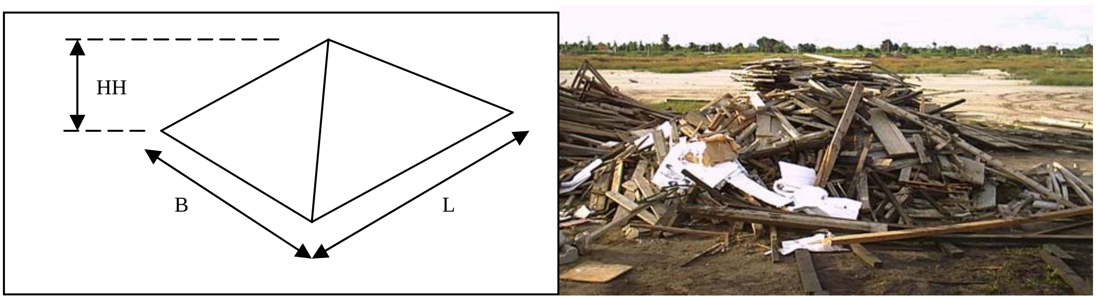


Fig. 1 Stockpiled waste

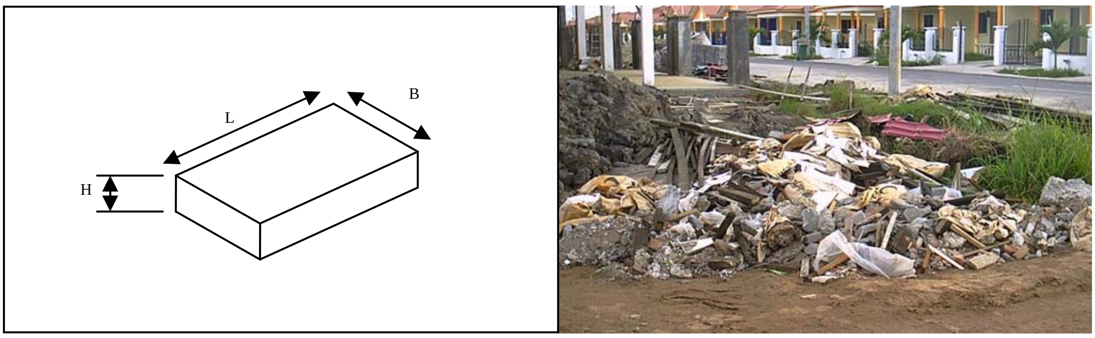


Fig. 2 Gathered waste

Scattered waste can be divided into two categories. The first consists of waste with similar size, such as broken bricks, cement bricks, roof tiles and cement bags. The second consists of waste with large variation in size, such as offcuts of steel roofing sheet, plastic packaging and offcuts of gypsum or plaster board. For scattered waste with similar size, three samples were randomly chosen and weighed. The values obtained were averaged and assumed to be the same for all other samples. Subsequently, the number of samples scattered around the site were counted and recorded. The average weight per sample multiplied by the number of samples gives the total weight of the scattered waste. For stacked waste, it was measured in a similar manner as scattered waste. First, three randomly chosen samples from a particular stack of waste were weighed and averaged. This average weight is assumed to be uniform for the whole stack. This was followed by counting the number of samples in the stack. This value was then multiplied by the average weight per sample to obtain the total weight of the stack. This method was applied except where there is a large variation between sample sizes. In that case, the stacked waste was sorted out into similar sizes before the method was applied.

3.2 Numerical Computations

The amount of construction waste generated, in terms of weight, was taken as the net difference between materials ordered and actual materials needed. This assumption is similar to that adopted by floor Poon et.al, 2004.

3.3 Field Survey

Interviews were conducted with the contractors and site supervisors on the study sites. The survey basically questions the characteristics of waste generated during the construction process, including the sources and causes of waste generation, and steps taken to reduce it. In addition, regular site monitoring is conducted for this research. Site inspection was carried out at least once per week on the study sites. Associated sources and causes of construction waste generation at different construction stages were documented

4. Pilot Study Results

The sources of construction waste generation was investigated on all pilot-study sites through field observations and site monitoring, particularly for the main components of construction waste: wood, concrete, metal, brick and others. The common sources of construction waste generation identified were shown in Table 1 below:

Table 1. Common sources of construction waste generation

Waste Type	Descriptions	Sources
Wood	Dimensional lumber Plywood Timber props Sawn timber	Formwork, roof truss Formwork Falsework Formwork, roof truss
Concrete	Substructure Superstructure Drains and gutters	Footings, piling Beams, columns, floor slabs Drainage works
Metal	Reinforcement bar Wire mesh Roofing sheet Aluminium frames	Reinforcement fixing Reinforcement fixing Roof Window, false ceiling
Brick	Clay brick Cement brick Cinder block	Wall, fencing works, gutters Wall, fencing works, partition walling Wall, fencing works
Others	Packaging Gypsum & cement board Plaster Ceramic PVC Pipe Conduit & wiring	Cement packaging, plastics, cardboard, timber pallets False ceiling False ceiling, finishing works Roofing tiles, floor tiles, wall tiles Plumbing works Electrical works

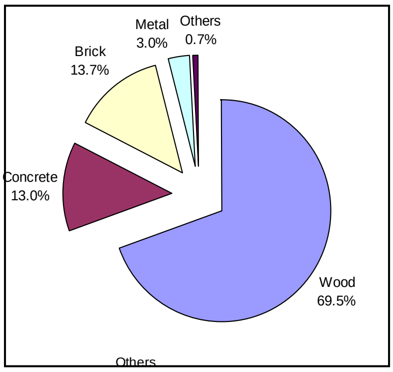
Generation of construction waste covers almost every construction stage. Common causes of construction waste generation observed on the studied sites are offcuts from cutting materials to desired length, improper handling, stacking and storage, end of life cycles, spillage and leftover materials

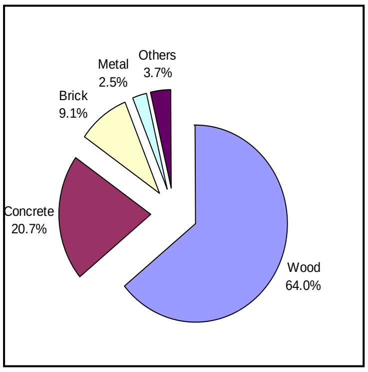
4.1 Quantification and Composition of Construction Waste

Construction waste generated per block at Site A, B and C was 11.79 tonnes, 4.75 tonnes and 12.86 tonnes respectively. The generation rate of construction waste on these sites ranged from 86.34 to 229.72 tonnes per hectare. The generation rates and composition of construction waste obtained for Site A, B and C, are shown in Table 2 and Fig. 3.

Table 2. Summary of construction waste generation rates at site A, B and C

Site	A	B	C
Waste Type		Rate (t/ha)	
Wood	97.99	55.28	80.71
Concrete	18.37	17.91	85.71
Brick	19.28	7.87	42.50
Metal	4.29	2.12	3.57
Others	1.03	3.16	17.22
Total	140.95	86.34	229.72





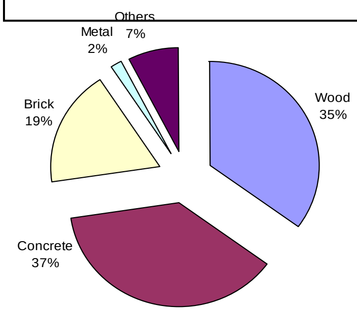


Fig. 3 Composition of construction waste at site A, B and C

4.1.1 Wood

Wood refers to waste resulted from timber products, such as formwork, falsework, plywood, dimensional lumber, framing, roof truss and others (US EPA 1998). It is the highest waste stream by means of total weight produced at Site A and Site B. Wood is widely used in the construction industry and due to the relatively large timber resources available in Sarawak, as well its utilisation by the comparatively cheap labour force in the local construction industry, historically regarded as an expendable resource. Among all the studied sites, the lowest wood generation rate is identified at Site B. At site B, formwork and falsework were extensively reused. Thus construction works in Site B utilizes a comparatively lesser amount of wood in construction. Whereas site A and site C has a relatively similar generation rate. It is actually idealized in this study that 30 % of the wood turned into waste at the end of the construction, where the remaining 70 % will be reuse.

4.1.2 Concrete

Concrete waste is also one of the major waste streams in construction waste. The concrete waste component comprises the highest percentage of construction waste at Site C. Concrete waste generation rates at site A and B are quite similar. There is a large difference among these three sites as Site C's result is idealized through numerical computations and not all of the waste generated can be measured or quantified as at site A and B. This is because some of them were buried or mixed with other earth materials. Thus it is no longer identifiable for quantification operation to be carried out. Still, there are some concrete wastes scattering around the site even though some portions were being gathered aside.

4.1.3 Brick

It is one of the main components of construction waste. It is lowest in terms of generation rate at Site B. Construction works at Site B consist mainly of clay brick, comparatively expensive than cement brick or cinder block. Local unloading methods play a part in the generation of brick waste. Again, due to the different methods used for estimation, generation rate at Site C shows a relatively higher value, due to the same reason as for the case of concrete waste. The brick used in Site C comprises solely of cement bricks, one of the cheapest type of bricks available in the market.

4.1.4 Metal

Metal refers to waste generated from ferrous or non-ferrous materials, such as reinforcing bars, pipes, steel, aluminium, copper, brass and others (US EPA 1998). It is among the lowest waste generated from the four main components of construction waste. It is mainly due to the relatively high cost and high recycle value in the local market. Offcuts of reinforcement are usually collected and placed properly for future use or recycle. Other metal products, such as steel roofing sheet, aluminium panels and frames, made up an insignificant amount of waste around the site and were normally recollected.

4.1.5 Others

Other arisings usually refer to waste generated from finishing works, such as packaging of materials, ceramic tiles, insulation and others (US EPA 1998). A relatively higher value was obtained at site C however quantification of these wastes is generally difficult due to the scattered form of the waste around the sites. The generation was basically dependent on the practices of the workers on the site. Even with different estimation method, there is a significant increase of generation rate for this type of waste particularly packaging waste. Packaging waste is the biggest waste stream sub-group in Europe.

5. Study Constraints

This study achieved some success despite various constraints in terms of site sampling, waste data collection and others. Due to the small number of the residential development projects in Miri, the sites are randomly selected according to the criteria identified. However, this is a major restriction to results generated due to the variable differences of design, specification and construction methods at the different project sites chosen. It was also found that there is no collection facility for the construction waste generated on site. Construction waste can be found lying on the site compound, adjacent to the buildings, roadside or even dumped at nearby premises. These poor housekeeping habits complicate the waste data collection as many contractors are interested in other disposal alternatives as long as these alternatives do not result in increased costs. These alternatives are usually cost driven rather than carried out for environmental benefit. In many cases, recycling is driven not by the value of the materials but rather by the avoided cost of disposal. All these factors hamper the waste data collection for this pilot study. At present, no facilities were established for the recovery or recycling of construction waste in Miri. Whilst waste is being adressed to a very limited extent by different contractors' own ad-hoc means of disposal for economic advantage, it is argued here that the local construction industry needs registration to formalise the waste management process and progress towards increased re-use and recycling of waste arisings.

6. Conclusions

Through this pilot study, a better understanding of construction waste generation in Miri, Sarawak is achieved and the common causes and sources of construction waste generation for residential projects in Miri were determined. As a result, a database of information concerning the quantification of construction waste generated for residential projects was developed. An appropriate methodology for performing construction waste assessment was produced and deemed appropriate for further waste assessment studies. An investigation into case-study sites was effectively undertaken with regard to construction waste generation. The results obtained will help in improving current waste management practices in Sarawak by providing useful information concerning representative quanities and the potential for reusing and recycling local construction waste.

Acknowledgements

The study is carried out as part of a Curtin Sarawak Research Fund (CSRF) project. Mr Gary Chong Vui Leong, final year degree student, is acknowledged for valuable site-measurements.

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WASTEWATER TREATMENT SYSTEMS FOR SMALL SITES IN SARAWAK

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Abstract

The discharge of untreated or inadequately treated wastewater will impose heavy loads on the capacity of the receiving water body, endangering public health and the surrounding environment. For Sarawak, this is crucial as most of its source of water supply comes from rivers. The predominant domestic wastewater treatment system in Sarawak is primary treatment of municipal sewage (blackwater), accomplished with individual septic tanks (ISTs). There are also a handful of small, centralized wastewater treatment facilities for small sites. Effective alternative wastewater treatment systems need to be explored to improve wastewater management. In this study, examples of sustainable wastewater treatment systems from a variety of sites and situations will be presented and discussed. In addition, various existing methods used for both domestic and commercial wastewater treatment in Sarawak are presented. The principle treatment processes for each method are briefly discussed, and benefits for the system are presented. Furthermore, there is a need for a study on centralized wastewater treatment facilities for small, commercial or institutional sites, such as a University, or other institution of higher learning. The wastewater generation patterns for such sites may be different from the expected characteristics for domestic wastewater generation. The Intermittent Decanted Extended Aeration (IDEA) Activated Sludge System used in Curtin University Sarawak Campus, Miri is investigated and the viability and sustainability of the system to be adopted for other institutions of higher learning or campuses in Malaysia is discussed. Furthermore, to characterise wastewater generation for a commercial site, the wastewater production and generation pattern in Curtin University Sarawak Campus is studied. The main finding from this study is that diurnal wastewater generation patterns for commercial sites are different from diurnal domestic generation patterns. The overall wastewater production during the semester break is significantly less than during teaching weeks, and is comparable to wastewater production during the weekends of the teaching weeks. The main factors that influence the wastewater variations in an institution of higher learning is the size of the population and the activities carried out in the institution, including seasonal activities. The data collected from the wastewater quantification study could be used as a useful reference data for other similar institutions of higher learning, in choosing a viable and sustainable wastewater treatment system.

Keywords: Wastewater treatment, wastewater generation, domestic wastewater, sustainable wastewater treatment

1. Introduction

Wastewater management is an increasingly serious issue, demanding attention in both developing and fully industrialised nations worldwide. It is one of the associated problems that developing countries like Malaysia experiences due its rapid development and urbanisation. In Malaysia, about six million tons of wastewater is generated annually by its 26 million inhabitants (Asian Development Bank 2006). The wastewater is treated to varying levels and discharged into the rivers, from which most of Malaysia's fresh water supply comes from. This is certainly unhealthy and an unsustainable means of disposing wastewater. A more effective and sustainable wastewater management would be required.

Similar to the rest of the country, the state of Sarawak is also growing and developing rapidly. Most cities in Sarawak such as Kuching, Miri, Sibu and Bintulu are experiencing explosive development. While this is an encouraging sign towards the growth of the nation, such rapid development could quickly degrade the quality of the surrounding environment if it is not planned carefully.

The predominant domestic wastewater treatment system in Sarawak is primary treatment of municipal sewage (blackwater), accomplished with individual septic tanks (ISTs) as with most of Malaysia (Tan, 2006). The discharge of this partially treated wastewater will impose heavy loads on the capacity of the receiving water body, endangering the health of the various rivers and streams. This will in turn affect public health and the surrounding environment. This is a crucial issue as most of the source of water supply comes from rivers.

A river quality baseline study (Larsen & Lynghus 2004) for Sarawak River in Kuching showed that the river was seriously polluted with faecal derived coliform bacteria due to discharge of partially treated or untreated wastewater rom the city into the river. This result created an alarming warning to the authorities to have a more effective wastewater management system for the city and for the whole state of Sarawak. Therefore all sustainable and feasible solutions for wastewater management in Sarawak and indeed Malaysia need to be explored urgently. It is important to have a wastewater treatment system that is appropriate in scale, cost, efficiency and flexibility, according to local situations.

In this study, sustainable wastewater management practices from various sites and situations are presented as case studies. A study of practices and management practices from overseas could be a starting point for our authorities to design and implement our own wastewater management techniques. Also, different wastewater treatment systems used in Sarawak were investigated and presented, particularly in the cities of Kuching, Miri and Bintulu. The principle treatment processes for each method are briefly presented, and any tangible benefits or disadvantages are discussed as well. This outlines the current wastewater management in practice in Sarawak.

In particular, the Intermittent Decanted Extended Aeration (IDEA) activated sludge wastewater treatment system used in Curtin University of Technology Sarawak Campus is studied, and the viability of the system to be adopted in other commercial or institutional sites such as institutions of higher learning are discussed.

There is also a need to investigate the centralized wastewater treatment for commercial sites, starting with small to medium sites such as a University or other institution of higher learning. The reason for this is because the wastewater generation patterns may be different from the established domestic diurnal wastewater generation patterns. If so, a study would be required to aid in design and planning of wastewater treatment and management facilities in such sites. In addition, commercial sites constitute major land usage in Sarawak and Malaysia, similar to residential sites. Thus the information and data derived from such studies could be useful for planners and engineers.

To characterise the wastewater generation for an institution of higher learning, a study on the quantification of wastewater based on water consumption was performed for Curtin University of Technology Sarawak Campus, which is located in Miri. From the obtained data, generation patterns of the wastewater could be derived. For new institutions of similar type in Malaysia, the data developed from this project will be a useful reference for estimating wastewater flow in the planning and design of their wastewater treatment facilities.

2. Research Methodology

To carry out this research, a desktop study of sustainable wastewater treatment and management practices around the world was undertaken. In addition, various wastewater treatment systems currently being used in Sarawak to the authors' knowledge was undertaken. In addition, numerous site visits were made to investigate the different wastewater treatment systems in Kuching, Miri and Bintulu. To collect data and information, interviews were carried out with engineers, maintenance technicians and other personnel-in-charge from local councils and other government regulatory bodies. Special attention was paid to the Intermittent Decanted Extended Aeration (IDEA) Activated Sludge Wastewater Treatment System at Curtin University Sarawak Campus, to investigate its feasibility for other institutions of higher learning or campuses in Malaysia. This is presented in the following sections of this paper.

A study into wastewater generation was also carried out at Curtin University Sarawak Campus, where the results and discussion are presented in the fourth section of this paper. Water consumption is used in many international surveys as an indicator of wastewater generation (Larsen & Lynghus 2004; Tchobanoglous, Burton & Stensel 2004). The fundamental assumption is that tap water consumed equal wastewater discharged into the wastewater treatment system. Therefore, the same approach is adopted for the wastewater generation study, by monitoring the water meters in Campus. Readings from the water meters, in units of litres, were taken every day from morning to night (7am to 9pm), for time intervals of 1 - 3 hours. These readings were collected everyday for the duration of a week, representing one wastewater generation data set. A total of three data sets were collected from the campus water meters for the study, during two typical teaching weeks and one semester break. The collected readings were then converted to cubic metres (m^3) and plotted against time as seen in Fig. 1 and 2.

3. Some Instances of Sustainable Wastewater Treatment

Many communities around the world are studying and testing alternative, small-scale and decentralized wastewater treatment systems. These systems are designed to be more environmentally friendly and sustainable. Some examples are presented here.

In anticipation of the 2008 Olympic Games in Beijing, the city is working with German collaborators, striving for long term solutions for wastewater treatment and its reuse with an Olympic-oriented programme (Ernst, et al. 2007). The main thrust of the initiative is to reclaim and reuse the treated wastewater. A total of 14 new wastewater treatment plants will be constructed to collect and treat 90% of the city's wastewater. Higher rates of reclamation are planned so that 50% of the treated wastewater will be reused mainly in the "Olympic Green", the centerpiece of the Olympic Games, consisting of stadiums, athletes' accommodation and artificial surface waters. The Beixiaohe and Qinghe Sewage Treatment Plants will supply the reclaimed water. At the moment, the envisaged treatment scheme had not been finalized yet. A partial choice of membrane bioreactor (MBR) at Beixiaohe and a submerged microfiltration system at Qinghe is decided for the moment. Testing on the usage of fixed-bed granular ferric hydroxide (GFH) absorbers for the MBR are already underway. This pilot project would be a good example for sustainable reuse technology throughout China and indeed the rest of the world.

In Australia, it appeared that there was no development of sustainable on-site wastewater treatment systems for remote resorts, which were not connected to the mains water and sewerage network. As presented in Kavanagh and Keller 2007, a pilot-scale engineered ecosystem (PSEE) system was designed to treat wastewater for a population equivalent (PE) of five persons, and operated for two years. The objective was to assess the performance of the system in terms of chemical oxygen demand (COD), solids and nutrients removal. It was found that the system was effective in removing influent COD (over 90%) but had low removal of nutrients (5% and 6% of influent nitrogen and phosphorus each). This is due to poor performance of some components of the system, indicating that further development may be necessary.

A wind-aerated, lagoon-based system was designed for the community in Errol, near Dundee in Scotland (Horan, et al. 2006). There was no history of wastewater treatment in the town. The treatment system treated screened sewage by both oxidative and reductive reactions. This would be similar to an oxidation pond treatment system. However, diffused air was provided to the lagoon when wind power was not sufficient. The system was found to be effective, producing highly treated effluent with low levels of biochemical oxygen demand (BOD) and suspended solids (SS), as well as nutrients and faecal coliforms. However, the cost incurred for the system per capita was quite high at 420 pounds.

4. Wastewater Treatment Systems in Sarawak

For most wastewater management systems in Sarawak, wastewater is separated at the generation source into blackwater and greywater. Blackwater is commonly treated in septic tanks or similar communal treatment facilities in housing estates or commercial buildings (Larsen & Lynghus 2004). Greywater is discharged directly into the local storm water drainage system or any receiving water body without any treatment; except in a few places where centralized wastewater treatment facilities are used, in which all the blackwater and greywater are collected together.

4.1 Individual Septic Tanks (ISTs). The predominant wastewater treatment system in Sarawak is primary treatment via individual septic tanks (ISTs) and there are only a few centralized wastewater treatment facilities for small sites. There are about 65,000 septic tanks in use in Kuching, 39,638 in Miri and 8,649 in Bintulu (Tan, 2006). Recent advances in the use of ISTs for domestic wastewater treatment to achieve complete or near-complete treatment of wastewater includes the use of infiltration trenches (Quisenberry et al., 2006), drainfields (Rainwater et al., 2005) and other modifications to the traditional ISTs. A low-cost, high-efficiency treatment system involving a combination of septic tanks, baffled facultative ponds and aerated rock filters was designed and used in the United Kingdom (Mara, 2006). However, to the authors' knowledge, these systems are not used in residential wastewater treatment in Sarawak.

Typical septic tanks have two simple chambers connected in series and a filter. Proprietary prefabricated septic tanks, which are typically cylindrical in shape, are made of fibreglass material. The performance of ISTs is greatly dependent on the retention time and regular desludging of the tanks; hence do not consistently achieve effluent quality Standard B of Environmental Quality Act 1974.

The main disadvantage of ISTs is that it only provides primary sewage treatment and is not an efficient means to treat wastewater. Properly designed and regularly maintained and desludged ISTs can only reduce the organic matter by about 50 % (Larsen & Lynghus 2004). In addition, pathogens and nutrients in the wastewater are not significantly reduced by the treatment. Effluent from the ISTs is discharged into the local drainage system, which is a network of open sewers that eventually outfalls into the local river system.

4.2 Imhoff Tanks (ITs). Imhoff tanks (ITs) are the second most commonly used wastewater treatment systems in Sarawak after septic tanks. The Imhoff tank used in Wisma Sarawak Electricity Supply Corporation (SESCo), Kuching serves a population up to 500 PE. Basically, the imhoff tank comprises of two compartments; namely the sedimentation compartment and sludge compartment. Sedimentation of solids takes place in the upper sedimentation compartment. The settled solids (sludge) pass through an opening in the bottom of sedimentation compartment into the lower sludge compartment, where they undergo anaerobic digestion (Crites & Tchobanoglous1998, p. 328). Similar to ISTs, ITs only provide primary treatment and the efficiency in treating wastewater is not consistent.

4.3 Open Aeration Wastewater Treatment System. The wastewater treatment system used in the Normah Medical Specialist Centre (NMSC), which is located at Petra Jaya, Kuching, is an elevated open-aeration centralized treatment system. It treats domestic wastewater from the medical centre and has a design capacity of 500 PE. The system consists of two aerators that operate alternatively, three pumps, one settlement tank and two chlorine injection points. The wastewater flow goes through the aeration process at the aeration tank before entering the sedimentation tank. After the sedimentation process, the treated wastewater will go through the chlorination process and lastly discharged into the local drainage system. The open aeration wastewater treatment system is capable of treating wastewater to a high extent. However, regular maintenance works are needed.

4.4 Extended Aeration Activated Sludge (EAAS) Wastewater Treatment System. Extended aeration activated-sludge system (EAAS) is one of the modified activated sludge treatment processes. The EAAS process requires a low organic loading and long aeration time (Crites & Tchobanoglous 1998; *Guidelines for Developers: Sewage Treatment Plants* 1998). By having longer hydraulic retention times, the system can operate more effectively over widely varying flow and waste loadings. The EAAS treatment system that serves Taman Jasmine is the only EAAS system in Bintulu.

The EAAS treatment process requires two operational units, in which aeration and settlement take place in each unit (Standards & Industrial Research Institute of Malaysia 1991). The screened wastewater will flow into the aeration unit where it is mixed with activated sludge and aerated. The sedimentation unit may be integrated with the aeration unit or it may be separated by partition. The sludge, which is separated from the wastewater in the settlement unit, is then recycled back to the aeration unit by gravity pump or airlift. This type of system requires less land use and is quite efficient in treating domestic wastewater. However, the excess sludge needs to be removed to eliminate operating problems. Other disadvantages include high maintenance costs as well as sound and odour nuisances to the nearby residents.

4.5 Hi-Kleen Wastewater Treatment System. The Hi-Kleen wastewater treatment system is an example of prefabricated package plants that function based on the principle of EAAS treatment process (PJBumi Berhad 2005). The incoming wastewater first passes through a screen chamber and a grit and grease chamber in order to remove the solids and inorganic materials. Then, the wastewater enters to the Hi-Kleen treatment system that consists of a series of tubular tanks. In the equalization tank, homogenous liquor is created by mixing the wastewater via air diffusers. The wastewater is then pumped into the flow control box, in which the flow will be regulated into the aeration tank. In the aeration tank, further mixing of wastewater takes place for a period of over 10 hours (PJBumi Berhad 2005). The mixing is created by the turbulence induced by diffused air from air diffusers. Sludge generated from the treatment process is separated in the sedimentation tank. A major portion of the sludge is recycled back to the aeration tank for continual operation of the treatment process. The excess sludge, on the other hand, is channelled to the sludge storage tank before disposal to the sludge drying bed.

The Hi-Kleen wastewater treatment system is used in University Malaysia Sarawak (UNIMAS). The two Hi-Kleen wastewater treatment plants in UNIMAS can serve up to 10,000 PE and 20,000 PE. The sludge from the treatment facilities is treated into horticultural fertilizer or soil conditioner for the university's plants.

4.6 Pond System. Pond or lagoon systems are engineered basins constructed to treat wastewater. Ponds are usually categorized by their aerobic status or dissolved oxygen concentration as well as the source of oxygen supply (Crites & Tchobanoglous 1998). Bintulu Town has a total of 33 pond systems to treat domestic wastewater, where by 30 ponds are individual temporary treatment ponds and the other 3 are centralized pond treatment systems, located in Kidurong 3, Jalan Tun Ahmad Zaidi and Jalan Tun Hussein Onn. Among the 33 ponds, only 5 of them are equipped with an aeration system. The ponds that are equipped with aeration system are known as aerated ponds, while the others are oxidation ponds.

Oxidation ponds are typically 1.5 m to 2.5 m deep. The treatment process in oxidation ponds is carried out by bacterial action in the upper layer, which is aerobic, and in a lower layer, which can be anaerobic. The oxygen is provided via photosynthesis by algae as well as natural surface aeration via wind action. The degree of wind-induced mixing affects the aerobic status of the lower layer of the pond. The advantage with this system is low construction and maintenance costs, minimal sludge generation and handling.

4.7 Ecological Sanitation (ecosan) Wastewater Treatment System. This pilot project at Hui Sing Garden in Kuching is a collaboration between the Sarawak Government and Danish International Development Assistance (DANIDA). A row of 9 terrace houses were selected for carrying out the pilot project (Bjerregaard 2004, p.14). The terrace houses are linked to the ecosan system, which is constructed at a large recreational park adjacent to the houses' backyards.

In the ecosan treatment system, the blackwater and greywater is treated separately. The greywater treatment system consists of oil and grease traps, biological vertical filters and a constructed wetland. The trap allows separation of the oil and grease from the greywater and settlements of solids. From the pilot project, it is found that the trap is 88% efficient in removing the oil and grease and effective in removing the bacteriological parameters and organic matter (Bjerregaard 2004). From the oil and grease trap, the wastewater is pumped into four domes, which act as biological filters (Bjerregaard 2004) to degrade the organic matters. After the filtering process, the wastewater flows to a constructed wetland before being discharged through an outlet pipe into the existing storm water drain (Bjerregaard 2004). The wetland consists of a layer of particle filter made of crushed limestone, which is used to absorb phosphorous from treated wastewater. The limestone can be used as fertilizer.For blackwater management in the ecosan system, holding tanks are used to collect the blackwater from toilets. The holding tanks should be emptied or desludged at a regular interval and the collected sludge will be sent to the sludge treatment plant at Matang, Kuching by tanker trucks for further treatment.

5. IDEA Treatment System In Curtin University of Technology Sarawak Campus

The wastewater treatment facility used in Curtin University Sarawak Campus is the Intermittent Decanted Extended Aeration (IDEA) Activated Sludge Wastewater Treatment System, which is one of the modified activated-sludge processes. In the IDEA activated sludge treatment system, all steps of the activated sludge process happen in one single reactor (Crites & Tchobanoglous 1998). The biological treatment and sedimentation processes are carried out sequentially in the same operational unit, which generally is an aeration tank. The wastewater inflow into the aeration tank is continuous and the mixture remains in it for the whole activated sludge treatment process (*Guidelines for Developers: Sewage Treatment Plants* 1998). As returning of sludge is not needed to maintain the sludge content in the aeration tank, separate secondary sedimentation facility is not required in IDEA system.

The current system faces problem in maintenance after about 5 years of operation. Large quantities of sand and grit are frequently found in the wastewater pumped from the students' lakeside apartment. This may be caused by the leakage of the underground piping system due to uneven settlement of the ground. It is observable that the ground at many areas in the campus is settling down gradually, since its completion in year 2002. Kaniraj and Joseph (2006) stated that the campus sits on soft clayey soils and could have settled more than 100 mm since 2002.

The IDEA activated sludge wastewater treatment system is a reliable treatment system, which can treat wastewater effluent to a high quality, with provision that regular maintenance is carried out. Hence, this system is viable to be used in other campuses or institution of higher learning in Malaysia. However, for a big campus with large compounds, a long piping system for the IDEA treatment system would be costly. Additionally, if the campus is located on soft soils or peaty areas, then the problems caused by soil settlement to the piping system would further deplete the values of the IDEA system. The maintenance works in repairing the leakage of the piping system or other similar malfunction would need to be carried out throughout the life-span of the system, incurring a high cost.

6. Wastewater Generation for an Institution of Higher Learning

Wastewater flow rates can be estimated from water consumption records (Larsen & Lynghus 2004; Tchobanoglous, Burton & Stensel 2004). The data collected from water consumption records are very useful for areas where the water usage for landscape irrigation is insignificant and 90 percent or more of water consumed becomes wastewater. Wastewater generation for Curtin University Sarawak Campus is quantified by monitoring the main water meter for the campus. Three sets of data have been collected during (i) Week 11 of semester one (end of a typical semester), (ii) Week 2 of semester two (beginning of a typical semester) and (iii) week free (semester break). The readings were collected from 7 a.m. until 9 p.m. with a time interval of between 1 to 3 hours. The three periods are chosen in order to investigate the difference in water consumption during regular sessions when classes are carried out as well as when classes are not in session (week free) to show seasonal variations in water consumption.

The water consumption or wastewater flows varies according to the time of day, different days throughout the week and during different periods or seasons in a year. The first and second variations are referred to as short-term variations in this paper, while the third variation is referred to as seasonal variation. Due to space constraints, only results from Week 11 of the semester will be shown, as seen in Fig. 1 and 2.

6.1 Week 11 of Semester One. The average cumulative water consumption in a day for Curtin University Sarawak Campus for week 11 of semester one is presented in Fig. 1 and the corresponding average hourly variation of water consumption in a day is shown in Fig. 2.

From Fig. 1, the water consumption during the weekends is significantly lower (38%) than the water consumption during the weekdays. This variation in water consumption between weekdays and weekends is expected, as classes are not held during the weekends. Fig. 2 shows that there is a lag time of 1 hour between the occurrences of the peak average hourly water consumption during the weekdays and weekends of week 11 of semester one. The peak average hourly water consumption during the weekends is about 44% less than that during the weekdays.

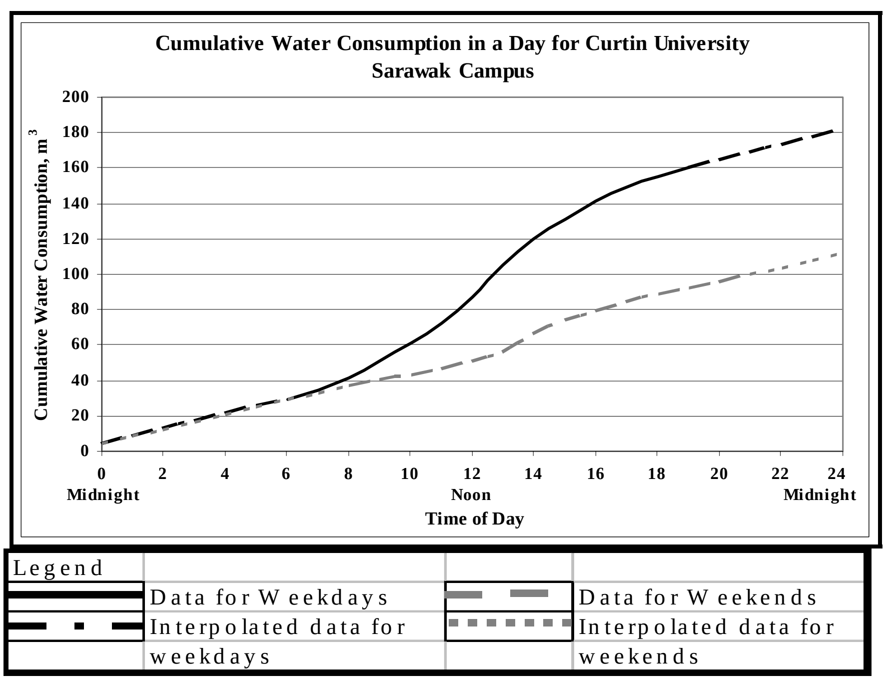

Fig. 1: Cumulative Water Consumption in a Day for Curtin University Sarawak Campus for Week 11 of Semester One.

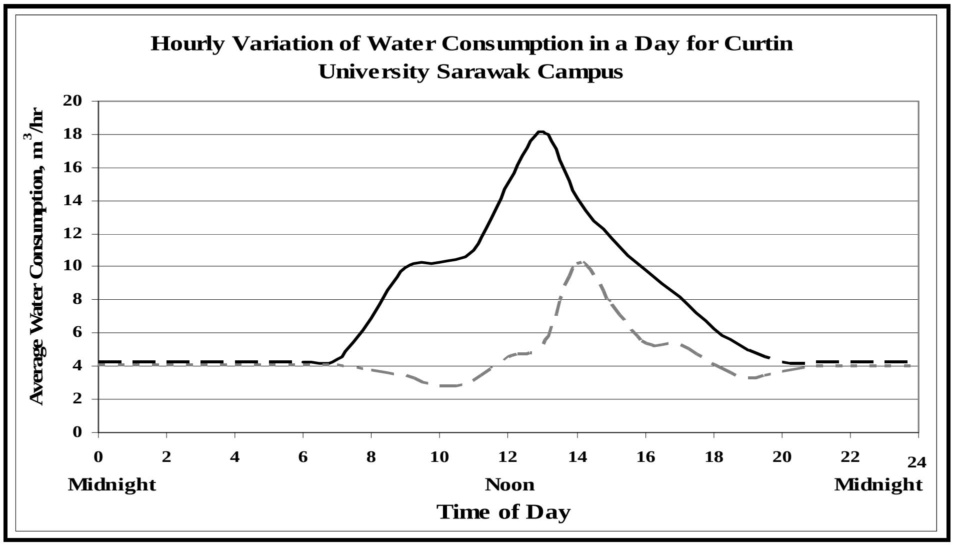

Fig. 2: Average Hourly Variation of Water Consumption in a Day for Curtin University Sarawak Campus for Week 11 of Semester One.

6.2 Week 2 of Semester Two. The total average water consumption for Curtin University Sarawak Campus during the weekdays for week 2 of semester two (145 m^3) is about 29% more than that during the weekends of the week (105 m^3). Similar to the average hourly variation of water consumption for week 11 of semester one (Fig. 2), a lag of time for the occurrence of peak hourly water consumption for weekdays and weekends is observed for week 2 of semester two. The peak of average hourly water consumption during the weekends (11 m^3) is 32% less than weekdays (7.5 m^3).

6.3 Week Free (Semester Break). The average total water consumption during weekends for a week free during semester break is about 6% than during the weekdays. The peaks average hourly water consumption during the weekdays and weekends for the week free occur at 12 noon, with the peak average hourly water consumption during weekends 25% less than that during weekdays.

6.4 Short-term Variations: Diurnal Variation. From all the figures presented, it is obvious that the water consumption changes during the course of a day. Fig. 2 shows that the variations in water consumption for the whole campus tend to follow a diurnal pattern. This is also seen in the results for Week 2 and Week Free. However, this pattern for an institution of higher learning is different from the typical diurnal pattern of domestic water consumption.

From the observation of the typical domestic water consumption or wastewater generation curve, there are two peaks in a day: the first peak generally occurs around 8 a.m. in the morning, while the second peak arises in the early evening between 6 p.m. to 8 p.m. (Tchobanoglous, Burton & Stensel 2004). However, the hourly variations in water consumption in Curtin Sarawak Campus during the teaching weeks of semester 1 and 2 present another type of pattern: the maximum peak usage occurs around 1 p.m. during weekdays and 2 p.m. during weekends. In addition, the peak average hourly water consumption occurs around 12 noon during the weekdays and weekends of the week free of July's semester break.

In general, the water consumption for Curtin University Sarawak Campus during weekdays starts to increase around 8 a.m. in the morning when all the activities are just starting and reaches the maximum during the lunch break in the midday. The water consumption decreases during late evening when the classes end, and there are less people in the campus.

Hence, from the results an important conclusion is that the diurnal variation for water consumption in an institution of higher learning is different from diurnal variation in domestic water consumption, and varies according to its population's activities during the day.

6.5 Short-term Variations: Variation for different days in a Week. Water consumption in the campus during the weekends is significantly less (ranging from 29% - 38% less) than during the weekdays. It was also found that the water consumption during the teaching week 2 of semester two is comparatively less than teaching week 11 of semester one. This is because during week 2 of semester two, some departments in the University have not commenced their teaching weeks yet; hence, the students' population in that period of time is relatively smaller than in the week 11 of semester one.

Therefore, it can be seen from these main observations that the population in the campus has direct influence on the quantity of water consumed during the day in a week.

6.6 Seasonal Variations. Seasonal variation is observed to be dependent on the activities in the campus. The extent of seasonal variation is expected to be dependent on the size of the community and the seasonal activities (Tchobanoglous, Burton & Stensel 2004). Seasonal activities are not held regularly over the period of the year. For an institution of higher learning like Curtin University Sarawak Campus, this would be the variation between the period during commencement of classes and the period during holidays where there are no classes. It is shown that the water consumption during a non-teaching week is as expected, less than the water consumption during a teaching week due to significant decrease in students' population during the non-teaching week. However, the water consumption for the weekends of the non-teaching week is as high as the water consumption for the weekends of a teaching week.

Conclusion

It is of utmost importance to investigate the feasibility of different wastewater treatment systems in the effort to improve our wastewater management system. Examples of different designs and plans used in foreign countries could be investigated for use in Sarawak. In selection of wastewater treatment system, the criteria to be considered are cost, capacity of the plant, land requirements, efficiency and reliability of the plant, operation, maintenance and sustainability of the plant, environmental impacts as well as energy and chemical consumption. For any institution of higher learning or campus, IDEA activated sludge wastewater treatment system would be viable to be adopted, provided the soil condition of the site is suitable for long piping system.

From analysis of water consumption data, the diurnal variations in water consumption for an institution of higher learning are shown to be different from the diurnal variations for domestic water consumption. Additionally, the main factors that influence the variations in wastewater generation in an educational institution are found to be the size of the population and the activities carried out in the institution. The data collected in quantifying wastewater generation in Curtin University Sarawak Campus could be used as a useful reference data for other similar institutions of higher learning in Malaysia.

It is proposed that future study on effective sludge management system should be carried out. Sludge treatment is another important part in wastewater management. Malaysia produces 3.2 million cubic meters of domestic sludge annually, but the facilities to treat and dispose the sludge are very limited (Indah Water Konsortium Sdn. Bhd. n.d.). Most of the sludge produced is sent to 230 landfills, which have been operating close to their full capacity (Asian Development Bank 2006; Ng, K.B. 2006). From these studies, it is estimated that only 1 to 13 percent of the sludge produced by Malaysians are recycled. An effective, efficient and environmentally sound sludge management is a milestone in Malaysian's approach in moving towards a sustainable wastewater management system.

Acknowledgement

The help an assistance of numerous staff members from various government and private organizations in Kuching, Miri and Bintulu in collecting information for this project is gratefully acknowledged.

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ALTERNATIVE CLAY BRICKS ADMIXED WITH NATURAL OR WASTE MATERIALS

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Abstract

With the rapid development of the country, building materials like bricks are always in demand. However depletion of natural resources is necessiating the search of alternative raw materials to promote a more sustainable and environmental-friendly development plan. To this end the feasibility of an alternative breed of clay bricks admixed with natural or waste materials were explored and investigated. The new clay bricks could be used as an alternative to conventional bricks, but having the advantages of being relatively cheap (clay and natural or waste materials are free, the costs incurred will only involve those of labour and manufacturing) and environmentally-friendly. The clay used was retrieved fro the RECESS test site itself. In today's world where natural resources are being exhaustively utilised, developing alternative construction materials (e.g. bricks) using waste products is apparently a positive move towards conservation and promoting sustainability. Socially, the low budget bricks can be of substantial help in providing homes for the poor and needy. Besides, the new composite materials can open up new opportunities for creativity and innovation in the construction industry, especially in the design of structural components. Laboratory testing of the clay composite specimens using geotechnical and material engineering test equipment were carried out. Focus was placed on establishing the mechanical properties, as well as determining the suitable admixed material(s) and the optimum mixing proportions. Comparisons with conventional bricks were made to ascertain and highlight the added values of the newly developed products.

Keywords: Bricks, clay, natural materials, wastes, sustainability, environmentally-friendly.

1. Introduction

Brick is an essential component of buildings and it is also the most ancient building material developed by mankind. The art and craftmanship have evolved over the centuries and today there are well over 1200 varieties of bricks available in the market (Sutton 2006). These bricks come in various sizes and mixtures, formed using different manufacturing processes and sometimes, produced for specific purposes. Cost-wise, bricks alone account 50 – 80 % of the total material cost (Abdullah and Othman 2005). These go on to show the significant role bricks play in the construction industry.

In Malaysia, bricks are essentially made of clay. Other materials are sometimes added to improve the properties of the clay bricks. Laterite soil, for instance, is added in the mixture to achieve better plasticity; or combined with cement to form non-baked bricks (Abdullah and Wan Omar 2007). Although the raw materals for producing bricks are readily available to date, it is unwise to rest on our laurels and keep turning the handle without giving a thought to other replacement materials. Making bricks out of waste materials is not a novel idea, as attempts had been made by several other researchers, including Liew et al. (2004) who made bricks out of clay shale and sewage sludge, as well as Lin and Weng (2001) with their effort using sludge ash.

Based on the arguments above, the abundance of soft clay sitting beneath the grounds of UTHM itself now seemed an utter waste to be left as it is and not utilised at all. Therefore the idea of this project was conceived to explore the possibilities of producing clay bricks, using the local clay admixed with natural or waste materials which come without a charge. Five admixtures were experimented with the UTHM clay with three mix proportions each. Combining geotechnical and material testing methods, properties of the raw materials and individual bricks were examined to identify the suitability of each admixture and mix proportion.

2. Objectives

The exploratory nature of this study had a three-fold objectives as given in the following:

i. To identify the properties of both the original clay samples and the new composite materials.

ii. To conduct laboratory tests to ascertain the relevant engineering properties- compressive strength, tensile strength (if necessary), water-proofing, etc.

iii. To establish advantages of the new composite products as compared to other conventional bricks for various purposes.

3. Materials and Methodology

The base material used in the clay bricks were clay retrieved from the RECESS (Research Centre for Soft Soils) test site, while the natural and waste materials added comprised of coconut coir, egg shells, palm oil clinker, sugarcane dregs and broken roof tiles (Fig. 1 and 2). Each mix consisted of the base clay and only one of the admixed material. The compositions are shown in Table 1.

Table 1. Composition of the bricks.

Sample	Admixture	Percentage of admixture (%)
C1	Coconut coir	2
C2		4
C3		6
E1	Egg shell	10
E2		20
E3		30
P1	Palm oil clinker + 5 % sand	5
P2		10
P3		15
S1	Sugarcane dregs	3
S2		6
S3		9
R1	Broken roof tiles	5
R2		10
R3		20

The percentage of admixed material was based on the dry weight of the base clay. It is apparent that only small percentages were added to the mixtures. This was mainly to avoid cracking in the bricks as excessive amounts of fibers (as in the coconut coir and sugarcane dregs mixes) could affect the bondings developed between the clay and admixtures.

All raw materials were initially dried in the oven at 105^{o}C overnight prior to being shredded or crumbled. This was to ensure that better water content control in the mix, and also to make it easier to shred or grind the fibers. The dried clay clumps were broken into smaller particles using a rubber mallet, then processed in a grinder and lastly sieved through a 1 mm opening size sieve to avoid including any clumps in the mixture. All the other processed admixtures were also grinded into finer particles prior to mixing.

Fig.1 The base clay being retrieved from site.

Fig.2 Oven-dried base clay in a tray.

With suitable amounts of water added, the raw materials were then thoroughly mixed by hand in a tray. Care was taken to ensure an even and uniform mix was produced. Next the mixtures were placed in pre-made wooden moulds to form bricks measuring 100 mm x 50 mm x 30 mm. These dimensions were approximately half of the conventional bricks. The scaled-down prototypes were simply to save on materials and baking space in the oven and furnace, justifiable due to the preliminary attempt. The mixture pastes were next pressed into the moulds either manually or with the aid of compaction tools.

Before demoulding, the wet bricks were air-dried for a couple of days, before being demoulded and dried in the oven at 105^{o}C for several days. Finally the half-baked bricks were placed in a furnace and the temperature gradually increased to 900^{o}C in a few days. Note that although each mix was prepared with slight differences (to be mentioned in the following individual sections), especially in terms of compaction energy and drying or baking period, the main procedures of mixing, compacting, air-drying, oven-drying and furnace-baking were the same for all.

Once the baking process was completed, the bricks were then subjected to the common quality control tests: compressive strength, water absorption and efflorescence tests.

Natural and Waste Materials- Admixtures

3.1 Coconut coir

Coconut coir, being a plant fibre, is basically a rigid, crystalline cellulose micro fibril-reinforced amorphous lignin or hemicelluloses matrix (Bledzki and Gassan 1999). Plant fibres are more ductile if the micro fibrils have a spiral orientation to the fibre axis. Fibres are in general inflexible, rigid and have a high tensile strength if the micro fibrils are oriented parallel to the fibre axis. Fibres come in different sizes and shapes. They can generally be classified into two basic categories: with high or low elastic modulus. High elastic modulus fibres improves flexural and impact resistance whereas low elastic modulus ones can only improve the impact strength.

Coir fibres are obtained from the fibrous husk encasing the fruit of the coconut palm which is a by-product of the copra extraction process. The fibre are separated into bristle fibre (20 to 40 cm long) by combing and mattress fibres which are random fibres having a length of 2 to 10 cm. the diameter of coir fibres varies between 0.1 and 1.5 mm. the individual coir fibres are quite short which is around 500 μm in length. Coir is one of the toughest plant fibres available. The coconut coir used in the study was oven-dried, shreded and blended into particles passing the 8 μm sieve (Fig. 3).

Fig.3 The clay powder and coconut coir mix in a pan.

3.2 Egg shells

The egg's outer covering, accounting for about 9 - I2 % of its total weight, depending on egg size. The shell is an egg's first line of defense against bacterial contamination. It is primarily composed of calcium carbonate (i.e. about 94%) with small amounts of magnesium carbonate, calcium phosphate and other organic matter including protein. Shell strength is greatly influenced by the minerals and vitamins in the hen's diet, particularly calcium, phosphorus, manganese and Vitamin D. There are many factors that affect the overall quality and strength of the egg shell. Apart from the main constituent of calcium carbonate, other constituents include organic matter and egg shell pigment. There are also as many as 8,000 microscopic pores in the shell itself. As the hen ages, the thickness of the shell usually declines. Other egg shell quality factors such as the formation of abnormal ridges, calcium deposits, or body checks (ridges) are important considerations in determining egg shell quality. The egg coir used in the study was crushed and dried in the oven prior to mixing with clay.

3.3 Palm oil clinker

Fig.4 Raw palm oil clinker chunks.

Clinker is a lightweight aggregate with medium to high strength, which is commonly used for block work or structural purposes (Fig. 4). The strength of palm oil clinker can be measured by applying the aggregate crushing value test. The higher the crushing value, the lower compressive strength.

The palm oil clinker used in this study was collected from a boiler in the form of hard clinker of palm oil. Upon collection, it was first dried before being ground into fine particles.

3.4 Sugarcane dregs

Sugarcane dregs and wood fibre are commonly used for acoustic purposes. They are also used to make particle boards which can be erected as partitions and non-load bearing walls. Cuba and India, for instance, have advanced research facilities dedicated to optimize and reuse the unwanted sugarcane dregs.

The raw sugarcane dregs were first washed and cleaned. Next they were soaked in a bleach solution for 24 hours as pre-treatment. The bleach solution was then drained and the bleached dregs were dried in the oven overnight. Once removed from the oven and allowed to cool down, the dried dregs were transformed into powder form using the grinder (Fig. 5).

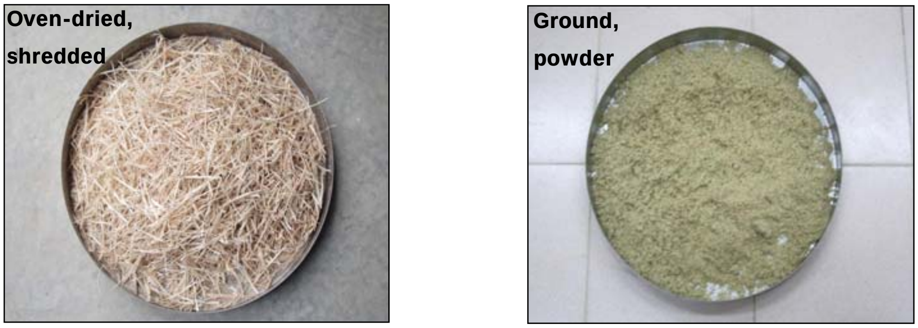

Fig.5 Sugar dregs- before and after grinding.

3.5 Broken roof tiles

Broken or unwanted roof tiles can be salvaged from demolished buildings, work sites or the manufacturing plants. The roof tiles were usually discarded as waste but they can actually be a compatible admixture in clay bricks. Seeing that tiles are essentially made of clay, the potential is definitely worth exploring.

Properties Determination and Related Tests

3.6 Bulk density

Density is defined as the measure of how much particles of an element or material is squeezed into a given space. The more closely packed the particles, the higher the density of the material. Higher levels therefore, indicate a corresponding degree of compaction. This is the mass of the masonry unit divided by the dimensional volume, mathematically expressed as:

$$\text{Mass of brick (kg)} / \text{Dimensional Volume of brick } (m^3) \qquad \text{Eq. 1}$$

3.7 Water Absorption

This is the weight of water a brick unit absorbs when immersed in water at normal day temperature for a predetermined duration of time. It is expressed as a percentage of the weight of the dry unit of brick. The absorption rate is defined as the weight of water absorbed when the unit is partially immersed for 1 minute in water. It is also defined as the rate of how much water a brick draws in during the first minute after contact with water. The ASTM C140-07 recommends maximum water absorption capacity of 240 kg/m^3. It is expressed mathematically as:

$$\text{Mass of saturated brick (kg)} - \text{Mass of dry brick (kg)} \; / \; \text{Volume of brick } (m^3) \qquad \text{Eq. 2}$$

3.8 Compressive strength

This is a term used to verify the quality of the brick unit and the effect of curing on the brick. It is defined as the unit's ability to withstand an axially applied load whether on the edge or bed face of the brick. It is usually taken as the average compressive strength of a test sample of six bricks and it is required that the weakest individual brick must not be less than 80 % of the average value. It is expressed mathematically as:

$$\text{Maximum crushing load (N)} / \text{Minimum surface area } (mm^2) \qquad \text{Eq. 3}$$

3.9 Efflorescence

The end of the brick is kept in a 150 mm diameter porcelain or glass dish containing 25 mm depth of water at room temperature (20 - 30˚C) till the entire water is absorbed or evaporated. The water is again filled to 25 mm depth in the dish and allowed to be absorbed by the brick or evaporated. Presence of efflorescence is classified as below:

- Nil - when the deposit of efflorescence is imperceptible
- Slight - when the deposit of efflorescence does not cover more than 10 % of the exposed area of the brick
- Moderate - when the deposit of efflorescence is more than 10 per cent but less than 50% of the exposed area of the brick
- Heavy - when the deposit of efflorescence is more than 50 per cent but the deposit do not powder or flake away the brick surface
- Serious - when the deposit are heavy and powder or flake away the brick surface

4. Results and Discussions

A summary of all the test results are shown in Table 2, while the relevant plots are in Fig.6.

Table 2. Summary of test results for all bricks.

Sample	Admixture	Water Absorption (%)	Compressive strength (Nmm^{-2})	Efflorescence (%)
C1	2 % coconut coir	24.11	2.00	>10 % < 50 % (for all samples)
C2	4 % coconut coir	31.40	2.05	
C3	6 % coconut coir	29.18	2.02	
E1	10 % egg shell	18.77	2.46	>10 % < 50 % (for all samples)
E2	20 % egg shell	15.26	2.38	
E3	30 % egg shell	10.61	2.42	
*P0	-	5.94	10.79	NA
*P1	5 % palm oil clinker	7.26	14.12	
*P2	10 % palm oil clinker	10.28	20.42	
*P3	15 % palm oil clinker	13.54	24.85	
S1	3 % sugarcane dregs	23.71	2.00	>10 % < 50 % (for all samples)
S2	6 % sugarcane dregs	25.59	2.05	
S3	9 % sugarcane dregs	29.23	2.02	
R1	5 % broken roof tiles	20.68	2.04	>10 % < 50 % (for all samples)
R2	10 % broken roof tiles	32.52	2.02	
R3	20 % broken roof tiles	30.14	2.00	

** plus 5 % sand*

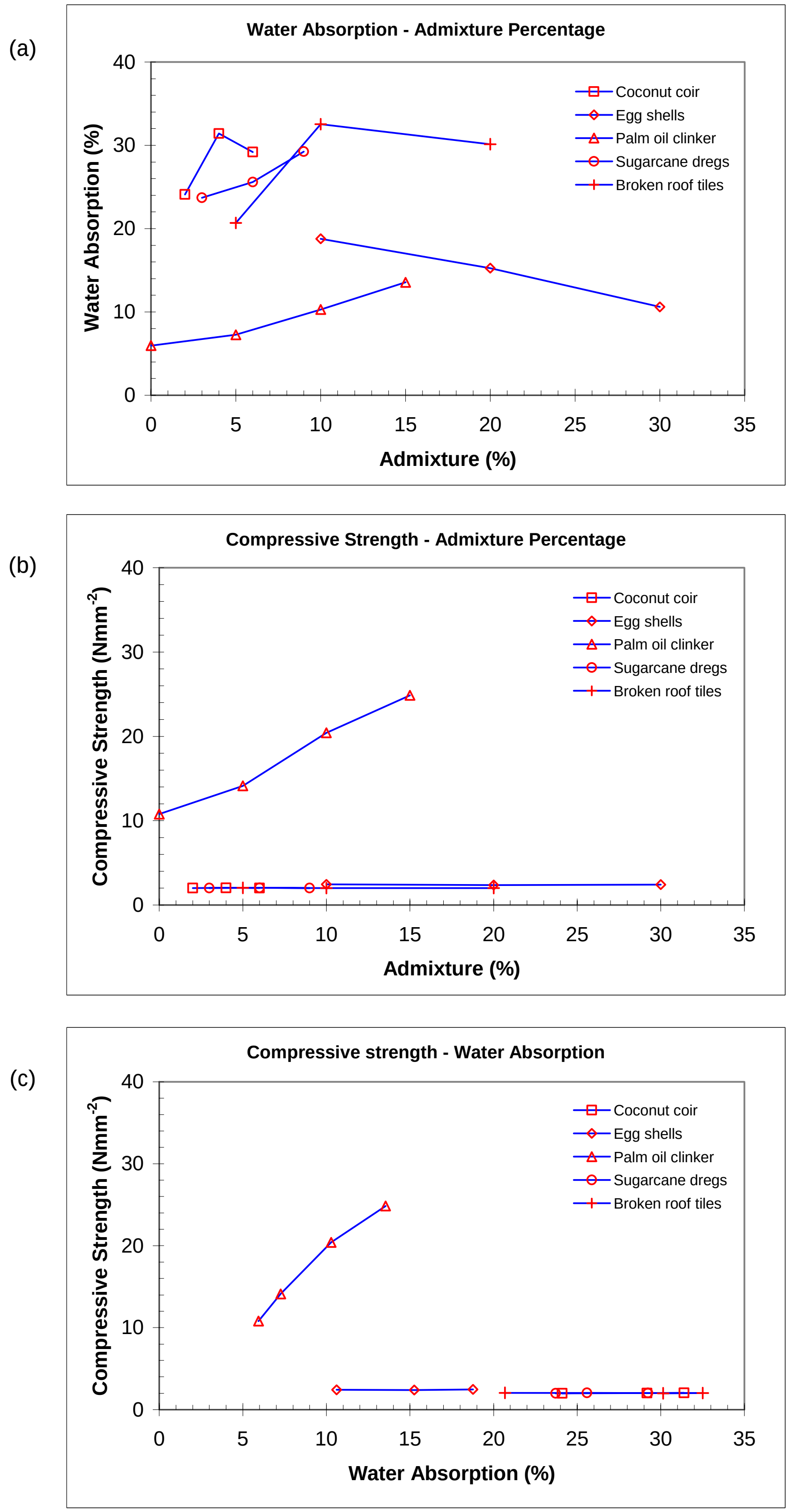

Fig.6 Result plots.

4.1 Water Absorption

Referring to plot (a) in Fig. 6, the water absorption of all the composite bricks initially showed an upward trend, apart from the mix with egg shells (E), which progressively declined with the increase of the admixture. However only the palm oil clinker (P) and sugarcane dregs (S) mixes showed consistent increase in water absorption, while the coconut coir (C) and broken roof tiles (R) ones displayed no particular pattern in the relationship. Nevertheless the percentage drop in water absorption for the latter two mixes were small and could be attributed to experimental errors. The increasing affinity for water could be caused by increased pore size within the bricks due to poorer bondage between the clay and the admixtures. It is admittedly unclear yet as to how each admixture affects the water absorption quality but it is almost certain that the inherent properties of the admixtures play a significant role.

4.2 Compressive strength

The trend line for the palm oil clinker (P) mixes clearly stood out in plot (b) in Fig.6 as the only one to be on the rise with more admixture in the mixes. Palm oil clinker has long been experimented and shown to have positive effects on the strength in a concrete mix, for instance. The almost linear rise in compressive strength indicates that there is a direct relationship between the strength gain and palm oil clinker portion added in the mix. The other mixes displayed no apparent improvement in strength and curiously bordered at just about 2 Nmm^{-2}, far below the generally accepted minimum value of 5 Nmm^{-2} for bricks.

It is however important to note that the batch of clay bricks with palm oil clinker as admixtures had 5 % sand in them, and were subjected to firing at 1000^{o}C in an industrial kiln for a week. The sand could have increased the crystalline network fromed within the brick in the firing process, resulting in higher strengths. The higher temperature and longer firing period were possibly the determining factors of the good strength gain for the bricks. It was also observed that the initial grey mixtures were turned yellow upon removal from the kiln.

Plot (c) in Fig.6 shows an effort to correlate the compressive strength and water absorption characteristics of the various mixtures. As the relationship was primarily dominated by the strength component, it was hardly surprising that the general pattern followed that of the compressive strength – admixture plot. It is however not yet conclusive as to whether or not these two main parameters in brick quality are linked in a unique way. To this end, further tests are required for verification.

4.3 Efflorescence

From Table 2, apart from the palm oil clinker mixes (data not available), all other mixes have their efflorescence values fall within the moderate range. It does seem that these mixtures may not make good damp proof bricks if put into prcatice, but then again, more future work on the subject may prove otherwise.

4. Conclusions

Although the project had been exploratory, the test results of some of the clay bricks admixed with natural or waste materials did show that these composite bricks have a promising prospect. Further work, including a more carefully planned test regime, is required to better understand the engineering characteristics, and to develop the right recipe for each mix. In a nutshell, there is definitely a potential to produce sustainable and environmental-friendly clay bricks from the soft clay from UTHM admixed with natural or waste materials, which come with versatility and perhaps enhanced quality compared to conventional bricks available today.

Acknowledgement

Special thanks to the students of *BKA4533 Advanced Geotechnics (Semester II Session 06/07)* for their effort demonstrated in conducting this project.

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THE SHORT-TERM PROPERTIES OF NICKEL SLAG-AGGREGATE HIGH STRENGTH CONCRETE

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Abstract

The paper describes a research to evaluate the performance of nickel slag-aggregate high strength concrete (NSA-HSC). Nickel slag, as a by-product from nickel mines, was used as aggregates, either as coarse aggregates or both fine and coarse aggregates, to produce high strength concrete. At present, most of these by-product materials are disposed in landfills, thus threatening the environment and becoming major task waste product management. In response to the challenge of producing more environmentally friendly concrete and promoting sustainable development of infrastructures, therefore the use of virgin material, as aggregate for concrete, should be minimized. One possible alternative is to replace or partially replace the use of virgin or natural aggregates with by-product materials. Nickel slag is mainly composed of Silicon, Ferro and Aluminum oxides. Instead of functioning as aggregates only, it is expected that the high proportion of silicon-dioxide (SiO_2) in nickel slag will undergo pozzolanic reaction with the calcium-hydroxide ($Ca(OH)_2$) from the hydration process of Portland cement, to subsequently cause an increase in the concrete strength, as well as, to strengthen the interfacial surface between the aggregates and the cement paste. Therefore, consequently nickel-slag concrete has potential to show excellent mechanical properties. The test results on mechanical properties showed that nickel slag-aggregate concrete has excellent short term performance.

Keywords: Nickel slag, high strength concrete, compressive strength, tensile strength, modulus of rupture, unit weight.

1. Introduction

Nickel slag is a by-product from the nickel mine. One mining location in Soroako, South Sulawesi, Indonesia, produces more than 2.5 million tons of nickel slag annually. At present, most of these by-product materials are disposed in landfills, thus threatening the environment and becoming major task waste product management.

To produce environmentally friendly concrete, Mehta (2001; 2002) suggested the use of fewer natural resources, less energy, and to minimize carbon dioxide emissions. He categorized these short-term efforts as industrial ecology. The long-term goal of reducing the impact of un-wanted products of industry can be attained by lowering the rate of material consumption.

In response to the challenge of producing more environmentally friendly concrete and promoting sustainable development of infrastructures, therefore the use of virgin material, as aggregate for concrete, should be minimized. One possible alternative is to replace or partially replace the use of virgin or natural aggregates with by-product materials. In this research, nickel-slag was used as aggregates, either as coarse aggregates or both fine and coarse aggregates, to produce high strength concrete.

High strength concrete in this paper is defined as concrete with compressive strength at 28th day more than 40 MPa (ACI Committee 363 1992). The compressive strength of concrete is normally depending upon the strength of the cement paste, the aggregates, and interfacial face or the transition zone between the paste and the aggregates. For normal strength concrete, the failure surface normally goes through the interfacial surface between the aggregates and the cement paste, to indicate that the interfacial surface is the weakest link of the concrete compressive strength (Aitcin and Mehta 1990), and often called the '*weakest link of the chain'* (Mehta and Monteiro 2006). For high strength concrete; which is normally produced by lowering the water/cement ratio; the strength of the cement paste is high; and thus the interfacial surface. The failure surface in many cases will be smoother, passing through the crushed aggregates, instead of on the interfacial surface. Thus, the strength of the high strength concrete is normally depending more on strength of the aggregates itself (Aitcin and Mehta 1990; Cetin and Carrasquillo 1998).

To further improve the strength of the interfacial face, most of the practices that have been carried out so far were by the incorporation of pozzolanic materials finer than Portland cement into the concrete mixtures, such as fly ash and silica fume. The finer materials will fill the gap among the coarser materials. Moreover, the pozzolanic reaction between the silicon dioxide (SiO_2) from fly ash or silica fume with the calcium hydroxide ($Ca(OH)_2$) from the hydration process of Portland cement will produce extra Calcium Silicate Hydrate (CSH) gels. As the results, the strength of the interfacial face will increase, as this area will become denser and stronger.

Nickel slag is mainly composed of Silicon (40%), Ferro (30%) and Aluminum (2.5%) oxides. Instead of functioning as aggregates only, it is expected that the high proportion of silicon-dioxide (SiO_2) in nickel slag will undergo pozzolanic reaction with the calcium-hydroxide ($Ca(OH)_2$) from the hydration process of Portland cement, to subsequently cause an increase in the concrete strength, as well as, to strengthen the interfacial surface between the aggregates and the cement paste. Therefore, consequently nickel-slag concrete has potential to show excellent mechanical properties. The paper describes a research to evaluate the performance of Nickel Slag-Aggregate High Strength Concrete (NSA-HSC).

2. Experiment Procedure

2.1 Materials

Table 1. The characteristics of the aggregates

	Nickel Slag		Natural Coarse Aggregates	Natural Fine Aggregates (River sand)
	Coarse Aggregates	Fine Aggregates		
Unit weight (kg/m^3)	1924	1930	1564	1583
Specific gravity (ssd)	3.18	2.99	2.54	2.50
Specific gravity (dry)	3.15	2.96	2.48	2.39
Water content (%)	0.125	1.883	0.819	2.667
Absorption (%)	0.778	1.215	2.555	4.603
Los Angeles Abrasion Loss (%)	10	NA	25	NA

Fineness Modulus (FM)	6.8	3.18	7.1	2.27

The Nickel slag used in this investigation was collected from a nickel mining location in Soroako, Luwu District, South Sulawesi Province, Indonesia. The cement used was the locally manufactured OPC conforming to ASTM type I. Tap water from the laboratory was used in the concrete mixtures. For the control mixtures, locally available granite-type coarse aggregate was utilized, together with the locally available river sand as the fine aggregates. Both the natural and the nickel slag coarse aggregates have maximum size of 20 mm. To improve the workability of the fresh concrete, superplasticizer from the Napthalene Formaldehyde Sulphonate type was added to the mixtures. The summary of the characteristics of the aggregates used are shown in Table 1.

The specific gravity and the unit weight of the nickel slag aggregates were about 20% higher than those of the natural aggregates. Its abrasion loss was significantly lower compared to those of the natural coarse aggregates.

2.2 Mixture Proportion

Four mixture compositions were prepared for the investigation. The first mixture was the control normal strength concrete mixture, designed to have 28-day compressive strength of about 40 MPA. For this control mixture, the natural coarse and fine aggregates were used, with water/cement ratio 0.40. The second mixture was the control high strength concrete mixture, designed to have 28-day compressive strength of about 60 MPa. The aggregates used were of the natural types, with water/cement ratio of 0.28.

The third mixture utilized nickel slag as a replacement for the coarse aggregates only, while the fourth mixture was designed to utilize the nickel slag as replacement for both the natural coarse and fine aggregates. Both the third and fourth mixtures were having water/cement ratio of 0.28. Superplasticizer was added to improve the workability of the fresh concrete. The slump of the fresh concrete for all the mixtures was maintained about 65 mm. The summary of the mixture proportions are shown in Table 2.

Table 2. Mixture Proportions

	Mixture 1	**Mixture 2**	**Mixture 3**	**Mixture 4**
	Kg/m^3			
Cement	402	561	561	618
Water	161	159	159	175
Coarse Aggregates	1183 (natural)	1183 (natural)	1445 **(nickel-slag)**	1445 **(nickel-slag)**
Fine Aggregates	540 (natural)	415 (natural)	456 (natural)	458 **(nickel-slag)**
W/C ratio	0.4	0.28	0.28	0.28
Superplasticizer	5	7	7	8

2.3 Specimens and Testing

The preparation and curing of the specimens were performed in accordance to the relevant ASTM standards, as well as the tests on the specimens. Five 150x300 mm concrete cylinders were tested for every compressive strength test and indirect tensile splitting strength test. The results given in the various Tables are the mean of these values. Tests were conducted at the age of 3, 7, 14 and 28 days.

Flexural tests were conducted on concrete prisms with the dimension of 150x150x600 mm to measure the Modulus of Rupture. The number of specimens was five for each test. Test was conducted at the age of 28 days as simple beam with centre point loading.

3. Results and Discussion

3.1 Compressive Strength

Table 3. Compressive Strength at Different Ages (MPa)

	Mixture 1	Mixture 2	Mixture 3	Mixture 4
3rd day	18.5	42.1	48.3	47.9
7th day	31.6	44.8	58.2	60.0
14th day	40.0	51.8	62.5	66.1
28th day	43.0	62.4	70.7	73.6

Concrete from Mixture 3 and 4 which utilized nickel slag as aggregates significantly showed higher compressive strength compared to the control mixture. The Nickel Slag-Aggregate High Strength Concrete (NSA-HSC) consistently showed higher compressive strength since from the early age.

The significant improvement in compressive strength most probably was caused by the improvement of the interfacial surface between aggregates and cement paste due to pozzolanic reaction between the SiO_2 from the nickel slag and $Ca(OH)_2$ from the cement hydration. This pozzolanic reaction resulted in more CSH gels as an addition to what have been produced from the hydration of the cement paste. However, as the nickel slag was also having lower Abrasion Loss, as shown by the Los Angeles Test, the hardness of the materials might also contribute to the increase in the compressive strength (Cetin and Carrasquillo 1998). A microstructure investigation on the properties of the interfacial surface or a test on the bond strength between the aggregate and the cement paste may reveal the real phenomenon. Concrete specimens from Mixture 3 and 4 did not show any significant difference in their compressive strength.

3.2 Indirect Tensile Splitting Strength

Table 4 shows the results from the indirect tensile splitting test. These test results show that the indirect tensile splitting strength of the Nickel Slag-Aggregate High Strength Concrete (NSA-HSC) is only a fraction of the compressive strength.

Carrasquillo et al. (1981; 1981) recommended the following design expression to determine the tensile splitting strength of concrete:

$$f_{ct}' = 0.54 \sqrt{f_c'} \quad \text{(MPa)} \qquad \text{Eg. 1}$$

where fc' is the compressive strength.

Neville (2000) recommended that relation between the indirect tensile splitting strength and the compressive strength of concrete may be expressed as:

$$fct' = 0.3\ (fc')^{2/3} \quad (MPa) \qquad \text{Eg. 2}$$

Table 4. Indirect Tensile Splitting Strength at Various Ages (MPa)

	Mixture 1	Mixture 2	Mixture 3	Mixture 4
3rd day	2.6	2.6	4.5	4.4
7th day	3.3	3.6	4.8	4.9
14th day	3.6	4.2	5.0	5.0
28th day	3.6	4.3	5.9	6.1

Table 5. Relationship between the Indirect Tensile Splitting and the Compressive Strength

	Compressive Strength at 28th day (MPa)	Indirect Tensile Strength (MPa)		
		Test	Equation 1	(Equation 2
Mixture 1	43.0	3.6	3.5	3.7
Mixture 2	62.4	4.3	4.3	4.7
Mixture 3	70.7	5.9	4.5	5.1
Mixture 4	73.6	6.1	4.6	5.3

Table 5 shows the relationship between the indirect tensile splitting and the compressive strength as determine by using Equations 1 and 2. The results indicate that the indirect tensile splitting strengths of Nickel Slag-Aggregate High Strength Concrete (NSA-HSC) (Mixture 3 and 4) are significantly larger than the ones using only the natural aggregates (Mixture 1 and 2), and are significantly larger also than the values recommended by Carrasquillo et al. (1981; 1981) and Neville (2000).

3.3 Flexural Strength/Modulus of Rupture

Carrasquillo et al. (1981; 1981) and American Concrete Institute (1992) recommended the following relation to predict the modulus of rupture of concrete based on the compressive strength, i.e.:

$$fr' = 0.94\ \sqrt{fc'} \quad (MPa) \qquad \text{Eg. 3}$$

Table 6 shows the relationship between the modulus of rupture (fr') and the compressive strength (fc') as determine by using Equations 3. The results indicate that the modulus of ruptures of Nickel Slag-Aggregate

High Strength Concrete (NSA-HSC) (Mixture 3 and 4) are significantly larger than the ones using only the natural aggregates (Mixture 1 and 2), and are significantly larger also than the values recommended by Carrasquillo et al. (1981; 1981) and ACI (1992).

Table 6. Modulus of Rupture (MPa)

	Compressive Strength at 28th day (MPa)	Modulus of Rupture (MPa)	
		Test	Equation 3
Mixture 1	43.0	6.8	6.2
Mixture 2	62.4	7.1	7.4
Mixture 3	70.7	8.6	7.9
Mixture 4	73.6	10.4	8.1

The larger values of the indirect tensile strength and the modulus of rupture of Nickel Slag-Aggregate High Strength Concrete (NSA-HSC) may bring benefit as it may improve the bond strength between reinforcement bars and concrete in the case of reinforced concrete structures, and the bond between tendons and concrete in the case of pre-stressed concrete structures.

3.4 Unit weight

The unit weight of concrete depends on the unit weight or specific gravity of the aggregates, as aggregates occupy the largest volume in concrete, i.e. about 70-80%. Because the specific gravity of the nickel slag is higher compared to those of natural aggregates (see Table 1), the unit weight of Nickel Slag-Aggregate High Strength Concrete (NSA-HSC) is also higher than concrete with natural aggregates (see Table 7). This may not be favorable if Nickel Slag-Aggregate High Strength Concrete (NSA-HSC) is used for upper structures, especially for the rise buildings, as the increase in the unit weight may cause an increase in the self weight of the structure. However, the increase in the compressive and tensile strength of Nickel Slag-Aggregate High Strength Concrete (NSA-HSC) may result in smaller dimension of the structural members, and thus may compensate the larger unit weight.

Table 7. Unit Weight of Concrete (kg/m^3)

	Mixture 1	Mixture 2	Mixture 3	Mixture 4
Unit Weight	2356	2340	2679	2783

4. Conclusions

This paper presented the results of investigation on the use of nickel slag as aggregate replacement in concrete, either as replacement for the coarse aggregates only or both coarse and fine aggregates. Based on the experimental work reported in this paper, the following conclusions are drawn:

- The use of nickel slag as aggregate replacement in concrete showed superior results in terms of compressive strength, indirect tensile strength and modulus of rupture compared to concrete incorporating only the natural aggregates.
- The increase of the strength may be attributed to the pozzolanic reaction between the SiO_2 in the nickel slag and the $Ca(OH)_2$ from the hydration of Portland cement to produce CSH gels as an addition to the gels that have been produced by the hydration of Portland cement, thus strengthen

the interfacial surface between aggregates and cement paste. The hardness of the slag may also contribute to the betterment of the mechanical properties of concrete.

- The unit weight of Nickel Slag-Aggregate High Strength Concrete (NSA-HSC) is larger than the unit weight of concrete using natural aggregates, due to higher specific gravity of the nickel slag.
- Nickel slag has potential to be used as aggregate replacement in concrete.

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A CASE STUDY OF GREEN BUILDNG DESIGN APPROACH FOR A SUSTAINABLE COMMUNITY

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Abstract

Green Building Design approach forms the most basic principle for a sustainable community. This paper presents the experience of adopting a holistic approach in the planning and design of a public housing redevelopment project in Upper Ngau Tau Kok of Hong Kong. The Project has won the Grand Award under Research and Planning Studies Category for the Green Building Award 2006 organized by Hong Kong Professional Green Building Council.

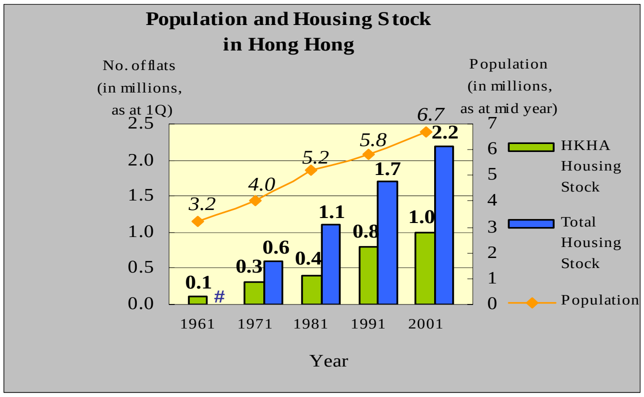
This project demonstrates the whole process of planning and design, from studying the constraints and opportunities at the Site, formulating the design solution and getting into partnering relationship with various stakeholders. They include prospective residents from Lower Ngau Tau Kok Estate, academia, researchers, councilors, green groups and concerned groups. The Project will revitalize the old Ngau Tau Kok Estate and their neighbourhood, with a design that balances the major aspects of sustainability in economical, social and environmental aspects.

Keywords: Healthy Living, Sustainable Community

1. Introduction

Born in the wake of the tragic fire that gutted the entire Shek Kip Mei squatter area on Christmas Day in 1953, the first public housing in Hong Kong was built to resettle the some 50,000 victims of the disaster. Since then and during the 1960s, the Hong Kong Government built more than 200 resettlement blocks for housing people who lost their homes in similar fires and other natural disasters. During the 1960s and 1970s, more subsidized housing blocks were built to relieve the squatter problem as a result of the large amount of people coming from mainland China. With only 22% developable area, Hong Kong's urban areas are characterized with high-rise and high-density developments.

Today, there are almost one-third of the total Hong Kong population (over 7 million) living in public rental housing developments. The challenges for public housing is to provide adequate and affordable housing to all families in genuine need with limited housing resources. To keep pace with the rising aspirations of the community, the Hong Kong Housing Authority (HKHA) is leading the construction industry in a paradigm shift towards sustainable design, construction, management and maintenance. In the ensuing sections of this paper, we share a case study on how partnering works for all stakeholders in planning for a sustainable community.



Legend - # Data not available

Notes –

HKHA housing includes both rental and sale flats but Housing Society flats are excluded. Total housing stock excludes institutions, rooftop structures and other temporary housing. (Resource - from Hong Kong Census and Statistics Department)

Fig. 1 Population and Hong Kong Housing Stock in Hong Kong

2. Background

Redevelopment of Upper Ngau Tau Kok Estate Phases 2 & 3 (UNTK 2&3) is the last of the Comprehensive Redevelopment Programme (CRP) of the HKHA that commenced as early as 1988. The old Upper Ngau Tau Kok Estate was built in the 1960s. CRP was launched for the redevelopment of housing blocks built before 1973, most of them being Resettlement and Government Low Cost Housing Blocks. CRP is designed to re-house residents in the same district, with reception estate close to the residents to be re-housed. With CRP there has been better opportunity to replace dilapidated resettlement buildings with better equipped new housing blocks and well-planned community of sufficient amenity provisions.

UNTK 2&3 is the reception estate for residents from the Lower Ngau Tau Kok Estate Phase 2 (LNTK 2) which was also built in the 1960s. Currently, there are about 11,000 people living in LNTK 2, with almost one-third elderly (average age above 75). The redevelopment proposal revitalizes the old Ngau Tau Kok Estate and its neighborhood with objectives to plan for a “Sustainable Community” with balanced economic, social and environmental initiatives.

Fig. 2 Site Location Plan

3. Shaping a Green Community

In the high-rise, high-density environment of Hong Kong today, environmental performance of buildings has a significant impact on the public. The population density is over 63,000 people per hectare. Healthy living is a key focus in the public housing developments. A sustainable home provides the base for our physical, mental as well as social health. It also enhances productivity of the society.

HKHA is fully committed to building a healthy living environment and nurturing a sustainable community. It is a collaborative process and its success relies on the Partnership in tune with the residents, project team, academia, and other stakeholders.

Fig. 3 Perspective of Redevelopment Scheme

4. Economic Sustainability

The economic performance of an organisation provides the key to its success and hence its sustainability. Cost effectiveness is critical to the HKHA because decisions on any aspect of the housing programme from design, through construction, to operations and maintenance will have such an impact on the public purse.

4.1 Life Cycle Costing and Life Cycle Assessment

In 2002 to 2005, we commissioned consultants to carry out a study of life cycle costing and assessment on typical domestic buildings. The study confirmed that the materials that are used, achieve an optimum environmental performance and life cycle cost effectiveness. Designers are now using this life cycle costing and life cycle assessment software to make decisions on the choice of new materials and help to reduce the maintenance burden in future.

4.2 Application of Modular Design, Precasting and Mechanized Construction Methods

Modular design for domestic units, precasting and mechanized forms of construction are adopted to improve built quality, efficiency, and reduce the use of labour-intensive and skill-sensitive wet trades on site. Our teams have worked with contractors to perfect the use of large panel formwork systems, pre-cast concrete and other pre-fabrication techniques for a wide range of building components. These include pre-cast concrete facades, staircases, floor slabs and other components such as door-sets, cooking and sink benches produced in factories.

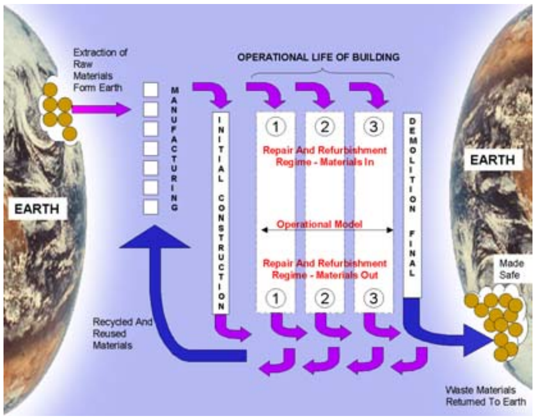


Fig. 4 LCA and LCC Study

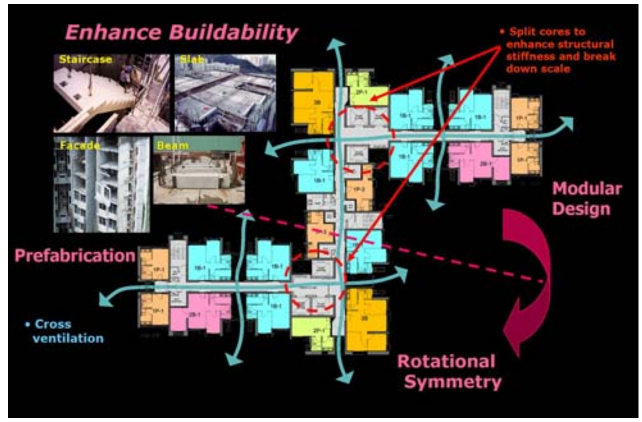


Fig. 5 Modular Design, Precasting and Mechanized Construction Methods to enhance buildability

5. Social Sustainability

Social sustainability enhances the well-being of people. The low rents in public housing represented a subsidy to low income families. The housing programme promoted social stability, economic prosperity and fostered harmony in the community. The HKHA has been involving the residents in the customer satisfaction survey and feedback on newly completed projects and statistical data in the constant review of flat mix, spatial standards, general estate facilities, domestic flats and communal areas. Four focal social elements in our housing planning and design are community cohesion, sustainable home, greening and accessibility. These elements are inter-related and collectively contribute to the physical, mental and social realm of healthy living.

5.1 Community Cohesion

5.1.1 Heritable Neighbourhood Living

In this project, local residents were involved in formulating the community identity and neighbourhood character throughout the planning and design process. In 2003, a casual heritage exhibition was organized by HKHA and non-government organisations to commemorate the neighbourhood living established by the residents. As inherited by the old neighbourhood, "People in harmony with healthy families" has become the spiritual identity of the subject redevelopment project.

Fig. 6 Heritage Exhibition to commemorate neighbourhood living

5.1.2 Planning for Social Interaction with Community Participation

Social interaction is vital for social health in high density living environment. HKHA has been motivating residents to participate in building, managing and maintaining their green environment by introducing community farms and art walls at different layers of open space. Potential residents made encouraging contributions in design workshops and forums organized by HKHA and Non-Government Organizations throughout the planning, design and construction stages. It is through this process that a communal entrance plaza is created with integration of adjacent external garden areas for social interaction among residents of different age groups. Covered walkways link the domestic towers horizontally with active and passive zones. The landscape design encourages residents of all age groups to meet, chat, interact and participate in communal activities.

Fig. 7 Community Participation through Workshops and Forums for Communal Facilities Planning

5.2 Sustainable Home

A sustainable home provides the base for our physical as well as mental health. Lots of public housing tenants in Hong Kong spend the rest of their life in the domestic units. Not only the number of family members may vary with time but also the physical condition of the tenants changes with their age. "*Universal design approach*" is adopted to secure the layout, fittings and fixtures of the living and dining room, bedrooms, kitchen and bathroom fitting for all physical conditions of the tenants. This saves alteration costs due to changes of tenants' health condition.

Figure 8 Universal Design approach for sustainable home

5.3 Greening

Heritage trees at prominent locations, including entrance communal courtyard, viewing deck, foyer of heritage gallery, landscaped areas along the pedestrian circulation network, were preserved for memory re-collection of the old neighbourhood. Existing mature trees have been preserved at selected sitting areas to create a focal heritage feature for the redevelopment. Ornamental species are to be planted at focal areas and sitting areas to provide variety of colours and interests all year round.

Fig. 9 Heritage greening

5.4 Accessibility

Accessibility increases mobility particularly the elderly people and encourages activities like morning exercises and social interaction. The project team utilized the redevelopment site to enhance the accessibility of the neighbourhood as well as residents of the whole estate. A barrier free pedestrian covered walkway, with network of tactile tiles for visually impaired persons, is designed to facilitate accessibility for the disabled and elderly. This serves to enhance the circulation pattern within the estate. By utilizing the public transport interchange and car parking facilities in the vicinity, private car parking facility is reduced to 25 number of spaces within the redevelopment site and much space can be surrendered for greening purpose.

6. Environmental Sustainability

Healthy living is always a major concern of the society particularly after SARS in 2003. Through a holistic approach on planning and design for a 'Sustainable Community', the proposed redevelopment revitalizes the old Ngau Tau Kok Estate and their neighbourhood. Building on a site with a gross floor area of about 3.5 hectares, the redeveloped estate comprises six 39 to 40-storey domestic blocks, amounting to a total of 4,600 units of 200,000m^2 gross floor area. The domestic blocks are planned in two groups as if they are two embracing hands in response to the site configuration, topography and the as-built environment.

6.1 Micro-climate Studies at Planning and Design Stage

A development with good environmental performances optimizes life cycle costs. Specialist consultants were engaged in the project team to conduct micro-climate studies in areas of wind environment, natural ventilation, pollutant dispersion, daylight, thermal comfort, environmental noise and room acoustics.

6.1.1 Wind Environment and Natural Ventilation

Current local statutory control secures basic natural ventilation for habitable spaces. In this project, computerized fluid dynamics simulation was applied to explore the most desirable master layout and building design option, including configuration, orientation, disposition and permeability of domestic towers. This enhances site specific wind environment and natural ventilation in different seasons -

- A wind corridor is planned in response to the easterly prevailing winds and as-built surroundings;
- Orientation and disposition of the domestic blocks are adjusted to enhance the wind speed at range of 1.5 to 3 m/s;
- Open deck heritage garden is introduced at low level of domestic blocks, and ventilation points at each typical floor to enhance building permeability for wind penetration;
- External garden layout and landscape features are designed with wind speeds at passive and active

open space being 1 to 2m/s and 2 to 3m/s respectively;

- Refuse storage rooms and collection point are sited at well ventilated locations with desirable dispersion rate justified by CFD simulation.

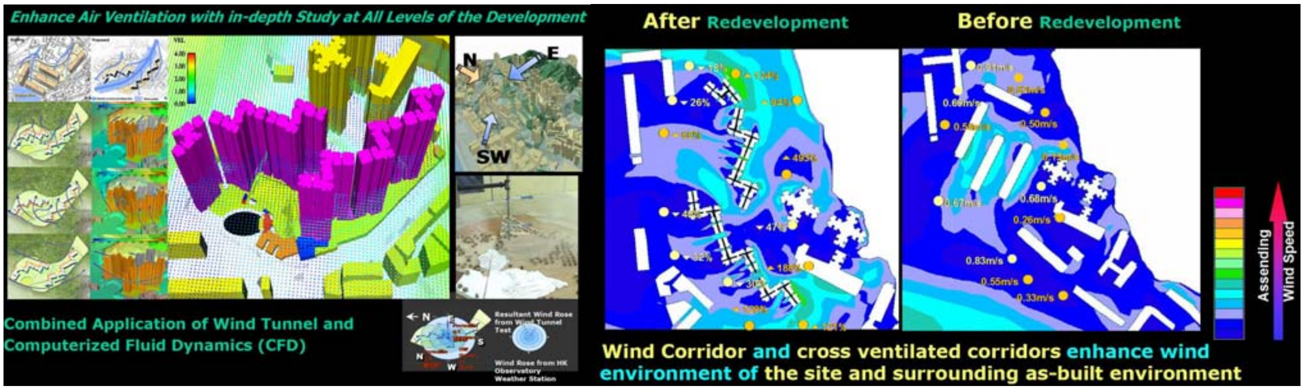


Fig. 10 Micro-climate study on wind environment and natural ventilation

6.1.2 Daylight and Thermal Comfort

Daylight has psychological effects and increases the comfort level of individual space. It is also essential to minimize the solar heat gain for high-rise domestic premises, particularly in Hong Kong under tropical climatic condition. In terms of site planning, the layout of active and passive open spaces is designed in response to the duration of sunlight exposure. In this project, we use the micro-climate studies as building design tool to optimize daylight penetration in domestic units and public areas of domestic blocks for energy efficiency, comfort and health, and optimize the passive and active open space layout planning within the development.

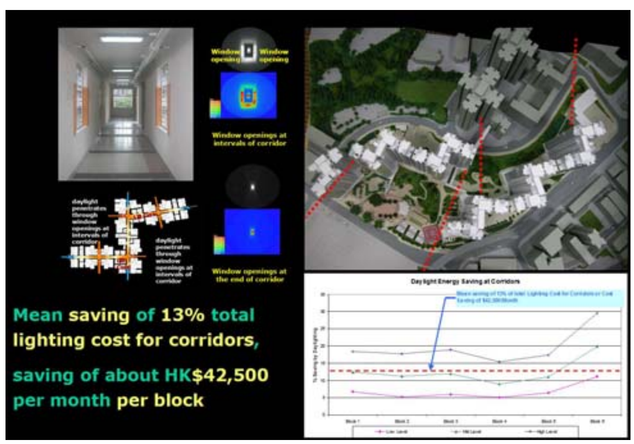


Fig. 11 Daylight and Thermal Comfort Study

6.2 Environmental Noise and Room Acoustics

Road traffic noise is the major environmental noise factor in high density, high-rise living environment. In mitigating the noise impact for public housing, the domestic towers are set back from the north western corner of the site and the principle facades are inclined at an angle to the noise source from public road. In terms of room acoustics, detail studies are conducted, taking into account of the reverberation time, air-borne noise isolation, impact noise isolation, background noise levels, and vibration from building services equipment and external sources, to mitigate the impact of environmental noise and optimize room acoustics.

6.3 Partnering with Builders at Construction Stage

The construction stage of a development can have the greatest impact upon quality of product and surrounding developments, and if not properly managed can lead to complaints and delay to projects. To minimize the possible impact, we have required our contractors, through comprehensive contractual provisions, to develop "green building practices" and they in turn cascade the message down through the supply chain to workers on site. Since commencement of site works, we have been running project partnering workshops in building and piling contracts to foster more effective communication and cooperation amongst team members, including contractors, subcontractors, project staff and consultants. We form partnership with builders to conduct rigorous site inspections and have implemented thorough Performance Assessment Scoring Systems to monitor the performance of contractors to ensure that they meet their obligations by strict compliance with specified environmental standards. Partners have become more proactive in working towards achieving common project objectives, including quality, site safety, environmental and customer service performance.

A further enhancement to reduce the impact of our works and improve conditions at site level has been the requirement for temporary paving in this construction site. This practice has provided a healthier and cleaner site with much better dust control, material storage and handling and more effective control of surface water runoff. The builder has gone further by the use of re-usable precast concrete slabs instead of in-situ concrete. This has been shown to be very effective, not only in minimizing the environmental impact but also in improving site safety, and gradually changing the behaviour and culture of the workforce where more clean and green working practices are becoming the norm.

Fig. 12 Green initiatives in construction site

Fig. 13 Off-site Precast Façade Panel

7. Conclusions

"Healthy Living" with its wide spectrum of coverage, in the context of HKHA with her sizable portfolio of affordable quality housing, means that it is not only a single organization's input but its collaboration with all stakeholders and residents towards cultivating sustainable awareness. This is a big challenge as well as an excellent opportunity to bridge the gap between policies and practice for the good of the coming generations. In terms of planning and design, a holistic approach should be adopted with balanced economic, environmental and social considerations. With a common goal and concerted effort, more healthy living environment will be created for Now and the FUTURE.

Acknowledgements

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HYPOTHETICAL MODEL OF MULTI-LEVEL GREENING FOR DENSE URBAN AREA IN HONG KONG

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Abstract

Results of many empirical studies in the past few decades have manifested a lot of environmental problems as generated in dense urban environment while urban heat island (UHI) effect receives the broadest concern. It has also been validated that vegetation is one of the effective means to ameliorate UHI problem by reducing ambient air temperature. Due to limited land resources in Hong Kong, urban green space is acute shortage in supply. In this study, based on the current administrative context for building development in Hong Kong, such as Building (Planning) Regulations (B(P)R) as associated with the Building Ordinance, Outline Zoning Plans (OZPs) and Hong Kong Planning and Standard Guidelines (HKPSG), a hypothetical model is established with an approach to optimize all greening opportunities at different levels of a development at a hypothetical site. By amalgamation of land lots within the site, development flexibility can be maximized. It thus envisages more new greening initiatives can be furnished in the re-developed site in order to lift up the livability and quality of life of the built environment. The model will possibly lend support to future development to integrating more greening in the dense urban environment.

Keywords: multi-level greening, urban greening, urban design, landscape architecture

1. Introduction

Considering the limitations on land supply in urban areas and rapid urbanization, designers are looking skywards to optimize the development potential. Closely spaced high rise buildings are the prevailing scenes which can be found in cities around the world. The opportunity cost for the concentration of tall buildings on a confined land is the limited provision of quality greening and open spaces. Such concentration subsequently triggers tremendous environmental threats to the built environment, such as urban heat island effect, low wind speed, pollutions and air quality degradation. Conversely, the importance of a quality and livable environment as well as the need of balanced urbanization and nature is also being recognized.

Lack of urban green space is a chronic concern of researchers for many years. There are profuse studies investigated means to provide more greening and open space at- and above-grade levels. Organic treatment of high-rise buildings, such as podium garden, green roof and sky garden, encourages vertical propagation of greening which adds green space without taking up extra space on ground level. Such provision also affords much-needed spaces for outdoor recreation and offers accessible alternatives to those who do not live near traditional parks.

From the environmental viewpoint, the oxygen-producing properties of vegetation can be used not only to reduce the likely heat-island effect for the locality, but also to create a localized air-cleansing environment in addition to absorbing much of the carbon dioxide and carbon monoxide emitted by the concentration of built systems. In considering the example of tall buildings grouped or linked together and sheltered by one another, stagnant areas on the leeward side of the buildings will be created while "wall effect" will be another serious adverse effect. According to an experimental study Yau (2001), for a dwelling with a single side openable window, the effectiveness of natural ventilation for the dwelling will be decreased if the window is facing the stagnant regions. When sky garden is designed at intermediate storeys of the development, the building permeability can be promoted which eventually improve the stagnant areas on the leeward side. As the wind speed within that area increases, the performance of natural ventilation adjacent to it is more substantial.

From the landscape design viewpoint, more strategic planting to be integrated in building can gain both ecological and aesthetic benefits. Different greening layers are introduced to enable more options for users to have direct contact with the outside environment. Besides, integration of gardens at above-grade levels will help to give a sense of relief to the high-rise housing environment. With more greening and gardens at both at- and above-grade level to connect to the natural world, the living environment can be more inviting for living and relaxing, and create a better sense of community and neighbourhood.

In Hong Kong, like many other generic urbanized cities, the dense built environment cause serious pollution problems and insufficient provision of open spaces and plantings. Even though parks and street plantings are provided, their qualities and growth are checked by many factors, such as poor surrounding environment, poor management or maintenance, inadequate facilities, underground utilities, or even 'ad hoc' provision. Many urban areas in Hong Kong are undergoing or awaiting renewal or redevelopment, hence it is a prime time to establish a hypothetical model for the provision of multi-level greening with an aim to create a more pleasant environment in the future. It is also the main objective of the study.

2. Emergence Of Dense Strip City And Pocket Open Spaces In Hong Kong

2.1 Historical and economic reasons

The population bloom in Hong Kong was starting around 1950-60 which was due to a substantial influx of refugees from the Mainland China as a result of the civil wars. A cheap labour offered a vast pool for labour-intensive industry. Coincidently around the same time, a big fire disaster at Shek Kip Mei destroyed a large temporary squatter camp while 50,000 people lost their home. Both incidents had exerted a tremendous demand on housing. The government responded with a 'multi-story buildings' as a prototype. Those facilities provided in these buildings were very basic and just served the fundamental needs. However, it laid the milestone for developing high density buildings.

In 1960-70, there was an economical bloom in Hong Kong. People were becoming wealth off and desired to have a better living place. Meanwhile, the government initiated a new policy, i.e. "individual flat selling", which further boosted up and encouraged people to purchase their own flat at the tenement building. All these conditions helped making the property market flourished. Many land owners had started to build new tenement buildings, which is up to 5 to 6 storey, with almost 100% site coverage in order to maximize the profit. Narrow pedestrian walkway (approx. 2m) was provided at the perimeter for just serving the circulation and infrastructure facilities purposes. The concept of urban greening was even not being initiated at that moment

To further satisfy the substantial demand on land and the needs for housing this increasing population, a policy on reclamation was launched to resolve this shortfall. The reclamation was mainly at the edges of Victoria Harbour. Various styles of mid-rise and even the high-rise buildings were constructed in line with the reclamation plan in different period of time. As a result, various 'strips' appeared along the shoreline of Hong Kong. The reclamation policy has now been suspended as it exerts a substantial environment impact on water quality and visual quality of Victoria Harbour.

Most of the communal green areas in urban area of Hong Kong are pocket open spaces. They are small and various in sizes. Their emergences are mainly due to the government's decision on the land resumption when the demolished old tenement buildings' ownerships could not be identified for a long time. This type of pocket open spaces is an essential space for social gathering especially the elderly, and for the greening initiatives. As they are scattered in nature and lack of strategic design and planning, the potential of the space cannot be fully utilized.

2.2 Building typology and its implication on greening

The opportunity cost of greening is the amount of Gross Floor Area (GFA) for the development. This mutually-exclusive relationship became more apparent particularly when the size of plot was usually small and it is a common scenario for those old tenement buildings. The owner of land will try to maximize the development potential. In fact, the evolution of building typology gives hints for greening initiatives. The typology in Hong Kong can be classified chronologically into four types (Fig.1) (SD, 1992). They are:

(1) Verandah Type (1920-);
(2) Cantilevered living quarters type (1950-1960)
(3) Rectangular mass type (1970-)
(4) Podium tower type (1980-)

For the verandah and cantilevered type, normally, the mass of buildings extended over the pedestrian walkway. With 100% site coverage low-rise buildings, at-grade and other forms of greening are not feasible either in public and private realm. During the course of evolution, awareness of the importance on communal green open space increased, more spaces were reserved for this purpose, especially for the podium tower type. Several forms of greening initiatives could be incorporated by means of development set-back, reserved spaces at podium and roof level. This is the initial attempt for the multi-level greening in dense urban areas.

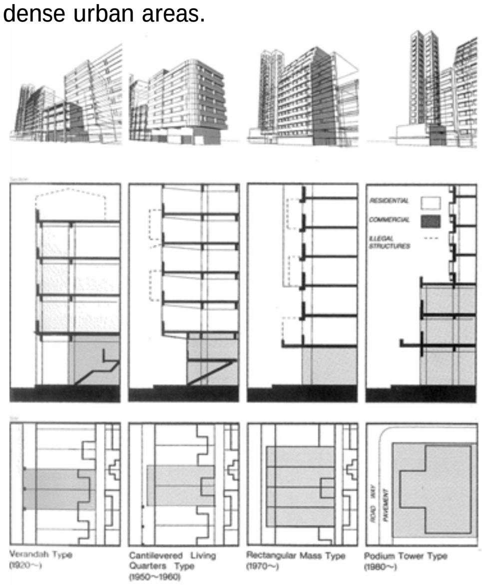


Fig. 1 Building Typology *(source: SD 92-03)*

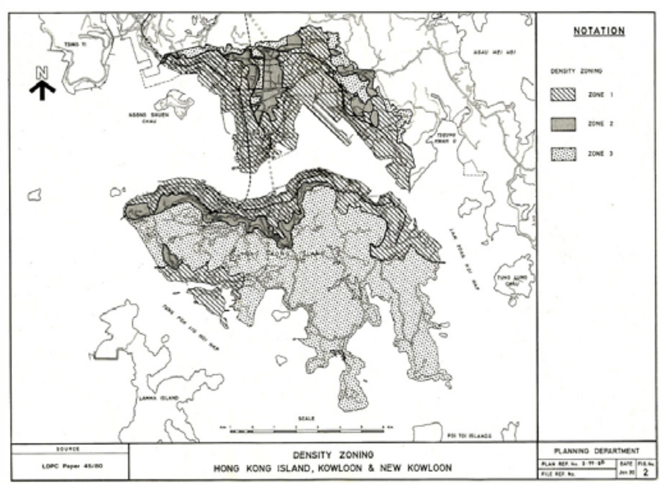


Fig. 2 Residential Densities *(source: HKPSG, Ch. 12)*

2.3 Current land development control in Hong Kong

Proper and effective land use planning and design control system is important for Hong Kong due to its scarcity of land supply and high population density. Based on the different physical and environmental settings, areas of Hong Kong are sub-divided into three different density zones: Zone 1, Zone 2 and Zone 3. (See Fig 2) while the densest metro-urban area falls into Zone 1 category. The macroscopic land use planning and control starts with the statutory Outline Zoning Plan (OZP). It is developed in accordance with the Town Planning Ordinance and depicts all possible permissible developments within a particular zone, the height restriction, the maximum development intensity (i.e. permissible plot ratio (PR)) and more essentially, the overall planning intention for the area.

The second control measure is implemented through statutory ordinance and regulation, they are Building (Planning) Regulations (B(P)R)/ Building Ordinance (BO). B(P)R stipulates a detailed control on the site coverage, PR, development height and public open space provision. The total permissible PR, either for domestic and non-domestic portion, will be varied with respect to the characteristic of the site. The third control measure is enacted by the Lease Conditions which is tailored made for a particular piece of lands. Different control detailed clauses form the development parameters. The amount, quality and even greening coverage are always constituted a part of the development conditions.

Apart from the aforementioned statutory control mechanisms, a set of concise guidelines titled Hong Kong Planning Standards and Guidelines (HKPSG) is developed which lay out different recommended practices and parameters for the building and design profession, such as development density, environment, urban design, public open space, local private open space, and greening. It is an important source of reference from government departmental level for assessing the development integrity.

3. Greening In Dense Urban Area Of Hong Kong

3.1 Types of multi-level greening in high-rise building

3.1.1 On-grade

- *gardens and parks* – These are the traditional type of green spaces in urban areas.

- *street planting* - By introducing various types of planting along road edge and central dividers of the roads, the overall appearance of the district will be improved. It not only lifts the environmental quality of the district, but also enhances its vitality.

3.1.2 Above-grade

- *green roof* – The most popular types of above-grade greening around the world. Based on the depth of substrate layer and the design intention, it can be categorized into intensive and extensive type. Intensive green roof can support a variety of trees and shrubs and facilities such as seating, water features or children play equipment for the physically access and enjoyment of users. It is treated as a roof garden. With a shallower layer of soil, extensive type green roof is designed only for environmental, aesthetic and ecological benefits as small plants such as herbs, grasses and wild flowers can be included.
- *Podium garden* – The type of garden is situated at the podium level of a development. Compare with roof garden, its size is generally larger. The garden can support much more varieties of plant materials and facilities. It is commonly found in Hong Kong especially in residential developments. Most of the benefits are similar to those of roof garden.

- *Greening in intermediate storeys* - This includes garden, planting on facade and on balconies. Gardens to be provided in the intermediate levels of the building, such as sky garden or the use of recessed terraces or 'sky courts' to serve as interstitial zones between the inside areas and the outside areas (Yeang, 1998). This type of greenery can be accessed and enjoyed by users. Depends on the design and its configuration, it can also serve purposes in different aspects, such as environmental, social and economical. It can help to improve the natural ventilation of a development and increase the amount of recreational and communal space.

- *Facade planting* - Facade with planting can be in the form of creepers, planter boxes on walls while balcony planting is normally privately owned and managed by the occupants.

3.2 Benefits of multi-level greening

The importance of greening in urban area is reiterated in many studies. Urban heat island effect and global warming are the two major environmental concerns recently. It has been proved to mitigate the urban heat island effect by reducing the ambient air temperature (Hough, 1995; Kurn et al., 1994 and Wong, 2003) and improving natural ventilation (Yau, 2001). Plants can absorb carbon dioxide and release oxygen which improves the total air quality of the environment (Green Roofs). Facade and balcony planting help shading the external wall and internal space and cutting down the amount of external heat reflection and glare into the building (NParks, 2002 and Yeang, 1998). Plants also act as visual screens and sound diffusers, especially at the sky courts, to reduce the sound and smells of the city below (Yeang, 1996).

Parks and greening play a vital and integrated role in our urban environment. Research across different disciplines has shown that greenery directly benefits the urban environment and makes the city livable (Yuen et al., 2005). They give city dwellers a place to connect to the natural world, reduce the stress of daily urban life (Ulrich, 1979; Jackson, 2003), a higher level of residential satisfaction and general well-being when view of trees can be enjoyed or even knowing an open space exists nearby (Ulrich, 1979; Skjaeveland et al., 1997). Introducing greening into workplace, employees' productivity and happiness can also be improved with an improved quality and effective working environment. There are strong public-health arguments for the incorporation of greenery, natural light, and visual and physical access to open space in homes and other buildings. (Jackson, 2003)

If the greening is introduced on the building roof, it also generates several economic benefits. It will increase the amount of usable space for amenity or recreational use in urban area, increase life span of waterproofing membrane on roof and reduce air-conditioning cost. The use of planting at the faces of the bldg enhances the aesthetic of the building as a foliaged structure. Plants help soften the hard architectural surfaces, provide texture to nondescript surfaces and hide ugly rooftop services (NParks, 2002 and Yeang, 1996). With the introduction of sky courts or sky gardens at intermediate stories, it helps to break the visual massiveness of the entire development or even the district.

3.3 Current greening policy review

There are no specific ordinances, regulations and comprehensive greening policy in Hong Kong for governing the urban greening even though the merits of its existence are fully acknowledged by most of the policy administrators and citizens. Compulsory greening provision may be spelt out in some of the Lease Conditions of land. Otherwise, implementation of greening is mainly governed through some administrative measures, such as Practice Notes and Works Bureau Technical Circulars which are updated regularity to meet the administration and social aspirations. The Greening Master Planning (GMP) currently undertaken by Civil Engineering Development Department HKSAR, in fact, is a comprehensive pioneer study on reviewing the overall greening policy in dense urban areas and identifying adequate spaces for planting trees within this dense concrete jungle. The extent of its work is, however, only limited to the urban street level.

4. New Greening Initiative Through Amalgamation Of Land

'Land' is the key element for all development and greening initiatives. Most of the lands in Hong Kong urban districts have been developed since 1950-60s due to the large influx of emigrants from the Mainland. Those easy-to-construct and functional buildings were the resultant phenomenon which was emerged to satisfy the surge of demand, especially for residential buildings. In most of the old dense urban areas, many tenement buildings have been weathered for more than 30 years. Most of them are dilapidated especially in the hot and humid climate of Hong Kong. With the limitation of technology at that time, a typical building is only up to 5 or 6 storey with a typical floor area around 81 square meter (i.e. 4.5m x 18m). Narrow frontage of the ground level is usually reserved for non-domestic portion while the remaining part is residential portion.

The principal of the hypothetical model in this paper is to achieve an equilibrium for the development and the provision of quality public green open spaces through amalgamating the lands in the old dense urban area. Multi-level greening initiatives could be achieved through this mechanism as different land uses could be regenerated and redistributed within the given piece of land. The prime objective is seeking opportunity to provide adequate quality communal greening niches in this dense urban area.

Fig. 3 illustrates the possible building form and public open space provision under current development control practices of B(P)R. Since the size of plot is small for the typical old tenement building, 66.6% site coverage of a residential portion is permitted if the building height is less than 15m (i.e. 5-6 storey). The ground floor could be reserved for non-domestic use while the remaining should be residential portion. The remaining 33.4% of the site could be reserved for communal open space in which greening could be realized. Under such circumstances, typical floor area above ground could be reduced and the incentive for redevelopment is low. Many owners may opt for other rehabilitating measures to extend the building life. In real situation, multiple ownerships on a building pose another difficulty on reaching a consensus for redevelopment of the site. As a result, there is no room for attaining more spaces for greening in the dense urban area.

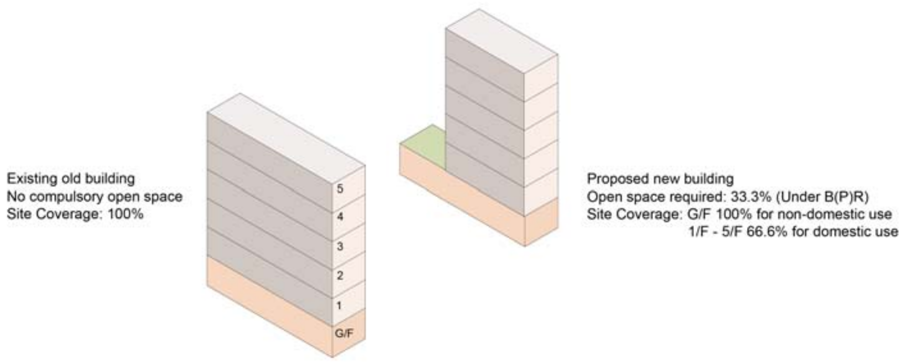
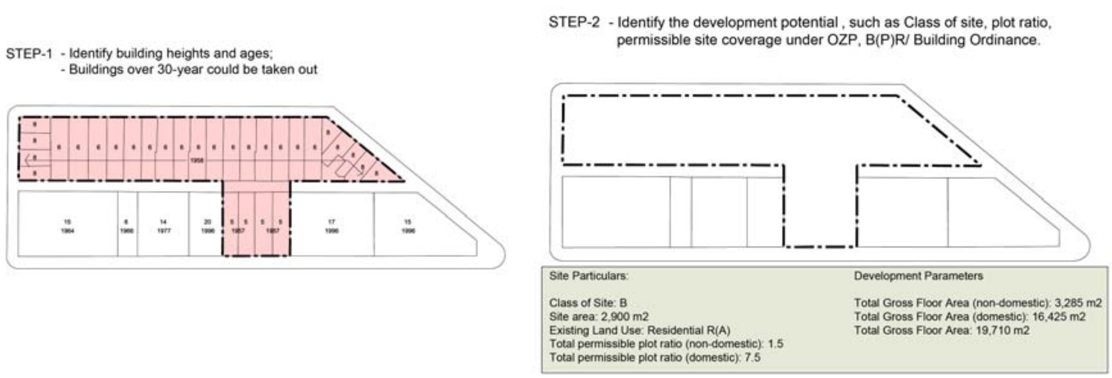
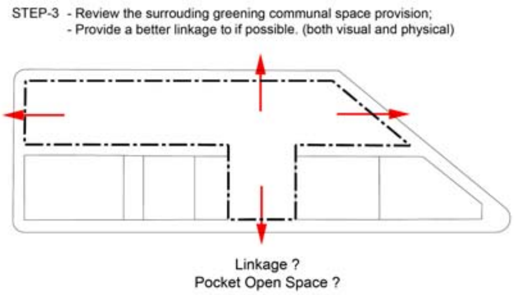


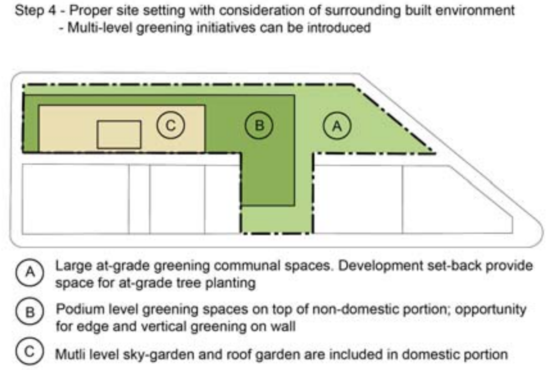
Fig. 3 – Comparison between existing building and the possible development under B(P)R

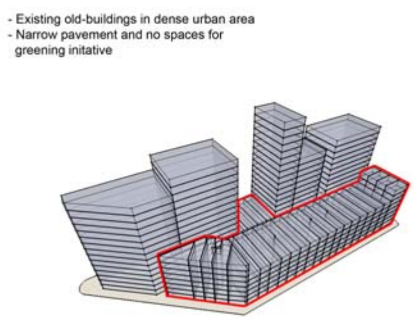
4.1 Hypothetical model for multi-level greening provision

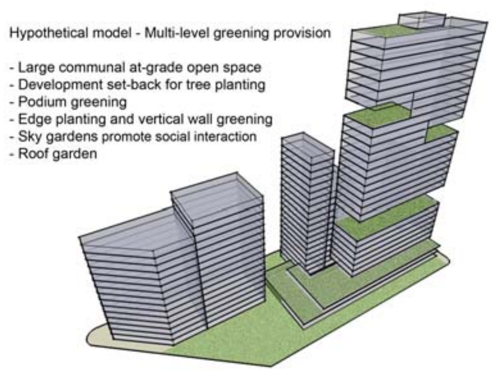
The hypothetical model of multi-level greening is based on the assumption that all buildings aged over 30 years could be acquired for redevelopment. This is a current policy used by the Urban Renewal Authority of HKSAR for land acquisition. The prime objective of the amalgamation of lands is to seek opportunity to re-distribute the land use and gain flexibility to regenerate adequate quality communal green open space at multi-levels so as to improve the living environment and to mitigate the urban environmental problems. The methodology for attaining this multi-level greening communal spaces is illustrated in the following steps.











4.2 Assumptions and limitations

The hypothetical model, in fact, is developed in accordance with the current development control mechanism in Hong Kong, i.e. Town Planning Ordinance, Building (Planning) Regulations/ Building Ordinance, Joint Practice Notes 1 and 2 and Hong Kong Planning and Standards Guidelines. However, there are several assumptions and limitations are noted:-

- All old buildings aged over 30 years could be acquired regardless of their conditions. In fact, other rehabilitation proposals may be applicable for extending the building life. It is important especially for the old building with a cultural and historical significance.
- The most valuable shop frontage at ground level is reduced. However, it could be justified through a comprehensive study on commercial retail mixing in the surrounding areas. The best and complementary compositions could be achieved for a new development.
- New development attracts more traffic to the vicinity which may pose another traffic problem. Those ingress and egress points may limit the greening proposals. Traffic impact assessment should be evaluated fully to minimize the traffic impacts and maximize the planting flexibility.
- The design and orientation of the high-rise building should be carefully examined. A stepping tower profiles and sky-gardens could be proper positioned in order to promote the air ventilation by taking into account the surrounding buildings.
- The layout and positions of building may alter the existing urban form of the district.
- For simplified calculation and illustration, the plot ratios for non-domestic and domestic are kept for 1.5 and 7.5 respectively. The impact on Class of the Site as per Schedule 1 of B(P)R is ignored in this study.

Conclusions

Greening is essential to any city especially to those dense urban areas like Hong Kong. Through the concept of this hypothetical model, adequate and quality multi-levels greening open spaces can be introduced to gain environmental and economic merits. Different land uses and greening initiatives can be redistributed and regenerated as to match with the public aspiration and social needs. Various forms of greening initiatives can be incorporated, which will not only mitigate the urban environmental problems, but also give a good visual relief in the dense urban areas. Natural air-ventilation can be promoted through a careful creating a stepped-profile buildings and sky gardens (HKPSG). Communal sky gardens at different intermediate levels enable social gathering which helps to foster community interaction. For a more macroscopic land use planning, the possible redistribution of land use through this amalgamation of lands can attain a substantial benefit on multi-level greening initiatives. It gives opportunity for urban regeneration, especially for a mid- to long-term development in dense urban districts.

In this study, a hypothetical model for multi-level greening provision is established with reference to the Hong Kong context and her current development controls. The benefits earned by amalgamation of land lots as proposed in the model are two-fold. The development can enjoy a greater flexibility in design while the development potential and greening initiatives can still be balanced. On the other hand, the greening coverage is inevitably increased when compare with the land solely developed individual owner under the practice.

With more greening and quality open spaces, the UHI effect, other environmental can be relieved. Social interactions and network can be established not just limited in ground level. The resultant development also will be more human and sustainable which contributes to a more livable and vibrant environment. The model could be used as a reference in assisting and motivating various project parties to realize various greening opportunities in the new development which thus eventually to improve the dense urban environment. It helps to convey a positive change in the cultural practices of such provision. Though there are limitations in the actual situation during the application of the model, it thus lays a basis footprint for the further development of a more sophisticated model.

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DEVELOPMENT OF URBAN ENVIRONMENTAL MONITORING SYSTEM

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Abstract

In the Tokyo metropolitan area, the heat island phenomenon has become increasingly serious from year to year. The national government of Japan and the Tokyo metropolitan government have proposed many kinds of countermeasures to prevent the heat island phenomenon. Under this situation, countermeasures, such as rooftop gardening, water-retentive pavement, have been employed in the central Tokyo by the initiative of the local government. Many test cases have been implemented in many places, but performance assessment and evaluation of potential side-effects have not been done enough. Also, public interest and understanding are not so high.

In 2006, the local government of Shinagawa Ward located in central Tokyo has developed the microclimate measurement network called *Shinamoni* as a new tool for Eco-Conscious Urban planning. This system is designed to verify countermeasures of the heat island phenomenon, and to raise awareness of urban environment by providing real-time data on the website. The data is also used for prevention of heat attack and environmental education at elementary schools. This paper highlights the operational situation and utilization of this system.

Keywords: Heat Island Phenomenon, Environmental Monitoring System, Environmental Education

1. Introduction

In major Japanese cities, including the Tokyo metropolitan area, the effect of the urban heat island (UHI) is increasing every year. In order to counteract the UHI effect, it is essential to examine the thermal environment of a target area and to introduce appropriate mitigation measures and assess their effectiveness. Both the Japanese national government and Japanese municipal governments have been taking various actions to respond to the UHI effect. In Tokyo, especially in the 23 central wards, the local municipalities have been introducing rooftop gardening and water retentive pavement as UHI countermeasures, for example. However, most municipalities have not been able to adequately assess the actual cooling effects of these practices and any environmental impacts that the mitigation might have. The municipalities also feel the need to raise local residents' awareness of the heat island phenomenon and promote understanding of municipal countermeasures.

Because of this situation, it is important to establish an environmental monitoring system in Shinagawa Ward, one of the 23 central wards in Tokyo (population about 340,000; 22.72km^2). This monitoring system is named *Shinamoni* (short for Shinagawa monitoring). In establishing Shinamoni, a system and equipment of *Banpaku* AMEDAS (*Banpaku* is the Japanese name for the World Expo; AMEDAS stands for Automated Meteorological Data Acquisition System), previously developed for the 2005 World Expo in Aichi Prefecture was used

A website was set up that enables people to browse real-time data obtained by Shinamoni. This website is used for raising public awareness on the UHI effect and its countermeasures, for issuing heat stroke warnings, and providing environmental education materials for local elementary schools.

In this paper, an overview of the monitoring system and its use, are presented together with reports on its performance during the first year of operation.

2. Shift from Banpaku AMEDAS to the Shinamoni Monitoring System

As described above, Banpaku AMEDAS was the predecessor of the Shinamoni monitoring system and was developed for monitoring the site of the World Expo that took place in Aichi Prefecture in 2005. The central theme of this Expo was “Nature’s Wisdom”, and extensive environmental considerations were made from the construction phase onward. Banpaku AMEDAS was developed and operated as part of these environmental efforts, and provided real-time meteorological data and different types of surface temperature measurements via a multihop wireless network. We also started the Banpaku Eco Club on the Internet, and posted data obtained by the Banpaku AMEDAS and environmental efforts made at the Aichi Expo in order to raise visitors’ environmental awareness. Having operated the Banpaku AMEDAS during the Aichi Expo, we were able to confirm the reliability of the monitoring system, test the effectiveness of various countermeasures, and use the meteorological data as an indicator to issue a warning against heat stroke.

While Banpaku AMEDAS was operated within the context of the Aichi Expo, Shinamoni is operating in a real urban environment where people actually go about their daily lives. Shinamoni reutilizes some of the equipment, however, that we used for Banpaku AMEDAS. Shinamoni is operated as a part of the Shinagawa Ward government’s environmental program, and is intended to function as a tool for counteracting the UHI effect in Shinagawa and its surroundings by providing metrological data, testing mitigation measures, and raising local residents’ awareness.

3. Current Situation of Mitigation for the UHI Effect and Environmental Monitoring

3.1 Mitigation Measures by Municipalities

A variety of countermeasures have been taken in those areas that the Tokyo metropolitan government has designated as areas where UHI effects are especially prominent and in need of mitigation measures. Even some non-designated areas have also implemented mitigation methods such as rooftop gardening and “lawn” schoolyards (growing a lawn on school yards) at elementary and junior high schools, along with water-retentive and/or heat-shielding pavement.

In order to gain more information about the implementation of UHI mitigation techniques in other municipalities, a questionnaire survey was carried out. The questionnaire was sent to 43 municipalities selected throughout Japan, including the 23 central wards in Tokyo, and 34 municipalities responded. According to this survey, many of the municipalities responded that they are neither conducting any public outreach activity nor measuring and verifying the effect of mitigation measures (Fig. 1 and 2). Some municipalities said that they would like to study the effect of mitigation measures, but they do not have the equipment or expertise necessary for doing so.

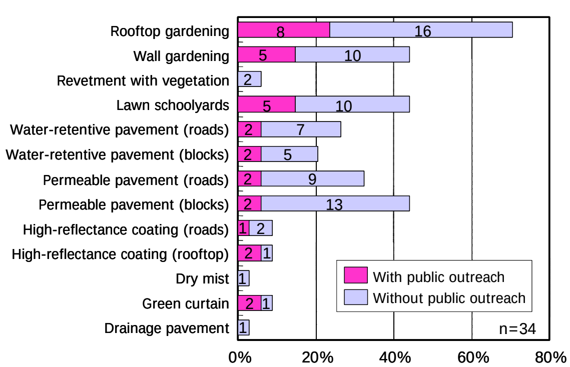

Fig.1 UHI mitigation and public outreach

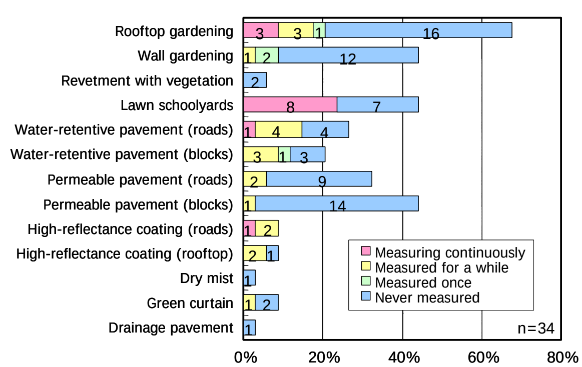

Fig.2 Measuring UHI mitigation

3.2 Current Situation of Meteorological Observation in Tokyo

For the purpose of assessing the reality of the UHI effect, meteorological observation in Tokyo has been scrutinized in more detailed. The most notable example of this is the METROS (Metropolitan Environmental Temperature and Rainfall Observation System) setup by the Tokyo metropolitan government. This system has 20 observation points on building roofs in central Tokyo, and 100 observation points at public elementary schools throughout Tokyo. Continuous observation from these 120 observation points provides a detailed picture of Tokyo's thermal environment. Also, as a part of the comprehensive development project by the Ministry of Land, Infrastructure and Transport, a group of researchers make an extensive meteorological observation for two weeks in summertime. However, there is little observation that offers useful information for the general public.

3.3 Significance of Urban Environmental Monitoring System

It is important to obtain characteristics of a local thermal environment to counteract the UHI effect, form a mitigation plan at the local government level, and verify its effectiveness. Moreover, it is desirable to view mitigation efforts as part of a local development project that involves residents and to set up a tool that provides residents with location-specific meteorological information. In summary, the significance of the Sinamoni project includes:

(i) studying the effects that different environmental parameters have on environmental amenity
(ii) collecting quantitative data to verify the effectiveness of mitigation measures
(iii) offering real-time meteorological data to the public so that people can use this information in their daily lives (e.g., heat stroke prevention)
(iv) applying the meteorological data to environmental education at local schools

4. Description of the Shinagawa Monitoring System

4.1 Observation Points

The study selected 18 observation points in Shinagawa Ward for Shinamoni (Fig. 3 and Table 1) and one more observation point in Recycle center was added. There are 19 observation points in total as of July, 2007. Observation points include places that are designated as mitigation targets and places we chose for the purpose of comparison. Other places included are asphalt pavement, parks, and the riverside wind corridors, in order to monitor a variety of environmental conditions. In order to draw a more comprehensive picture of the thermal environment, Shinamoni's data also includes temperature and humidity measured in Stevenson screens installed at public elementary schools in Shinagawa Ward. Many public elementary and junior high schools in Shinagawa Ward had already implemented mitigation measures such as rooftop gardening, so those schools were included to encourage them to use the data for environmental education. When the Shinamoni project was launched, two nursery schools and a park introduced water-retentive paving and heat-shielding coating on their grounds as mitigation techniques, so these places were also included for monitoring. These places were selected for special treatment because they are places where people can go and experience the effect of these techniques directly; our hope was to increase the visibility of the project and promote understanding as the data become public.

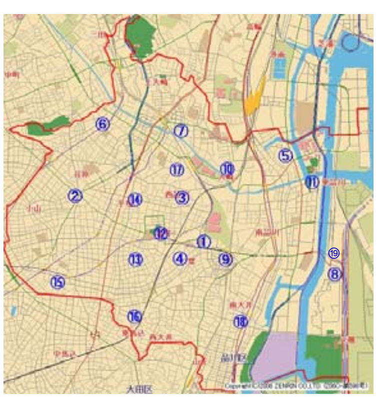

Fig.3 Shinamoni observation points

Table 1. Shinamoni observation points

No.	Location	Measured object
1	Shinagawa Ward office	Rooftop gardening
2	Hiratsuka Park	Water-retentive pavement, Heat-shielding coating
3	Nishi-Shinagawa Nursery School	High-reflectance coating
4	Futaba Nursery School	Water-retentive pavement
5	Daiba Elementary School	Rooftop gardening
6	The 4th Hino Elementary School	Rooftop gardening, High-reflectance coating
7	Hinogakuen School	Rooftop gardening
8	Yashiokita Elementary School	Lawn schoolyard
9	Oimachi Station	Asphalt pavement
10	Megro Revetment	Riverside environment
11	Higashi Shinagawa Marine Park	Branching bay environment
12	Togoshi Park	Park environment
13	Yutaka Shopping Street	Water-retentive pavement
14	Togoshi Ginza Shopping Street	Dry mist
15	Hatanodai Elementary School	Air temperature distribution
16	Ito Elementary School	Air temperature distribution
17	Hosui Elementary School	Air temperature distribution
18	Hamakawa Elementary School	Air temperature distribution
19	Recycle Center	Heat-shielding sheet on rooftop

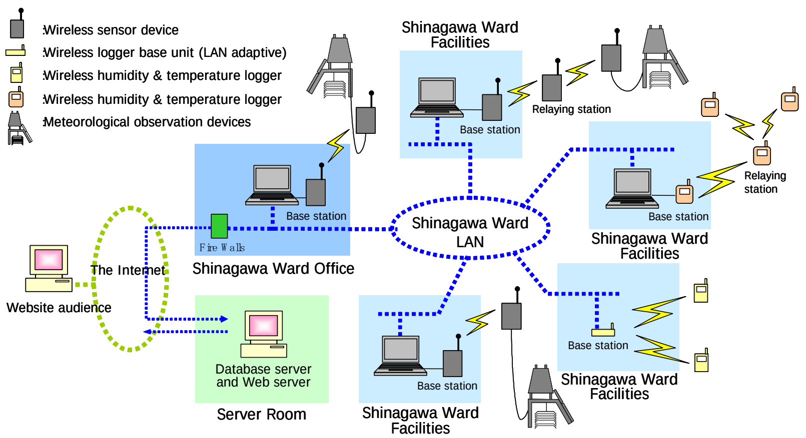

Fig.4 Shinamoni system overview

Fig.5 Shinamoni measurement equipment (Meteorological observation devices /Base station PC)

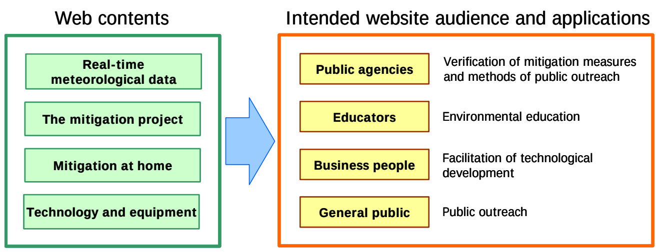

Fig.6 Web contents and possible applications

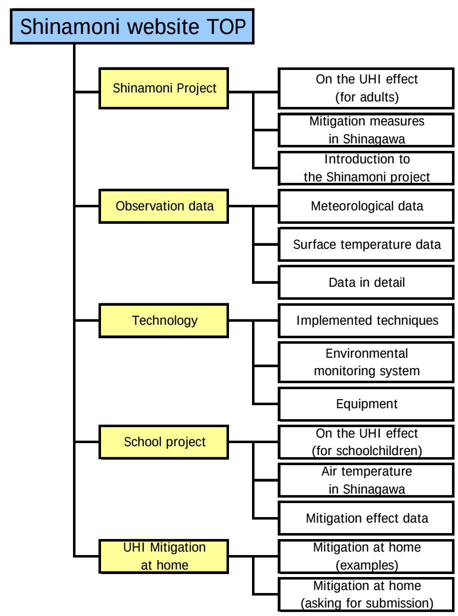

Fig.7 Shinamoni website sitemap

http://www.shinamoni.jp/

Fig.8 Front page of Shinamoni website (Left: for PC; Right: for Mobile)

4.2 The Mechanics of the Monitoring System

Fig. 4 gives an overview of the monitoring system and Fig. 5 shows the measurement equipment for data collection and dissemination. Basic observation items are outside air temperature and humidity, surface temperature, wind direction and velocity, amount of solar radiation, and precipitation. The system makes a meteorological observation at 10 minute intervals, and, from each observation spot, observed data are sent to a base station by wireless devices, and stored on the data server. Even though Shinagawa Ward is larger than the Aichi Expo site, the LAN that connects almost all Ward facilities makes it possible to make real-time meteorological data available on the Internet.

4.3 The Website

4.3.1 Policy. A website was built which allows people to browse the meteorological data obtained through the monitoring. Fig. 6 presents the information offered on the website and its potential use. Since the observation points include places where various people go, from a ward office to schools and parks, it is envisioned that four different categories of website audience will be involved: public agencies, educators, business people, and the general public. The website tries to address the needs of each group.

Fig.9 Maps on website showing real-time data (air temperature / Wind direction & velocity / Heat index)

4.3.2 Web Contents. The sitemap and the front page of the website are shown in Fig. 7 and Fig. 8 respectively.

The front page has the entrance to the following contents: about the project, meteorological data, introduction to technology, educational materials, and mitigation at home. A cellphone website was set up so that people can browse the data even when they do not have an access to a computer (Fig. 8), enabling people to easily access local weather information and use it for heat stroke prevention and other troubles caused by the heat. The website shows the real-time data only and is updated every 10 minutes. The possible uses of the website include:

(1) Raising awareness of mitigation efforts

The website can be used for raising awareness of mitigation methods and their effectiveness by providing information on mitigation sites in Shinagawa Ward and showing real-time data in a line plot.

(2) Increasing alertness to meteorological situation and preventing heat strokes

On the website, people can view the air temperature, wind direction and velocity, and heat index (summer only) of the observation points laid out on the map of Shinagawa (Fig. 9). Air temperature and heat index are shown in colors, and wind direction is indicated by arrows, and velocity by the length of arrows, so that the level of heat danger is visually perceptible. We think that this map can contribute to increasing people's awareness of local meteorological conditions and the danger of heat stroke.

(3) Offering materials for environmental education

In the hope of raising the environmental awareness of schoolchildren, several research projects were prepared for elementary and junior high school students that incorporate the meteorological data; for example, "A Study on Rooftop Gardening" and "A Comparison of Air Temperature in Different Locations".

(4) Familiarizing people with immediate countermeasures

On the website, illustrative examples of immediate countermeasures were provided such as water sprinkling and water-retentive paving, and encourage residents to employ these techniques.

5. Data Analysis

Data concerning air and surface temperatures are analyzed below, as they are within the realm of understanding for general website audience.

5.1 Air Temperature Distribution in Shinagawa Ward

Fig. 10 shows the air temperature distribution of a representative summer day in Shinagawa Ward based on the data observed at 6 A.M. and 1 P.M. on August 5, 2006. As shown in Fig. 10, air temperatures are lower in all the parks than the other places. Also, they tend to be low at the riverside and seaside, while they tend to be high in shopping areas. In other words, they illustrate salient characteristics of the air temperature differences caused by environmental conditions on a typical summer day.

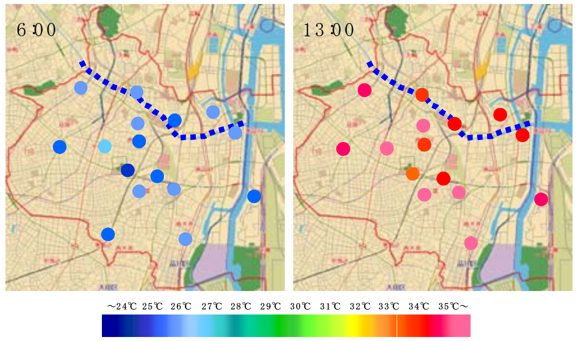

Fig.10 Air temperature distribution (August 5, 2006)

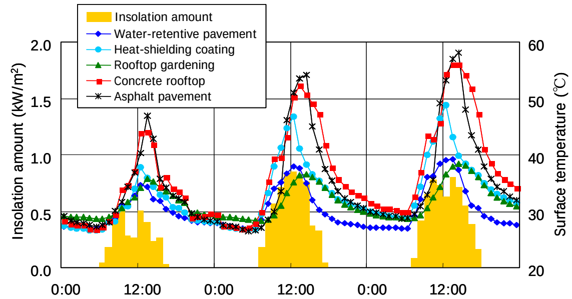

Fig.11 Changes in surface temperature after rainfall

5.2 Analysis of Surface Temperature Mitigation Techniques

Fig. 11 shows changes in surface temperatures at a representative observation point after a rainfall. On a sunny day after a rainfall, the surface temperature went up nearly 60 degrees C on the asphalt pavement and the concrete rooftop, while it stayed more than 15 degrees less than this on the water-retentive pavement and the rooftop gardens. In addition, the surface temperature of areas with heat-shielding coating was kept 5 to 10 degrees lower than those without. On the website, visitors can view these effects easily.

6. Performance of the Website

Fig. 12 shows a graph that shows the trend in website traffic over seven months (from July 24, 2006 to January 31, 2007). Fig. 13 shows the cumulative number of hits on each page of the website since the website was set up. Right after the start, from July to August, there were many visitors to the website, but the number of visitors decreases in September, and it seems to have reached a plateau for the time being. Overall, the web traffic was relatively high, even though it was the first year of the operation and without major publicity campaign.

In terms of individual pages, pages that show environmental measurements (meteorological data and surface temperature) ranked the highest. The second highest was pages that describe the project or mitigation techniques. It seems that the visitors were initially interested in browsing the real-time data and some were led further to browse the pages on mitigation measures. In other words, the website seems to have contributed to raising awareness of the UHI effect and to improving the visibility of the mitigation project and techniques.

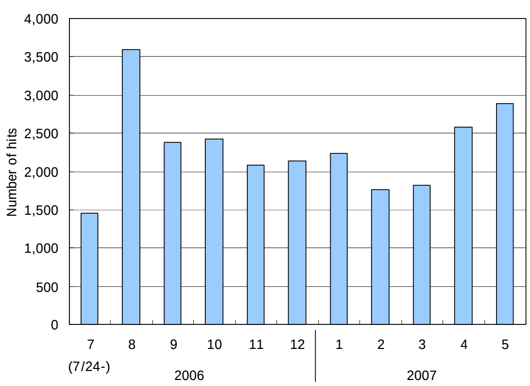

Fig.12 Shinamoni website traffic

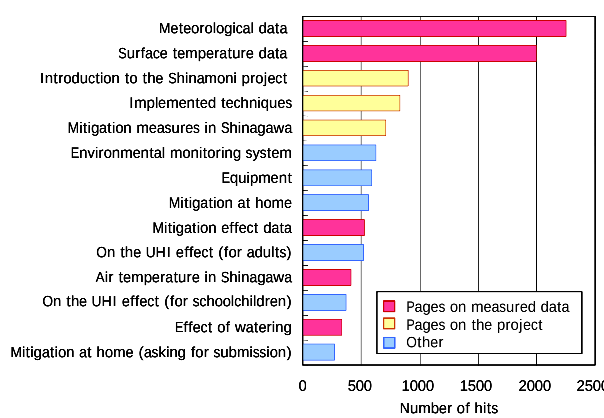

Fig.13 Cumulative number of hits per page

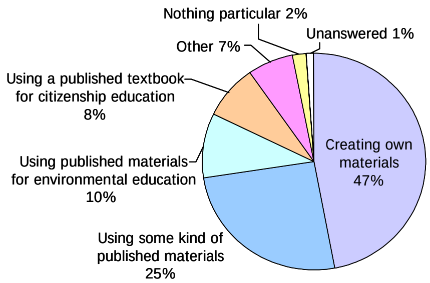

Fig.14 Teacher survey: Class materials for environmental education

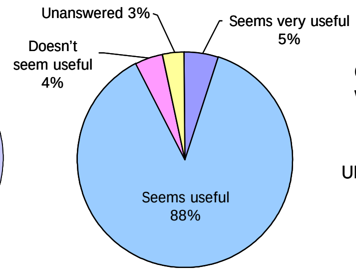

Fig.15 Teacher survey: Shinamoni's usefulness for environmental education

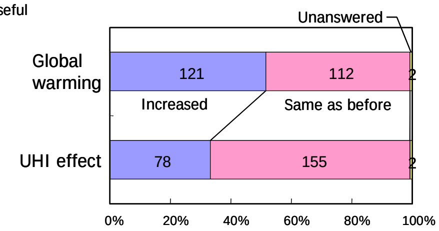

Fig.16 Student survey: Change in students' interest level (before and after summer vacation)

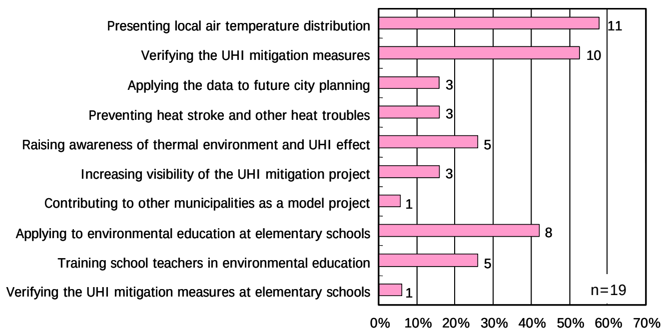

Fig.17 Municipality survey: Useful aspects of Shinamoni system

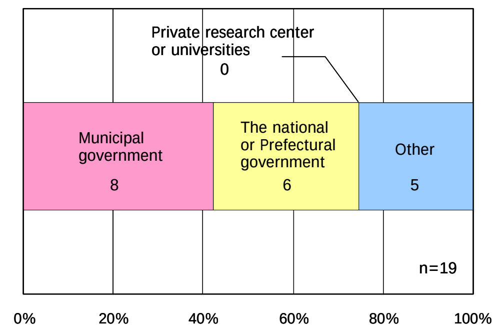

Fig.18 Desirable agency to administer environmental monitoring system

7. Application to Environmental Education

7.1 Teacher Questionnaire

As described above, one of the aims of this project is to utilize the data in environmental education, and some contents on the website are designed for elementary school students. In order to survey the current situation in environmental education and educators' interest in this project, a questionnaire was sent to teachers at elementary schools in Shinagawa, and 97 teachers at 20 schools responded. As a result of the questionnaire (Fig. 14), it was found that, since there are no designated materials for environmental education at elementary schools, many teachers are creating class materials and figuring out how to teach this subject along the way. In terms of applying Shinamoni to environmental education, nearly 90% of the teachers responded that it has potential applications for environmental education (Fig. 15). These results confirm the usefulness of Shinamoni in offering materials for environmental education.

7. 2 Student Questionnaire

Meanwhile, handouts were distributed to introduce Shinamoni and a session was held on research projects that utilized the observation data for elementary school students before summer vacation. After summer vacation, a questionnaire survey was conducted that involved 235 fifth graders from six schools to see if there was any change in students' interest level before and after the vacation. It was found that students' interest level in both global warming and the UHI effect had increased (Fig. 16), thus showing positive results in environmental education.

8. Municipalities' Views on the Environmental Monitoring System

In order to survey municipal governments' views of Shinamoni, hearings were conducted at the Shinagawa Ward government, the project implementing body. A questionnaire survey was carried out with 34 municipalities that are implementing some form of mitigation measures against the UHI effect. Many of these municipalities are among the 23 central wards in Tokyo.

8.1 Evaluation by Shinagawa Ward

Two main positive assessments came from Shinagawa Ward. As noted, the Shinamoni website offers detailed meteorological data to the public with 18 observation spots throughout Shinagawa Ward. With regard to this feature, they reported that it is useful because "Shinagawa residents have an easy access to information that allows them to grasp the local weather situation". They reported that the mitigation techniques and data showing their effectiveness that are provided on the website are beneficial because it introduces mitigation techniques and its effectiveness to the public. On the other hand, they think that "managing the system and the data can be a burden" on them. What they see as their future task is "to find a way to operate Shinamoni throughout the year". Finally, they also said that they wish to incorporate this project into other environmental programs in the future.

8.2 Municipality Survey

The surveyed municipalities responded that Shinamoni seems especially useful in "verifying the UHI mitigation measures", "presenting local air temperature distribution", and "applying to environmental education at elementary schools" (Fig. 17). Meanwhile, they said that "establishing the system and proving its effect" would be potential obstacles if they were to implement a similar monitoring system at their municipalities. However, when asked who should be the main body to administer such a system, they answered that it should be a public agency such as a local or prefectural government, or the central government (Fig. 18). In other words, they acknowledged that, despite of the obstacles, they feel that they should undertake such a project.

20% of the respondents are already seriously considering implementing some form of environmental monitoring, and 40% said they are open to the idea. One of the main reasons for doing a similar project is "because it seems useful for data collection and information dissemination", and for not doing it is "because it is difficult to establish such a system in terms of finance and human resource". In an open-ended question for those who answered that they think it is necessary to provide the public with observed data if they were to have an environmental monitoring system, some wrote that they should inform the public about energy use in public offices, or make indoor environmental observation as well. When asked about the website, some suggested that it can post other kinds of environment-related information, such as measurement of air and water quality".

9. Summary

This paper provides a detailed description on the development of the urban environmental monitoring system, Shinamoni, as part of Shinagawa Ward's UHI mitigation project, through he application of the environmental monitoring system developed previously for the 2005 Aichi Expo. After describing the current situation of the UHI effect in Tokyo, the significance of the Shinamoni urban environmental monitoring system and its applications were examined. After dealing with the system's development and operation, the performance during the first year was assessed. It is believed that this monitoring system accomplished certain useful results for Shinagawa Ward's environmental program and environmental education. Proposed future works include finding solutions to the issues that became apparent during the first-year operation and from the surveys, and on making appropriate improvements to the system. The possibility of applying the similar systems in other contexts will also be explored.

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SURVIVING 21ST CENTURY: THE ROLE OF CULTURAL HERITAGE IN URBAN PLANNING OF KUALA LUMPUR

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Abstract

Present urban development model anchors more on functional investment logic, replacing old building stocks, its original inhabitants and traditional economic activities, destroying old neighbourhoods that have often offer familiarity, connectedness and a sense of belonging to the otherwise sense of detachment and displacement in urban living. They exercise kinship and common values through tangible practices of mutual help and sociability, in religious and communal traditions via organization of the mosques, temples and community halls. Visibly disappearing through economic demands, yet lessons could still be learned from their strong sense of identity, if only perhaps to self-reflect upon the cultural stewardship of towns and cities.

It is inherently necessary for a city to respond to the challenges of globalization of the economy to remain competitive. However, it is also important to have a sense of identity, and attributes that adds to its differentiation from anywhere else. By conserving the cultural landscape through the built environment that expresses cultural diversity, will add dynamism, delightfulness and distinctiveness to any city. Cultural assets that are tangible in the theatre, arts, crafts, and others should be fostered within neighbourhood they have evolved.

The aim of this paper is to explore the notion of cultural heritage as urban economic development strategy for the city of Kuala Lumpur in the search for sustainable urban planning.

Key words: Ethnic, Community, Cultural assets, Globalization, Competitive, Identity, Shared values, Cultural stewardship, Kinship, Conservation

1.0 Introduction

Heritage includes history that is associated with the memories of the past. Cultural heritage is usually considered in two basic dimensions: one part being cultural landscapes, the other one being heritage cities, cultural sites and monuments. The latter is more easily identified with and relate to by most; they are those with deepest attachment and sentiment regarding roots and most often they are usually treated as precious resources for the society and the community, rather than constraint to social and economic development. Heritage cities arguably require special attention because they are in fact concentrations of material and immaterial cultural heritage. When poorly managed they may have negative impacts on the city as some of the cultural assets are sensitive and fragile.

Cultural landscape is generally identified as consisting of different layers, one being natural and the other one cultural. The natural landscape is the original landscape untouched by man, while the cultural landscape can be seen as a derivative natural landscape whose balance, structure and view is more or less influenced by human use (Anzuini and Strubelt. 2000). They in this context can be construed to be the physical environment that has evolved around the community's living and socialization process. They embody the community's identity, shared value and cultural evolution.

Culture not only involve the fine arts, music and local cultural shows but also the way of life, either in the professional or leisure capacity, and the existence of an identity associated with a community practicing a visible common values and norms. It provides a familiar and a strong sense of belonging and attachment with its environment physical or otherwise. One of culture's key strengths is the way it can add value to areas such as physical development, community cohesion, education, physical and mental health and well-being, as well as economic development. A vibrant local culture attracts investors and a skilled workforce. Cultural assets as the physical aspects of culture are seen as an important element to competitiveness of the region and to the quality of life for the people who live there. These assets range from people themselves, creativity, heritage, and natural resources. Collectively these all provided us with a sense of place, which attracts creative people and innovative employers. Taken as whole, culture can ensure successful communities and contribute to the regeneration process.

The following sections serve to lay a sound basis for preservation of cultural heritage as a strategy for heritage conservation, that in so doing it not only provide for peace and stability, cultural identity, knowledge and education but also reflects the social and economic opportunities it offers, for the City of Kuala Lumpur urban planning to draw upon.

2.0 Globalization of cities

The process of globalization results in global flow of money, capital, technology and information have become condensed in urban areas. Creating financial enclaves, and their associated service districts, the smart buildings and office towers, adorned in mainstream style external enclosures. Unwittingly they have displaced traditional urban economics activities and most likelihood of its original inhabitants too, leaving the cities without continuity of its past and identity. Inherently, global cities today have become central nervous system of the flows of capital, money, information and technology and catering for these services have become the backbone of the urban development model.

Increasingly, cities are witnessing the cultural domination of the populist culture when sections of urban areas are simply beginning to be invaded by the universal brands and retails catering for financial and other needs of the new urban gentry, pushing if not virtual eliminating the more traditional economic activities and cultural community lifestyle. Much of the task of city planning has now been given to city builders and real-estate developers whose interests are inextricably linked to banking interest and financial investment.

For obvious reasons, cities' importance for generating national economies cannot be argued; that much of the economic activities will be played out in cities and urban regions. However to succeed in the challenges of economic globalization cities will have to be competitive not only with other cities in their region, but worldwide.

3.0 Culture And Place As Wealth Creation

It is evident from examples that authentic urban environments bubbling with lively cultural and entertainment options are magnets that attract and retain creative people. This creative workforce in turn generates wealth in an expanding knowledge economy. Economists agreed that the second phase of economic revolution now underway is the emergence of creative economies rooted in culture and design; wealth creation is now driven less by the exploitation of resources of the land or the efficiency of manufacturing processes, and more by the exploitation of our imagination and intellect (Murray and Baeker , 2006).

Culture must be made part of a larger goal of urban planning if cities are to increase their capacity for wealth generation and creating rich vibrant urban environment, by integrating three kinds of urban planning: land use, economic and cultural planning. But time and again cultural assets fall victim to urban development programmes usually to change of landuse and construction of modern amenities, which often results in demolition not only of individual structures but sometime an entire district.

4.0 Culture As An Economic Enrichment

Preservation and conservation of cultural heritage can create job opportunities in traditional craftsmanship to maintain and restore the physical structures. It may also will invariably maintain its original activities and inhabitants, thus achieving continuity in the community and hence improve the living conditions. Cultural development has a positive effect on matters as the image, the quality of the living environment and the business climate. Increasingly around the world, heritage preservation is becoming an effective vehicle for economic growth.

For communities that have cultural assets and crafts products that represent economic opportunity, historic buildings often constitute the most appropriate physical locations for the manufacture, sale, and display of goods and the presentation of products. The physical context of the historic building adds to the sense of authenticity, originality, and indigenous ness of the art.

From a social dimension cultural heritage is about society's capacity for self-reflection. From economic perspective, heritage conservation offers opportunities for cultural tourism. Cultural tourism is now the fastest expanding segments of the tourism market and brings very relevant social and economic opportunities (Casalade. 2004)

5.0 Cultural heritage for sustainable development

The appropriate and wise use of heritage and cultural assets; that is the use of many opportunities cultural heritage offers without compromising their ethical aspects should constitute sustainable development. In general, society already values history and regional differences: those differences are the basis for tourist flows and for large number of social urban movements. From environmental perspective it is a culturally sustainable development (Anzuini and Strubelt. 2000).

Preservation of building or cultural assets on one hand means saving of energy and building materials, and another hand can be further expanded to mean building a sustainable local economy – creating locally what otherwise would have to be purchased elsewhere. Renovation of buildings generally means that there is a greater local economic impact in jobs and income than with the same amount spent on new construction. It also optimizes the existing infrastructure and reduces production costs because it reutilization of materials.

In some cities heritage conservation has been successfully integrated into the larger goal of local sustainability. Tourism plans and projects are incorporated in the cities' development programmes, enhancing heritage intrinsic value to the local economy. To some writers valuing buildings and cultural assets create a kind "royalty" linked to the fruition of its symbolic value and drives the insurance market, tourism and civic building, as noted before. In an extremely mobile and virtual economy it creates material property for the enterprises (Hari Srinivas, 1990).

6.0 Culture as generator of action and planning tool

If culture is an important factor for the construction of collective identity, cities on the other hand were understood as cultural entities, places that were shaped by their natural and human heritage, and a product of values and beliefs of their citizens. As previously discussed authentic urban environments bubbling with lively cultural and entertainment options are magnets that attract and retain creative people. So, culture appears as a key in understanding local societies. It forges our thoughts, our imagination and our behaviour. Renewing the functions of historic districts is an important factor in giving values to cities and correcting urban problems. Culture assists in identifying stable patterns in an ever-changing reality and the understanding of the city as a cultural artifacts helps in seeing more clearly its tendencies and patterns (Anzuini and Strubelt,2000). As globalization increases, local values also increases; it reinforces local identities as strategy for survival and valuing the individual. Today many people are more conscious and better able to identify with their cultural environment and collectively initiate preservation of their cultural assets; in general society shows more respect for them.

Products of culture are now an important economic factor. Cultural assets and unique places begin to develop market values and they are increasingly seen as guiding the social process. It has become successful as a vehicle for development in revitalization of historic districts in various parts of the world as Singapore, Bilbao, Spain and in many parts of Europe.

Planning for urban heritage and cultural tourism cannot be seen in isolation from professional tasks such as urban planning and urban design. Urban history and urban culture should equally form the basis for urban planning and urban design exercises.

Cultural mapping will help to understand in depth the local cultural systems and engaging communities before cultural planning could be formulated. It will help to define features of cultural resources in cities that the mapping will have to focus on.

7.0 Sustainable urban planning through heritage and cultural tourism

The importance of cultural heritage for cities can be viewed from three sets of factors: Social factors include enhancement of a city's image and identity (and hence leading to its residents' pride in the city), integration into day-to-day living and development of value systems for the community. Politico-economic factors are more easily understood, and involve the role of heritage in tourism (and hence the local economy), and its archeological and historical importance. Finally, planning factors – particularly applicable to architectural heritage – involves the reuse, redevelopment and regeneration of heritage objects to preserve and integrate them into larger development process of the city as a whole (Hari Srinivas, 1990).

It is important, therefore, to place the issues of heritage conservation within overall process of urban development, as well as interlink it with other issues such as tourism development, revitalization of the local economy and local governance. In responding to pressures of the future, inherent in its development pressures, economic conditions, and drive for modernization, it is vital not only to protect tourism resources, but also to promote community development that focuses on cultural landscapes.

8.0 Urban Development of Kuala Lumpur

Kuala Lumpur was selected as capital for then the newly-formed Federated Malay States in 1896. Over a generation city it grew from a small mining town to an administrative centre and focus of commerce and trade. The Chinese nucleus made up of the small two-storey shophouses with various elegant neo-classical or neo-baroque facades; some have remained the same as they were to this day. The government buildings were built in distinctively Moorish style and so were the banks, large commercial houses, schools, department stores, hotel and famous railway station of Kuala Lumpur. Also, a new Malay settlement named Kampung Bahru was then designated by the British across the river from Jalan Ampang, which to this day, it has curiously remained almost intact and has seen little commercial development. The city's colourful past can be still be seen and traced from the remnants of distinct ethnic neighbourhoods designated by the colonial masters during the formation of the city. These subsequent phases in the urban transformation and the network of settlements from which it sprang up represent a reference for the city's existence and cultural identity.

Today, Kuala Lumpur's modern landmarks reflect the changing values of urban living. Corporate offices and retail units are beginning to replace civic buildings in and around the city. Branding and imaging the city comes in more in the image of universal office towers, mega shopping malls, and up-market condominiums and service apartments that mainly catering on the new breed of city dwellers with their new modern lifestyles. Urban scale and appearance are now very much dictated by property developers who are more interested in marketing and gentrification of the city, leaving some parts of the city permanently scarred with incompatible development to the existing cultural heritage; eroding the importance and the intrinsic heritage values of buildings and environment with colourful past.

As has been argued earlier, cities need to be different and unique in order to be competitive. The city of Kuala Lumpur can thrive on its multi-racial, multi-religious, multi-cultural, and multi-lingual community urban cultural landscape; rich, diverse, and unique, to give it the product differentiation it rightly needed to survive the onslaught of economic globalization. Besides that, cultural heritage preservation can function as a means of stimulating mutual understanding among different races, cultures that are so diverse in Malaysia and also by other countries. Taken in a bigger context one that is more crucial, cultural heritage can foster peace and stability.

The city could well take the cues from the argument for preservation of cultural heritage previously discussed cities that have successfully integrate cultural heritage into the larger goal of local sustainability; creating vibrant, living cities with unique urban identity while ensuring marketability of the cultural assets as tourism products.

There are definitely measurable and non-measurable benefits of preservation of the existing tangible neighborhood activities of some of these sections of a city. Diversity in its inhabitants and economic activities will meet diverse economic demands and reduce reliance on a narrow source of global market demand.

Conclusion

It is clear from the discussion that integrating and identifying role of cultural heritage alone fully justifies the efforts that are made to preserve and conserve it, to ensure that future generations may benefit from the stabilizing effect four heritage. And while it is true that cultural heritage is under constant threat of economic globalization, awareness of the values of cultural heritage is increasing that it becoming an important means of resistance to globalization. Recognition of its various roles in cultural identity, generator of creative industries, as elements of tolerance and understanding amongst diverse group of people to name a few, put a strong argument for preservation of cultural heritage and its assets as an important strategy in urban development. However, central to this is that cultural heritage preservation is sustainable development.

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Refrigerant Selection for Sustainability

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Abstract

Since the Montreal Protocol has been enforced to phase out all ozone depleting refrigerants that have been commonly used in air-conditioning, many people perceive that pursuing alternative with zero ozone depleting potential (ODP) will be a long-term solution or is the best way to protect the environment. While the consequence of Climate Change issue is better known today, this argument will be challenged because of sustainability concerns. With reference to the recent scientific findings, it is further discussed in this paper through integrated environmental approach.

In particular, various methodologies in selection refrigerant for air-conditioning use in the building industry are reviewed. Impact of the zero-ODP approach on global warming and energy efficiency will then be fairly discussed with reference to competent research or scientific evidence existed in literature. Updated research results and scientific evidence reported in the literature will be referred to. Other possible non-zero ODP options are also evaluated and compared.

Green building, whole building or sustainable building has received more attention nowadays and a lot of building owners are willing to obtain proper certification as a branding effect. Different green building rating systems are investigated, especially regarding the environmental assessment to refrigerant selection. The paper is concluded with an environmentally balanced recommendation.

Keywords: Sustainability, Refrigerant, Environmental policies, Air-conditioning, Energy Efficiency.

1. Introduction

Refrigerant development has a long history. The first generation of refrigerants was introduced in the 1830s, with invention of the vapor-compression machine by Perkins.[1] Most of them are toxic, flammable, or both. Some refrigerants, such as sulfuric (ethyl) ether, ammonia and hydrocarbons were highly reactive. Many accidents occurred as the primary goal was only to provide refrigeration at that time. Later, another goal on durability was added. Propane was marketed as the odorless safety refrigerant.[2] As production increased following World War I, more attention was paid to safety and performance. Fluorinated refrigerants like chlorofluorocarbons (CFCs) came into place following the invention of positive displacement centrifugal compression machines in early 1930s. “Freon” is probably the most well-known refrigerants in the refrigeration and air-conditioning industry. These refrigerants are stable with low toxicity and flammability.

For almost half a century, fluorocarbons have been the dominant refrigerants until they were associated with the “ozone hole” story – the first global environmental problem identified by Molina and Rowland.[3] Since then, a landmark international treaty, i.e. the Montreal Protocol,[4] was set up to protect the ozone layer. Chlorinated and brominated refrigerants, along with similar solvents, foam blowing agents, aerosol propellants, fire suppressants, and other chemicals are scheduled to be phased out. Ozone depletion was the only environmental concern at that time.

2. Ozone Depleting Potential

Ozone layer protection is the only focused area in late 1980s in many countries due to politics. European countries moved quickly to phase out all substances that carry any ozone depletion potential (ODP). This has been adopted by many European firms as their company policy to demonstrate their green image or environmental responsibility.

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As a result, the market moved very quickly from CFCs to hydrochlorofluorocarbons (HCFCs) and then hydrofluorocarbons (HFCs) which have practically zero ODP. Unfortunately, this is an unhealthy move or mainly a commercial response rather than being environmentally responsible. Note that ozone depletion is not the only environmental issue. In fact, zero ODP policy is expensive for energy efficiency and global warming or climate change. For instance, a centrifugal chiller designed for using HCFC-123 as the refrigerant is far more efficient than that designed for HFC-134a. The best to best comparison can be up to 15% difference at the moment. There is potential to increase up to 18% or even higher.[5] This significant difference is not only due to thermodynamic characteristics of the refrigerant itself, which accounts only for 4.5%. Both the outgoing CFC-11 and its replacement HCFC-123 chillers are designed for multistage compression with direct-drive hermetic motor. The multistage-economizer technology would raise the efficiency by 3 to 7%, depending on the number of compression stages and direct-drive, avoiding a 2 to 4% loss in mechanical efficiency inherent to gear-drive compressors. Besides, the actual efficiency in building air-conditioning applications may be combined with reduced energy requirements for associated water circulating pumps as well as optimization with the cooling towers. Best practice examples can be found in China.[6]

Today, global warming is receiving more and more attention. It is believed that global warming has caused climate change. Its impact to the environment is far more significant and complicated than ozone depletion. The impact involves not only the scientific aspect, but also socio-economic and political. The associated international treaty "Kyoto Protocol" was signed ten years after the Montreal Protocol but not fully ratified until 2005. The Intergovernmental Panel for Climate Change (IPCC) formed a Technical Assessment Group, consisting of the top scientists around the world and reporting to the Conference of the Parties of Country Delegates. Studying global warming impact back in 1996, their task was two-fold:

(1) To conduct scientific assessment for investigating whether this effect is real, problems associated with it, and the potential impact;
(2) To conduct technical and economic assessment on possible solutions.

Their science report led to the conclusion that human kind is in fact affecting the climate of the planet. The average temperature is expected to increase by 2°C in the period from 1990 to 2100. The effect of this would be an average sea level rise of 50 cm, not evenly distributed. The message was clear, eliminate growth or build big sea walls. Thus, the objective of the Kyoto Protocol is to reduce greenhouse gas emissions that are affecting the climate. Evidence showed that the solutions are technically available today and are economically viable. For example, buildings built today are 50% more efficient than most existing buildings built in 1980s in China. Chiller efficiency has been improved 35% over the past 30 years. The minimum U.S. standard for residential air conditioners and heat pumps is 12 SEER (seasonal energy efficiency ratio), though 19 SEER systems are available. The United Nations press release for Kyoto Protocol indicated that:

"It (The Protocol) creates new incentives for technological creativity and the adoption of *no-regrets* solutions that make economic and environmental sense irrespective of climate change. Because activities and products with zero or low emissions will gain competitive advantage, the energy, transport, industrial, housing, and agricultural sectors will gradually move toward more climate-friendly technologies and practices."

The definition of "no-regrets" opportunities is to invest in the highest possible energy efficiency that pays back through its useful life – basically shifting to a life cycle costing purchasing approach, and away from a first cost approach. Obviously, not all of us purchase this way today.

3. HFC-134a ban in Europe

In the 1970's and 1980's, selection of good environmental refrigerant was easy. At that time, the only environmental issue of concern was that of ozone depletion. Merely selecting a zero ODP chemical such as R-410A, or R-134a seemed like the natural choice. HFC-134a refrigerant is a good substitute for CFC-12 phased out as per Montreal Protocol; and it will be one of the viable solutions to replace HCFC-22 being phased out R-134a does provide one of the many viable alternatives for the CFC refrigerants in the HVAC industry. However, a recent scientific report[7] of IPCC showed that the atmospheric concentration of HFC-134a has been increasing dramatically in the past decade as shown in Fig. 1. This is due to several factors, including the use of R-134a in highly emissive applications such as metered dose inhalers, fire suppressants and propellant. Additional emissions can be credited to the automotive industry, which has traditionally struggled to restrict refrigerant leakage for this application. Proper measures are required to slow down the growth, both its use and emission control. Such restrictions include automotive applications in the European Union. In the same report, however, the atmospheric concentration of HCFC-123 is practically negligible. Possible reasons are discussed below. The level of CFC-11 can be seen declining due to the Montreal Protocol.

HFC-134a has high global warming potential (GWP), though the ODP is practically zero. Therefore, the European Union (EU) passed a resolution in March 2006 to ban the use of HFC-134a in mobile air-conditioning (MAC) effective from 1 January 2011. To be more accurate, no new vehicles are allowed[8] to use HFCs with GWP greater than 150. A similar proposal to ban all HFCs (as one of the six greenhouse gases being regulated under Kyoto Protocol) in stationary air-conditioners by 2010 was voted down earlier. This proposal might be revisited in 2008, depending on the effort made by the industry in HFC refrigerant containment, recovery, certification and reporting.

4. HCFC-123 exemption from phase-out

As shown in Fig.1, the atmospheric concentration of R-123 is only 0.03 ppt (i.e. 867 times lower than R-134a) because of its extremely short atmospheric life (1.3 years) and super low emission rate (e.g. only 0.5% of charge including refrigerant loss in annual service). This is consistent with the UNEP review of ozone depleting substances (ODSs) published in 2003. It was specifically acknowledged[9] that:

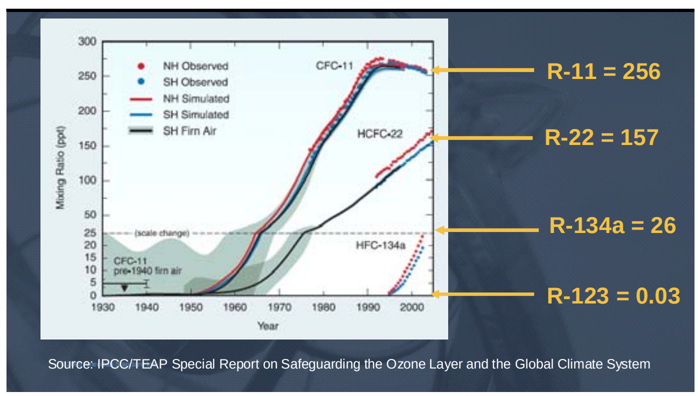

Fig.1 Observed global atmospheric concentration trends (from IPCC 2005)

"Refrigerant HCFC-123 has a favorable overall impact on the environment that is attributable to five factors: low ODP, very low GWP, very short atmospheric lifetime, extremely low emissions of current designs for HCFC-123 chillers, and the highest efficiency of all current options.

Based on integrated assessments, considering the tradeoffs between negligible impacts on stratospheric ozone and important benefits in addressing global warming, these studies recommend consideration of a phase-out exemption for HCFC-123".

5. Balanced environmental judgment

From sustainability point of view, selection simply based on zero-ODP is not an environmentally responsible approach by addressing only ozone depletion issue. Note that global warming and energy efficiency are equally important, if not more serious. Professional engineers or building professionals are challenged by some atmospheric scientists to take a balanced approach or judgment in selection of building materials, equipment and systems.

Recently, a prestigious science symposium of UNEP concluded that:

"We can further protect the ozone layer by accelerating the pace of phase outs. However, the acceleration can consider the impact of greenhouse gas accumulation. For example, HCFC-123 could be allowed in specific air conditioning applications where its use promotes superior energy efficiency and assures near-zero refrigerant emissions".

Well attended by atmospheric scientists from Australia, Czech Republic, Egypt, Mexico, Netherlands, Togo, U.K. and U.S., the symposium[10] was chaired by Molina, who was awarded the 1995 Nobel Prize in Chemistry with Rowland and Crutzen for pioneering ozone depletion science.

One of the well-known balance assessments[11] is shown in Fig. 2. A fair side-by-side comparison of ODP and GWP values is suggested. A refrigerant with the lowest resultant environmental impact to ozone depletion and global warming might be the best choice. For instance, HFC-152a will be an ideal choice with zero ODP and very low GWP. However, this agent is flammable. The safety measures must be considered for practical applications, especially for large commercial chillers. HCFC-123 chillers which operate under virtually no pressure and even a slight vacuum are very safe in case of accidental leakage because the refrigerant HCFC-123 is a liquid at room temperature. Obviously, environmental aspect should be considered only if the basic criteria such as safety are met.

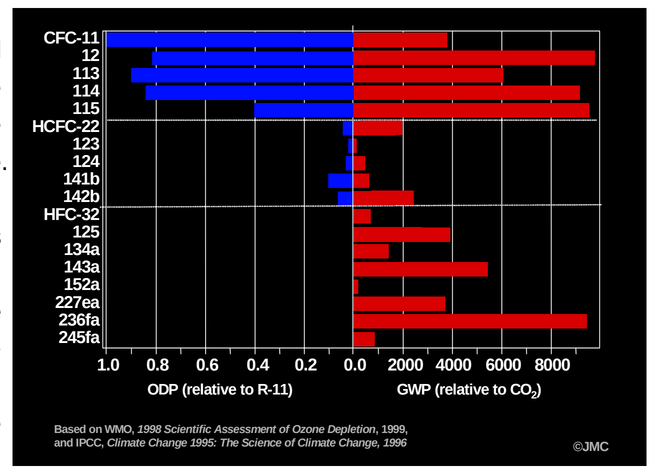

Figure 2: Balanced environmental judgment of common refrigerants (Calm and Didion 1997)

With increasing concerns of the environmental impact from modern buildings and construction, a new fashion of green building certification is being propagated quickly in recent years. There are many different rating systems such as Greenstar in Australia, HK-BEAM in Hong Kong, Greenmark in Singapore, etc. But the fundamentals are not so much different, that is to conserve energy, water and other natural resources whereas to reduce pollution and emission to the environment. Leadership in Energy and Environmental Design (LEED) of the U.S. Green Building Council (USGBC) has been using very successfully as a rating standard for green building projects nationally in the U.S. as well as internationally including many Asian countries. A new environmental assessment on refrigerant selection was adopted since January 2005, which was recommended by their Technical and Scientific Assessment Committee (TSAC) after years of research on environmental impact of commonly used HVAC refrigerants.[12] The life-cycle ozone depletion index LCODI (in lbCFC-11/RT.year) and life-cycle direct global warming index $LCGWI_d$ (in $lbCO_2$/RT.year) of the refrigerant used by HVAC system for a building, normalized per refrigeration ton of cooling capacity and per year of design equipment life, are calculated by the following two equations:

$$LCODI = \frac{ODP_r \times R_c \times (L_r \times Life + M_r)}{Life} \quad \text{Eq. 1}$$

$$LCGWI_d = \frac{GWP_r \times R_c \times (L_r \times Life + M_r)}{Life}$$ Eq. 2

where:

- GWP_r = Global Warming Potential of Refrigerant $0 < GWP_r < 12{,}000\ lbCO_2/lb_r$
- ODP_r = Ozone Depletion Potential of Refrigerant $0 < ODP_r < 0.2$ lbCFC-11/lb_r
- L_r = Refrigerant Leakage Rate (% of charge per year) $0.5\% < L_r < 3\%$/Year
- M_r= End-of-life Loss (% of charge) $2\% < M_r < 10\ \%$
- R_c = Refrigerant Charge (lbs refrigerant per ton of cooling capacity) $0.9 < R_c < 3.3$
- Life = Equipment Life (Years) 10 < Life < 35 Years
- RT = refrigeration ton
- Subscript "r" stands for refrigerant, "d" for direct emission.

A performance-based comparison was suggested:

$$LCGWI_d + LCODI \times 100{,}000 \le 100$$ Eq. 3

The two important factors are the leakage rate L_r and the refrigerant charge R_c. These variables impact the formula significantly and become key areas of contention from the manufacturers. Various refrigerant data are plotted in Fig. 3. Those scored 100 or less with the formula above (or under the 100-line) should get the credit. All the refrigerants have some points lying above the line. It is assumed that these are high leak, and high refrigerant charge applications.

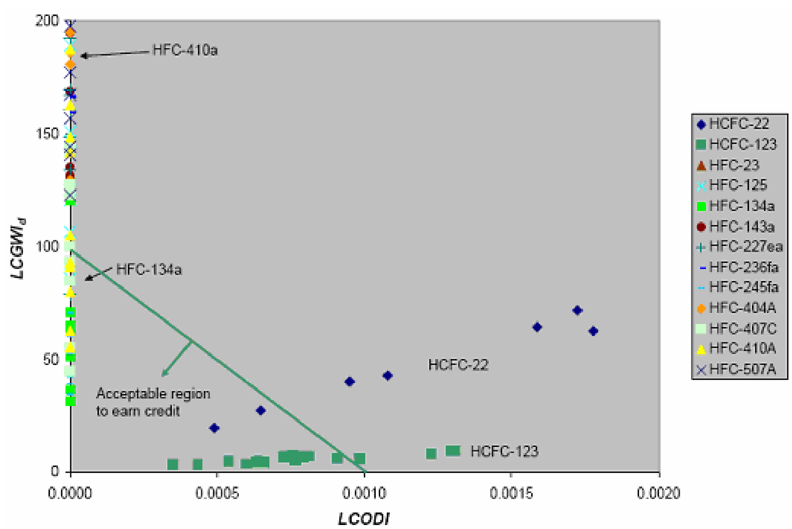

Figure 3: Environmentally acceptable refrigerants (USGBC 2004)

Conclusions

While ideal refrigerants with zero ODP and zero GWP have not yet come to existence, comprehensive assessment, such as the one derived by the TSAC of USGBC, is necessary for sustainability. It has incorporated an important concept of life-cycle impact which makes it more environmentally responsible, esp. to our future generations. Table 1 summarized the key environmental properties of the refrigerants commonly used for air-conditioning.[13]

Refrigerant selection based on a simple approach of 'zero ODP' will have to pay high cost to both global warming and energy efficiency. Using this single criterion is no longer environmentally acceptable today. The alarming increase in atmospheric concentration of HFC-134a suggested careful considerations of not over-using of any single compound in substituting ODSs.

Based on integrated assessment of ODP, GWP, atmospheric lifetime, energy efficiency and leakage, some HCFC refrigerants like HCFC-123 has been suggested by atmospheric scientists for longer-term use in specific air conditioning applications where superior energy efficiency with near-zero refrigerant emissions can be achieved.

Table 1. Environmental Properties of Common Refrigerants
(WMO 2003)

REFRIGERANT	Ozone Depleting Potential (steady-state)	Atmospheric Lifetime (years)	Global Warming Potential (100-Year)
CFC-11	1 (index)	45	4680
CFC-12	1.0	100	10,720
HCFC-22	0.05	12	1,780
HCFC-123	0.02	1.3	76
HFC-134a	~0	14	1,320
HFC-23	~0	270	12,240
HFC-125	~0	29	3,450
R-407C (HFC blend)	~0	~29	1,674
R-410A (HFC blend)	~0	~29	1,997

Notes:

a) *Source: Montreal Protocol Science Assessment of Ozone Depletion 2002*
b) *~0 means practically zero, upper limit of HFC-134a $<1.5 \times 10^{-5}$, HFC-23 $<4 \times 10^{-4}$, HFC-125 $<3 \times 10^{-5}$*
c) *R-407C and R-410A are blend refrigerants of R-134a, R-32 and R-125. Highest value among the components (i.e. R-125) is considered for the atmospheric lifetime.*

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CONSTRUCTION SAFETY AND HEALTH FOR THE PINNACLE @ DUXTON

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Abstract

The Pinnacle@Duxton will be the tallest public housing development in Singapore at 168 meters once construction works complete in 2009. Comprising of seven blocks, each 50 storeys, it has a total of 1,848 residential units. The Pinnacle@Duxton is an award winning design resulting from an international architectural competition, organized by Singapore's Urban Redevelopment Authority, to obtain the best design ideas for high-rise living in the city. The unique design feature of the super high-rise development is the twelve sky-bridges that link all seven blocks together at the 26^{th} and 50^{th} storey.

This paper explores the various safety and health concepts and innovations that were considered in all stages of the project's life-cycle, i.e. from planning, design, procurement, construction, and maintenance. The over-arching concept of 'designing out the risk at source' was the focal point for the architects and engineers, at the planning and design stages, to minimize construction risks and to ensure ease of maintenance in the future. Among the innovative tools which will be illustrated include the use of prefabrication technology, to minimize wet works and improve site safety and productivity, and the proactive safety and monitoring systems implemented on site during the piling, foundation, basement and the superstructure works, with the sole aim of preventing accidents and promoting safe and healthy work environment.

Keywords: Safety, Health, Super high-rise development, Risk at source, Prefabrication technology.

1. Housing & Development Board (HDB)

The Housing and Development Board (HDB) was set up as a statutory board on 1 February 1960 to provide public housing for the nation. HDB is responsible for the planning, development, and maintenance of quality affordable public housing. Within 40 years, it has built 840,000 homes housing 84% of the population, enabling nine out of ten of them to be homeowners. This has made Singapore one of the highest home ownership nations in the world. With only 650 km2 of land competing for residential, industrial and commercial use, HDB's challenge is not only to design and build affordable public housings, but also to develop a total living environment to satisfy a growing affluent population. HDB has developed over the last four decades, a total integrated systems approach to the design and construction of public housing to achieve a good balance between aesthetics, buildability and cost.

HDB with its vast experience in the planning, design and construction of public housing, has always adopted a pro-active approach in improving the safety and health standard of the construction industry. This is reflected in its four-prong strategy adopted, that is, implementing effective safety and health policies; enhancing safety and health knowledge through training to promote safety consciousness among site staff and workers; enforcing safety rules and provisions by conducting regular audits on site; and improving construction technology to reduce wet works on site through the use of prefabricated concrete and reinforcement and hence reduce the frequency of the accidents occurred.

To ensure the smooth implementation of HDB's massive annual public housing programme, emphasis was placed on the development of a comprehensive safety and health management system. An in-house safety management unit was formed with the responsibility of formulating safety policies and ensuring all stakeholders comply with the safety measures. With enforcement, HDB's safety and health management system has played an integral role in reducing HDB's work site accidents. The Accident Frequent Rate (AFR) for HDB site had reduced drastically from 7.18 (accidents/million man-hours worked) in 1982 to only 0.41 in 2006. Fig. 1 showed the AFR for the period from 1990 to 2006.

As such, HDB has always placed great emphasis on safety and health considerations of its projects during the entire development life cycle, ie from planning, design, procurement, construction and maintenance. This paper illustrates through the project Pinnacle@Duxton, on HDB's strong commitment and concerted efforts to provide a safe and healthy environment to the construction industry.

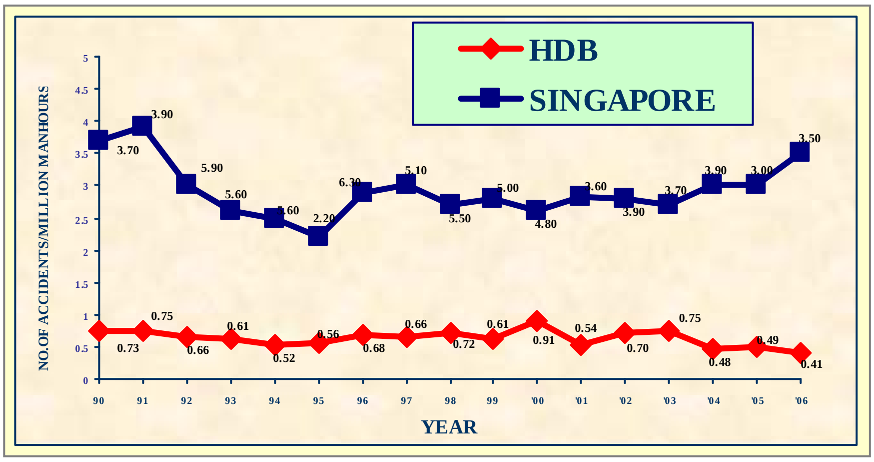

Fig.1 Accident Frequency Rate (AFR) for HDB & Singapore

2. Pinnacle@Duxton

The Pinnacle@Duxton consists of 7 residential blocks with one multi storey carparks. The project has a total of 1848 residential units. When completed in 2009, it would not only be the first 50th storey public housing development in Singapore but also the tallest, standing at 168m. The project site is situated on where the first two HDB blocks in the area, Block 1 and 2 Cantonment Road, were built in 1963. Due to the historical significance of the site, an international architectural competition was organized by Singapore's Urban Redevelopment Authority to obtain the best design ideas for high-rise living in the city. The winning design from ARCstudio architecture+urbanism and RSP Architects, Planners and Engineers was selected from over 200 designs received.

Unique features of design include skybridges and sky gardens at 26th and 50th storey linking all blocks and a variety of façade elements. The circuit board-like arrangement of bay windows, planters and balconies helps to differentiate The Pinnacle@Duxton from other "regular" HDB projects. The site layout plan is shown in Fig. 2.

Fig. 2 Site Layout Plan

Project Information

- Number of blocks and storey : 7 blocks, each 50 storey
- Total number of units: 1,848
- Type of unit S1 : 1,232 units (93 sqm - 97 sqm)
- Type pf unit S2 : 616 units (105 sqm - 108 sqm)

Facilities

- Basement : Carpark below blocks 1A to 1E
- 1st Storey : 1 food court, 4 shops and 1 convenience store and carpark
- 2nd Storey : Carpark at Blk 1A, 1B and 1D
- 3rd Storey (Environmental deck) : 1 childcare centre, 1 education centre, Playground, Event Plaza, Basketball Court, Pavilion
- 26th Storey (Active Zone) : Jogging track, 760m long
- 50th Storey (Contemplative Zone) : Viewing decks and themed garden

3. Housing Development Concept

For HDB's public housing development works, costs, timely completion, safety and health and maintainability of the project are key driving parameters that determine the success of the projects. Consequently these parameters will be key considerations in each phase of the development life cycle process, ie from planning, design, procurement, construction and maintenance.

Understanding that Singapore lacks the necessary local work force and natural resources to sustain its local construction development works, HDB have adopted a dual-pronged strategy of buildable designs and construction mechanization to propel construction productivity to higher levels of achievement. The buildable designs adopted have facilitated construction processes and changed construction works into more assembly-like activities that uses fewer workers but more mechanisation and prefabricated components. HDB site construction activities are radically transforming into an assembly centre. Off-site manufacturing activities are fast becoming the norm rather than the exception. This will leave the worksite neater and safer. Site installation of the finished products will be highly mechanised. This will motivate HDB's contractors to equip themselves with advanced construction technologies, which require multi-skilled workers in considerable smaller numbers.

Some of the methods adopted are outline below:

- Adopting buildable design with the use of modular coordination and standardisation of elements. With the block and unit variations kept to a minimum, a high degree of buildability could be achieved. Architectural components such as windows, doors, bricks and concrete blocks are also modulated and standardized. The buildable design adopted has facilitated the construction process and changed the construction works into a more assembly-liked activity that uses less workers and more precast components and thus reducing the accident rate on site;

- Use of mechanised formwork systems to achieve better surface finishes and minimise the risky plastering work to be carried out later;

- Upgrading of concrete/material handling machinery to provide safer working environment with less physically demanding work exerted on the workers;

- Use of prefabricated beam and column cages to cut down the cutting and bending of reinforcement on site; and

- Use of precast components to facilitate fast track construction, the main structure systems are standardised to a large extent to enable repetition of key components such as column, beam, slab and wall. The production of precast components in the factory allows each production line activities involved to be strictly controlled. Working under shelter allows the production process to take place independently of the weather, leading to more consistent quality and provide the workers with safer working environment.

4. Planning Process

The Pinnacle@Duxton is located in a highly built environment with many residential and commercial buildings surrounding the construction site. Careful planning in the design and construction was essential to ensure successful project execution. Hence the architects and engineers had to always bear in mind that the concept of 'designing out risk at source' as being more effective than trying to manage safety within a process that is inherently unsafe. A project that has taken safety and health into consideration in the planning and design stages would definitely result in cost and time savings for the owners and contractors as safety-related delays are minimized subsequently during the construction stage.

Over the years, HDB has adopted the use of prefabrication technology in the planning and design of its high-rise residential buildings, aiming to 'designing out risk at source'. The advantages of using prefabricated construction are as outlined below:

- Reducte accidents on site. Work can be shifted from a high elevation at the site to the ground at the precast plants. This would reduce accidents due to fall from height;

- Reduce labour and wet work on site, and allow the use of safer and automated equipment at the plants, such as bending and cutting. Site productivity would also increase as the production of the precast components in the factory can be done concurrently with the construction of the building on site;

- Reduce noise and dust pollution, which cause irritation and health problems to the residents staying near the construction site. Precast plants are usually situated far from the residential areas and air quality hazards in the factory can be better controlled through engineered ventilation;

- Reduce laborious works like block/brick layering and plastering and minimise the potential danger of falling bricks and plasters during the maintenance stage;

- Reduce metal formwork erection and dismantling on site and the potential risk associated with improper handling of such the activities; and

- Provide better quality finishes which would require less maintenance in the future.

Prefabricated reinforcement which are readily available in the market such as beam cages, column cages with column bars integrated and welded mesh are also used extensively in the structural elements whenever possible to reduce the bending and cutting of reinforcement on site. The use of prefabricated reinforcement has enhanced the buildability and increased site productivity. Construction process and methodology are designed to make it less labour intensive and hence reduction in accident rate.

In the planning for construction, it is important to identify the safety and health hazards early and eliminate them with the safe job steps and control procedures. Job hazards analysis must be carried out prior to start of the construction to reduce the accidents on site.

5. Design Process

During the design process for Pinnacle@Duxton, the ultimate challenge for the project team was, not just to transform the architectural design and intention into reality, but also enabling the construction works to be carried out in safe and healthy manner subsequently. It was important that the architects and engineers worked together during the design stage to reduce the inherent risks during the subsequent construction and maintenance stages.

As Pinnacle@Duxton was HDB's first super high-rise development, rigorous design analyses were conducted to ensure structural stability. Reinforced concrete construction couple with the building's beam-column-slab rigid frame was adopted for the structural system. All columns loads are transferred directly floor to floor down to the foundation. No transfer beams were used. 3D modelling of the structural systems was conducted to obtain the analysis results for the moment, shear and deflection for each structural element. Numerous wind tunnel simulations were also conducted at the laboratory to analyse the effect of wind currents on the seven tall buildings and also its environmental impact on the surrounding neighbourhood. Robustness was also being considered in the design with the provision of peripheral ties and internal ties, to ensure the building is not subjected to the effects of progressive collapse. In addition to the wind tunnel simulation, a traffic impact modelling and analysis was also conducted to ensure optimal travelling times for the two abutting major roads.

For the sub-structure design, thorough soil investigations had been conducted out around the site to ascertain the properties of the soil. The Duxton site consisted primarily of hard silty sandstone and concrete bored piles were used as foundation members. A total of 1330 bored piles were designed with an average pile penetration length of 19m. Each tower block was designed to sit on the 2.7 m thick raft foundation, which was supported by the 140 numbers of 1.5m diameter bored piles spaced equally. The raft foundation system provided structural stability and rigidity for the high-rise tower block and prevented differential settlement.

For Pinnacle@Duxton, conscientious efforts had been made by the architects and engineers to make the project buildable by adopting modularization and standardization concepts. The residential blocks, consisting of standard layout of S1 units and S2 units, were put together by mirror image and rotation of these unit plans. The modularization of the units was replicated to form the block design. The typical storey floor plans were also repeated for better efficiency in precasting and construction. The adoption of modularization and standardization had also enabled prefabrication to be cost effective due to the large repetition of the precast components, prefabricated reinforcement and prefabricated finishes.

The use of prefabrication technology had facilitated the construction works in a tight built-up working environment. It had also increased productivity and reduced environment impact on the existing area. Various precast components were utilised and these included prestressed plank, column, lift wall, household shelter wall, gable end wall, façade wall with bay window, façade wall with planters, façade wall with balcony, screen wall, refuse chute, staircase and parapet. The project team adopted the use of the large panel facades that had enhanced the tower crane utility and improved the site productivity. The wall panels were also designed to be hollow-cored so to reduce the weight of the components and minimise risk during hoisting and erection. The hollow-core portions would be cast-in-situ on site.

6. Procurement Process

HDB had always taken proactive and stringent measures in ensuring safety and health on its worksite. HDB had worked closely with the Ministry of Manpower and ensured that the contractors meet the minimum standards laid down in the Workplace Safety and Health Act and its Subsidiary Legislations.

Site safety and health policies had been formulated to provide a safe and conductive working environment.

HDB had included site safety and health measures as part of the contract specification. This would ensure the contractor to price in all the safety and health measures in their tender and maintain a safe and healthy environment on site at all times. This also was to ensure that ownership of HDB's safety and health policies would also be adopted by the building contractor. Some of the safety requirements included are as outlined below:

- the contractor is to submit the safety programme for approval prior to the commencement of the works;

- the contractor shall display safety posters at the site office, site canteen, exit/entry points of the buildings and passenger cum material hoist area;

- all construction equipment (mobile crane, tower crane, gondola, mast climbing platform, metal scaffold etc) used shall be obtained from Approved Suppliers registered with the Safety Unit, HDB;

- the contractor shall submit drawings, detailings and calculation for all temporary structures (peripheral overhead shelters, overhead shelters at exit/Entry points (Fig. 3); metal access scaffolding with construction screening net; metal swing gates at the material-cum-passenger hoist areas, protective hoarding etc) and certified by Professional Engineer;

Fig. 3 Overhead Shelter at Exit/Entry Point

- the contractor shall provide prefabricated mesh barricade for all the peripheral open sides (Fig. 4), of construction level of building where a person is liable to fall from height;

Fig. 4 Safety Mesh Barricade

- the contractor is required to employ full time safety officers and safety supervisors on site to ensure safe work procedures and implement the safety measures. The number of the safety officers and safety supervisors to be employed would be based on the contract sum;

7. Construction

HDB had earned the reputation in local building circles as a meticulous enforcer of site safety. Its top-down approach in cascading safety practices had promoted to greater safety awareness and improvement to the safety standards in the industry. Strong enforcement measures had been adopted to instill discipline and encourage "self-regulation" in contractors to comply with the stipulated safety requirements. Among measures implemented include safety education, enforcement of safety regulations as well as implementation of preventive measures, regular inspections, tracking the number of safety non-compliance cases, reported accidents and the compilation of accident statistics.

For Pinnacle@Duxton, safety and health management during construction are the responsibilities of the various project stakeholders. These stakeholders included the developer, consultants and contractor, ie:

- HDB – Project Director, Project Coordinator and Contract Management
- ARCstudio Architecture+urbanism, in collaboration with RSP Architects Planners & Engineers - Project Architect
- Surbana Consultant – Project Management, Civil & Structural Engineering, Mechanical & Electrical Engineering, Contract Management and Quantity Surveyor
- Contractor - Chip Eng Seng Contractors (1988) Pte Ltd

The project stakeholders had formed a committee to oversea all safety and health matters. The goal of the committee was to ensure 'Zero fatality'. The committee conducted all job hazard analyses prior to the start of each construction activities and demanded that these job hazard analyses also be carried out by all working subcontractors. Safety and health hazards were identified along with recommended control procedures that were implemented to prevent the corresponding accidents from happening. Among the various safety and health measures adopted on site are as listed below:

- requiring safety management system for construction works - The contractor was to ensure that all construction works were managed and coordinated. Safe procedures and practices were established. The approach includes the identification of hazards, evaluation and control of work related risks.
- conducting safety training to contractors' workers and site staff - The contractor' workers and the site staff were made aware of the potential hazards associated with the types of site works. Safety orientation courses were conducted to the workers and the site staff so that they could perform their duties efficiently and safely. Training was also conducted to all the supervising staff so that they were alert at all times to potential accidents (Fig. 6). Publication of quarterly bulletin for issuance to the site was done so as to enrich the site staff's knowledge on safe work practices.

Fig. 6 Safety Officer Conducting Briefing

- requiring immediate reporting of accidents on site - The contractor had been required to report to HDB immediately after any accident had occurred. The immediate reporting of accidents rather than periodic reporting had enable HDB to act promptly to identify the causes of the accident and to implement preventive measures to prevent similar accident from occurring again.
- conducting safety audits during construction - The contractor had been required to conduct safety audits to ensure compliance with the HDB's safety requirements, the Workplace Safety and Health Act and its Subsidiary Legislations. The safety issues and the potential hazards in the coming work were discussed in the site monthly progress meeting. HDB safety officers would also conduct audit on site from time to time to identify unsafe features or practices. The

safety audit report were given to the contractor for their necessary rectification and administrative charges would be imposed for failure to act promptly to the written direction.

On health aspects, the following measures had been carried out on site to improve the environment :

- maintaining a mosquito-free environment - Fogging (Fig. 7) were carried out once per week to cover all areas around the site to prevent the mosquito nuisance problem. All mosquito breedings found during the inspection were destroyed and the preventive actions had to be taken to eliminate the potential breeding grounds.

Fig. 7 Fogging Around Site

- implementing of erosion control - The erosion control measures were implemented to ensure minimum bare earth surfaces at all time. These were done by paving up the bare surfaces and all construction access with lean concrete (Fig. 8); and covering up the active work surfaces with canvas sheet during rain or at the end of the workday.

Fig. 8 Paving Up of Slope with Concrete

- implementing sediment control - The sediment control measures were implemented to trap, contain and treat the silty discharges from the construction site. These were done by providing silt traps properly designed with the usage of polymer block and geo-textiles; by providing a treatment system-cum-storage tank (Fig. 8) to separate the silt and sediments from the water before the silty discharge left the site.

Fig. 9 Silt Water Treatment Tank

7.1 Temporary Support Structure

The Pinnacle@Duxton project had one storey of basement of 3.6m in height. It was important to provide temporary support structure to ensure safety during the excavation and construction of the basement. Temporary support structure had been required to protect the foundations of the existing buildings from excessive movement and damage. Some movement, particularly settlement, of the ground next to the excavated soil may occur due to inward yielding of the excavation face. Ground water lowering during construction or ground heave might also cause ground movement.

The temporary support system had been designed to ensure ground movement was within acceptable limits. The stresses in the temporary shoring and bracing had been within limitations at all stages of construction. Water pressure, surcharge and additional unplanned excavation depth were considered during design of the temporary support system. As movements of the same magnitude as those occurred during excavation could occur during removal of the struts, provisions had been made to ensure proper transfer of load from bracing to the new structure.

There were three types of temporary support system adopted in this project, namely Contiguous Bored Piles (CBP) (Fig. 10), soldier piles, secant and soft piles. The choice of the support system used for each area depended on the nature of the ground, site geometry, sequence of construction, time available and relative costs. Ground anchorage system were also used to support and stabilise the temporary structure during its construction.

Fig.10 Contiguous Bored Piles

7.2 Instrumentation Monitoring

An instrumentation monitoring system to monitor the construction process had been implemented on site to ensure safety during construction and the integrity of the nearby structures, especially the train tunnel. Observations of settlement, lateral displacement and dissipation of pore water pressure during construction were used to control the rate of excavation to maintain continued stability and ensure that the construction was according to the intended design.

For this project, several instruments had been installed to monitor the movement of the soil and its nearby buildings. These instruments were installed to measure the soil movement during piling, excavation and construction works. They were :

- inclinometer : detecting lateral movement of soil
- ground settlement point : indicating change in ground settlement or heave
- building settlement point : indicating change in existing building settlement
- water standpipes : measuring change in water level
- pneumatic piezometer : measuring the pore water pressure
- vibration monitoring point : measuring vibrations of the existing building

The instrumentation monitoring specialist, had been required to visit the site twice per week to take the readings and produce reports to be submitted to the resident engineers. The readings taken were compared to the criteria levels recommended prior to the starting of the construction. These levels were alert level and work suspension level. Readings which were above the alert level would caution the resident engineers to take immediate remedial action to prevent further settlement of the soil or existing building structures. Readings which were above the work suspension level would cause the site to stop work completely until full safety measures and actions had been taken to eliminate the potential risks. The instrumentation monitoring had been carried out throughout the whole duration of the construction to ensure safe construction had been carried out.

8 Maintenance Process

The building structure and building components will deteriorate over time if the building is not properly maintained. HDB has constantly collected feedback from the residents and public to improve on its buildings and estates. Continuous R & D into better design and construction processes has reduced the defects such as concrete spalling, water seepage from exterior and leakage at the ceiling. The maintenance aspects considered in the design and construction of the Pinnacle@Duxton project included :

- provision of the air-conditioner ledge (Fig. 10) every unit to take care of the maintenance personnel when doing the air-conditioner servicing;

Fig. 11 Air-Conditioner Ledge

- provision of mechanical cloth hanging racks (Fig. 11) to replace the bamboo pole holders to ensure that water does not stagnate and remove the potential sources of mosquito breeding;

Fig. 12 Mechanical Cloth Rack

- provision of the cast-in windows to the precast facades to minimise the water seepage through the window frame;

Fig. 13 Cast-in Windows to Precast Facade

- reduction in the precast joints by integrating the precast beams with the façade walls and using large precast panels as far as possible;

- provision of gondola's trek at the roof top of each block for mounting and moving the gondola vertically and horizontally around the block when doing cleaning and painting works for the block;

- using high grade concrete to make the structure more durable and minimise the problem of concrete spalling. For the project, grade 60 is used for columns and walls and grade 40 is used for other structure elements.

9. Summary

Safety and health controls are essential features to ensure the successful of a project. With the advancement of construction technology and more high technology equipment and machinery are being introduced at worksite, there would be new potential hazards created. HDB is constantly prepare itself for these changes and work closely with the architects and design engineers to eliminate the potential risks at source during the planning and design stages. HDB has also worked closely with the contractors and suppliers to eliminate the potential hazards during construction and provide a safe and healthy working environment at the worksite at all time.

With HDB's strong commitment and concerted efforts to provide a safe and healthy environment to the construction site through planning, design, procurement, construction and maintenance, the site (Fig. 14) has achieved zero fatality to-date through the fast track prefabrication construction.

Fig. 14 Overview of Site Under Construction

LEGAL AND SOCIAL IMPEDIMENTS ON POLICIES FOR SUSTAINABLE BUILDING IN MALAYSIA

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Abstract

It is generally accepted that sustainable building can reduce the operating costs by using less water and energy. Rainwater utilization serves as a method that supports sustainable building. In Malaysia, the system is still not popular despite the introduction of Guidelines on Rainwater Harvesting in 1999. To date, the number of building with rainwater harvesting system in the country is still very low. This may be due to several reasons including lack of exposure to the Malaysian society or perhaps they lack environmental awareness. This paper discusses the benefit of rainwater utilization in sustainable building and the obstacles inherent for the implementation of the system in Malaysia. It also discusses the existing legal framework that relates to the rainwater harvesting and suggestions for the development of new policies for sustainable buildings in Malaysia.

Keywords: Sustainable building, Rainwater harvesting, Environmental awareness, Legal issues, Policies.

1. Introduction

Sustainable building aims to reduce impact of the building on the environment. Ideally, it should be built by using 'green' building material either from rapidly renewable plant or from forests certified to be sustainably managed. For buildings which require heating in cold winter, it should use solar system and well-insulated walls and windows to prevent energy loss and reduce energy usage. Sustainable building needs also be water efficient. This helps the environment by eliminating reducing the need for new reservoir and reducing the impact on ground water level. Rainwater harvesting system can be installed to achieve these purposes and the rainwater collected can also be used for flushing, gardening and even drinking. In Malaysia and most part of the world, rainwater has been collected during the old days but has been forgotten when piped water becomes common. In the light of the present global water crisis and the effects of global warming rainwater harvesting should be used in Malaysian building to make it more water efficient and sustainable.

2. Rainwater Harvesting in Sustainable Building

A water efficient building will use less water and have sufficient supply during drought or shortage of water supply. To this end, rainwater can be collected or harvested to make building more water efficient. It involves collection of rainwater from rooftop or permeable surfaces and channeled to the storage tank. For rooftop collection, first flush system is needed. It will dump the water that comes down the pipe first since it may be contaminated by animal droppings or dirt. Only when the rainwater coming down the pipe is clean does it get directed into the storage tank. The rainwater collected is then channeled to gardening, toilet flushing and general washing.

In today's urban concrete jungle, rainwater harvesting can reduce a building impact on the environment and guarantees a more sustainable development. The increasing numbers of new buildings, especially in cities, do put some pressure over the existing provision of water supply. Early this year alone, there have been calls for new dams as well as inter-state water supply to support the ever increasing water demand in Selangor, Kuala Lumpur and Putrajaya. Besides the high cost involves, these suggested projects will have a significant impact on the environment. If new or existing buildings are equipped with rainwater harvesting system, they will reduce the dependence of piped and treated water and protect the existing forest from turning into new reservoirs.

Besides supplying water to the residents, rainwater harvesting helps the environment by increasing the ground water level through artificial recharge. The increasing demand for potable water has resulted in extraction of more and more groundwater. Such extraction is far in excess of net average recharge from natural sources and requires artificially recharge aquifers to balance the output. Rainwater harvesting can replenish groundwater resources, thereby reviving nearby wells and groundwater pumps.

Since most parts of the cities are covered with impermeable concrete cement, heavy rain may cause the water level to rise easily at lower parts and caused flooding. Kuala Lumpur and Shah Alam face occasional flooding when heavy rain hits these cities. The use of rainwater harvesting system in buildings, at the macro level, can help in reducing environmental impacts of flooding since it lessen storm water runoff. In addition, if the system is installed in building on higher ground, the lowering of runoff may prevent excessive soil erosion during heavy rain hence prevent landslide.

As cities are highly populated, shortage or even temporary cut of water supply is not unusual. When Malaysia faced drought in 1998, water for daily use have to rationed and sent by lorry. If the system is used, rainwater kept in the storage can become an alternative source of water. Besides using the valuable natural resources, people can save money by utilizing rainwater. Money wise, the system will benefit both individual customer as well as the water service providers. For the individual customers, it saves them money by reducing the water bills. The reduction in the demand for the local water supply in return will reduce the stress on the part of the authority to find alternative water supply. It also saves them money in terms of the future cost of a new reservoir. Hence, a “win-win” situation to all as both parties benefit.

3. Rainwater Harvesting Policy in Malaysia

The 1999 “Guidelines for Installing a Rainwater Collection and Utilization System” can be seen as the initial phase of the rainwater harvesting policy in Malaysia. Introduced by the Ministry of Housing and Local Government after the 1998 drought, it aims at reducing the dependence on treated water and provides a convenient buffer in times of emergency or a shortfall in the water supply. It also proposes the construction of “mini dams” or rainwater tanks in urban areas instead of continuing to build giant dams upstream. This may not only conserve the treated water but can act as urban flood control. Nevertheless the guideline is only intended to be a reference for those who want to install the system[1].

Five years later, the same Ministry prepared another cabinet paper to the National Water Resources Council to encourage government buildings to install rainwater collection and utilization system. The Council agreed that rainwater utilization is to be encouraged, but not mandatory, in all federal and state government buildings. In addition the Council stated the need for rainwater utilization campaign and to provide a solution to prevent mosquito breeding in the gutters or tanks. As rainwater harvesting was very alien to many Malaysians then, as well as the fact that most of the system was not available locally, the implementation of that new policy was not really successful.

After the creation of the Ministry of Natural Resources and Environment in 2004, the National Hydraulic Research Institute of Malaysia or NAHRIM was established under the wing of the Ministry. It aims at conducting research in all aspects of water hydraulic and water environment, rainwater harvesting included. Besides having its own system, NAHRIM has also started three rainwater harvesting projects in a government building, a mosque and a residential house. It is also actively involved in designing and installing rainwater harvesting systems for several schools in the city centre. In April 2007, NAHRIM has organized a National Rainwater Colloquium in April 2007 as a forum to disseminate information on the system to the relevant and potential stakeholders.

[1] Guidelines for Installing a Rainwater Collection and Utilization System, p. 1

In August 2006, the Town of Country Planning and Development has formulated the National Urbanization Policy (NUP). The policy in particular stresses that cities need to improve water management efficiency which emphasize on the use of alternative sources and non-conventional of rainwater harvesting and water recycling[2]. Under the policy, the relevant agencies for implementation are the Ministry of Technology, Water & Communication[3], the Water Supply Department as well as both State and Local Authorities. At the moment Ministry of Technology, Water & Communication has initiated a water saving campaign with the Federation of Malaysian Consumer Association (FOMCA) and makes rainwater harvesting an important component in the water saving efforts. In its long-term plan[4], the Ministry also aims at installing rainwater harvesting systems in new government buildings and schools.

The most encouraging development for the success of rainwater harvesting in Malaysia came about after the announcement by the government to make it mandatory in March 27, 2007. Despite the fact that it will only apply to large buildings like factories, schools or bungalows, it is certainly a right step towards having more sustainable building in Malaysia. The government has finally come to realize that although initial steps were taken since 1999, not much progress has been made in conserving treated water. It is hoped that by making rainwater harvesting mandatory, Malaysia building are more water efficient and will have less impact on the environment as a whole.

4. Impediment on Rainwater Harvesting Policy in Malaysia

Despite these efforts by the government, the number of installation in the country so far is still low. Besides NAHRIM, few government departments have used the system for gardening and flushing. At the moment they are still restricted to those directly involve with water such as the Ministry of Energy, Water and Communication as well as the Department of Drainage and Irrigation. Besides these authorities, some local council has started their new development projects with the system installed, like in the new court complex in Seberang Perai, Penang and residential houses in Sandakan, Sabah. It is submitted that the slow development of the policy is due to the non-obligatory nature of the policies. The policies discussed above generally intended as a reference and Malaysians are only encouraged to use rainwater harvesting with no penalties for evasion.

Along the low intake, there was a case of a housing development where the residents removed the systems installed by the developer. This occurred in Kota Damansara, Shah Alam. The Shah Alam City Council would like to implement the water efficient building and successfully installed the system in this new development. Nevertheless, till now, almost half of the residents have dismantled the system to give way for renovation. It is observed that the storage tank installed was not underground and took a lot of space at the backyard. For resident who want to make extension, they have no choice but to pull the system out.

There are several reasons contributing to the above incident. First and foremost the storage tank itself is not space friendly. It occupies almost half of the backyard and the bulky size hinders the view. In this regard, architect and engineer should create design that which is more practical and have some aesthetic value. Australia is coming with more designs which are slimmer and practical for residential houses[5]. For large housing projects, it is submitted that the developer should use underground storage as it can certainly avoid the space issue. For existing building, installation cost can be quite burdensome. A simple system may cost the owner of the building about RM5000. For the new development, as in Kota Damansara, the developer may have passed the cost to the consumer in the selling price. However, as seen above, owners are willing to forgo the additional cost that they have paid and pull out the system to allow extension.

It is also submitted that lack of good response by the Malaysian towards the system is due to the lack of exposure by the authorities. With the exception to the 2007 announcement, the policies discussed above

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[2] National Urbanization Policy 18 Clause (vi)

[3] After the creation of the Ministry in 2004, the Federal Constitution has been amended in 2005 to transfer the authority over water supply from State List to the Concurrent List. By virtue of the amendment, the Federal Government can now legislate on matters of water supply.

[4] See Badriyah Abdul Malek, "Pelan Penjimatan Air Kebangsaan: Tanggungjawab Kerajaan" paper presented at the National Seminar on Water Saving Awareness in Malaysia, 22 Mac 2007, Berjaya Times Square Hotel, Kuala Lumpur.

[5] See for example at http://www.tankworks.com.au/water-tank-storage/sizealator.html, July 4, 2007

are mainly directed to the government building at both federal and state level. In regard to environmental issues, only the Ministry of Natural Resources and Environment who goes to public places to give environmental talk, especially in schools. Compared to other developed countries like Australia or United Kingdom, environmental awareness is made at all level, federal, state and even individual councils. In addition, the environmentalists as well as politicians discuss environmental issues like global warming or water crisis in television or radio. All these increase the environmental awareness of their people. Compared to Malaysian, they give better reception to new environmental policy, especially sustainable development and green building.

Another impediment to the implementation of the policy in Malaysia is the concern over health issues. This will be divided into two, the water quality and contamination[6], as well as the mosquito breeding. As most pilot projects use rainwater for non-potable use like toilet flushing or gardening, water quality might not be an issue at the moment. However if we start to have rainwater for potable use, quality should not be compromised for the sake of saving[7]. On the other hand, since Malaysia are common with mosquito related diseases, the public as well as government agencies are concerned with the possibility of mosquito breeding in gutters. To make rainwater harvesting work without this worry, architects and engineers should not only come out with an environmentally and space-friendly design, but also a design that allows easy inspection and detection of mosquitoes.

5. Experiences of Sustainable Building Policies from Other Countries

Malaysians are still alien to the concept of harvesting and utilizing rainwater in sustainable building. In order to make the new policy of mandatory rainwater harvesting in Malaysia, policy makers need to be aware of various approach taken by several countries in making the system works. Australia, Japan, Texas and India have been successful in implementing the policy. However each country has different approach in their implementation. The following discussion will look on how they developed the policy and how they encourage their citizens to become water efficient.

5.1 Australia

Australia is an active advocate for sustainable buildings. With regard to rainwater harvesting, Australian states are encouraging its use to reduce their dependence on piped water. This may be due to the fact that the cost of water is relatively high and is set to increase in the near future. Early this year, the Prime Minister himself, Mr. John Howard made an announcement that the government will provide Water Grants Scheme for water efficient projects that may help Australia as a whole to conserve its water resources. Rainwater harvesting project for school for instance may apply such grant.

One interesting features of Australia's effort in sustainable building is rating or labeling. The New South Wales Government for instance introduces BASIX or Building Sustainability Index to ensure homes are designed to use less potable water and lower greenhouse gas emissions by setting energy and water reduction targets for house and units. Under BASIX, the user, usually the building designer enters data on-line relating to the house or unit design - such as location, size, building materials etc - into the BASIX tool. These data will be analyzed by the authority and determines how it scores against the Energy and Water targets. The Certifying Authority who will also check compliance at various stages of construction will give the BASIX Certificate[8]. Since the certificate must be attached to the development application before it can be processed, all new developments in the New South Wales are guaranteed to be water and energy efficient.

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[6] A research conducted in Maldives shows that 40% of rainwater collected was contaminated with faecal. See Maldives Water and Sanitation Authority, 'Rainwater Harvesting and its Safety in Maldives', a paper presented at the 12th International Rainwater Catchments Systems Conference, New Delhi, India (November 2005)

[7] This is the same reason why rainwater harvesting is not popular United Kingdom. http://www.environment-agency.gov.uk/commondata/acrobat/rainharvest_june04_809069.pdf, April 13, 2006.

[8] http://www.basix.nsw.gov.au/information/index.jsp , April 16, 2007

Another effort by Australia's government to assist people to purchase more water efficient products is by providing rebates. The Brisbane City Council in Queensland provides rebates for homeowners who purchase water tanks and fulfill other conditions that have been set by the Council. A residential rebate of $500 is provided for the purchase of a tank that is equal to or more than 3,000 liters while a $750 residential rebate is given for a tank that that is equal to or more than 5,000 liters. In addition to the Council's rebate, the Queensland state government will pay up to an additional $1000.[9] In Sydney, rebates up to $800 is given for the installation of rainwater tanks, eligibility and amount of the rebate is determined on the fulfillment of required conditions, size of the tank and whether the rainwater is connected to your toilet or washing machine. There are certain conditions to be fulfilled before qualifying for rebate.[10]

Malaysia may follow Australian's steps to use rating and labeling in its effort to educate the Malaysian society on sustainable building. Malaysian may not feel the need to use rainwater today since the price of piped water is still low. However when we are hit with serious drought season as in 1998, both water service providers and consumers will have difficult times in finding alternative source of water. If the Malaysian states choose to follow the New South Wales's government to use BASIX system, Malaysia will also increase the market value of sustainable building and increase the number of it in the future.

5.2 Japan

Japan first use of rainwater utilization was in response to natural disaster such as the 1923 earthquake in Sumida City. As one of the developed states in the world, Japan has developed rainwater utilization system for water shortage mitigation, flood control and disaster prevention. Nevertheless, the implementation of rainwater utilization is still not statewide. Not all members of the public feel the immediate need for rainwater utilization. Various subsidies were created to encourage the use. Educational program has also been introduced at school and residential area to explain the use rainwater utilization and how it will benefit individual people and the country as a whole. As most of the Japanese are computer literate, detail information about the system was made available on-line in Japanese language. At the technical level subsidies are introduced to anyone who can create system that improve waterside environment and help prevent land subsidence and droughts caused by a lack of rainwater permeating underground due to urbanization.

To support the water efficient building policy, Japan has introduced a combination of guidelines and ordinance. In March 1995, the Sumida City in East Tokyo implemented "Rainwater Utilization Promotion Guidelines". It provides that rainwater utilization should be subsidized and installed in the future construction of city facilities. For large-scale development, the developer should be directed and encouraged to use rainwater. Due to its success, the number of local government who follow Sumida City's effort to subsidize rainwater tanks to their residents is around 30 today. Besides this, in July 2003, Fukuoka City Council adopted Japan's first ordinance to promote water conservation. It requires newly built large-sized building with more than 5000 sq. meters of floor space (or more that 3000 square meters in city center) to have installed a non-potable water system to use rainwater and recycled water. Owners of those buildings need to submit their water conservation plans when they erect new buildings or make expansions. Violators will be first warned, and then the names of those who ignore the warnings will be released publicly.

In all, subsidies are the main incentive given by local authorities to increase the use of rainwater utilization by their residence in Japan. Besides that, the authorities are also active in educating people on saving water, especially in school. They also encourage and subsidized new innovation on water saving equipment. The industry is responding by designing a more eco-friendly building. Compared to Japan that is a rich and highly developed, subsidies is rather expensive for our government. On the other hand, education program is practical and will benefit the country in the future. In addition few private companies in Malaysia have used the rainwater utilization system, notably the One Utama new wing complex. The saving made, at least in hundreds of toilet in such building, is huge. Government should encourage more of them and rate them as green or sustainable building.

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[9] http://www.brisbane.qld.gov.au/BCC:BRISWATER::pc=PC_1460, April 16, 2007

[10] http://www.sydneywater.com.au/SavingWater/InYourGarden/RainwaterTanks/Rebates.cfm, April 16, 2007

5.3 Texas, USA

As a drought sensitized state, Texas becomes one of the states in the USA that extensively use rainwater as its source of water. Although this old technology first use can be traced back as far as 4000 years ago in Negev Desert, it is enjoying a renaissance of sorts again. Texas Legislature has made several amendments to the Texas Constitution, Senate Bills and House Bills to encourage rainwater utilization.[11] For instance, under section 151.355, SB2, Subchapter H of the Texas Tax Code, Sales Tax Exemption is given for rainwater utilization equipment or supplies and water recycling and reuse equipment or supplies. In addition Property Tax Exemption for commercial installation is also given under section 26.045 to Chapter 26 of Texas Tax Code where it state "a constitutional amendment passed as Proposition 2 in 1993 to exempt pollution control equipment, including water-conserving equipment, from property taxes".

To make buildings in Texas more sustainable, the State Energy Conservation Office introduced Performance Contracting program. With regard to rainwater harvesting, it produced the Suggested Water Efficiency Guidelines for Buildings. It is a construction method that allows a facility to complete energy-saving improvements within an existing budget by financing them with money saved through reduced utility expenditures. This simply means "pay for the equipment through the savings in utility bills". Facilities make no up-front investments and instead finance projects through guaranteed annual energy savings. Performance Contracting is allowed under the Texas Education Code (Ch. 44.901, 51.927), the Texas Local Government Code (Ch. 302.004) and the State Government Code (Ch. 2166.406).

In the City of Austin, Green Builder Program is introduced to rate environmentally friendly house. Under the program, four aspects that are taken into consideration are energy, building materials, solid waste and water. To encourage water efficient building, the City produces simple rain barrel at the discounted price of $60 per barrel[12].   Rebate of up to $500 on installation cost of pre-approved rainwater utilization system for residential, and up to $40000 for commercial entities are provided under the Commercial Incentive Program. Besides this, in 2003, Hays County became the first county in Texas to provide the Rainwater Collection Incentive Program by offering a $100 development rebate and a property tax exemption of 100 percent of the cost of the installation[13]. If rainwater utilization serves as the sole source of water for a residence, the county grants property tax exemption from county taxes for the value of the system.

As a whole, Texas uses all form of incentives, legally, socially and financially, to encourage rainwater utilization. Malaysian legislature can follow its Texas counterpart to allow Sales and Property Tax Exemptions for such installation. It will be also be good if Malaysian local authorities can create simple and cheap barrel as in Austin. Performance contracting will also be a good example to follow. Both the facility and consumer will benefit from the program, one with increase sale and the other with reduced utility bills.

5.4 India

India faces both drought and monsoon season every year. As rainwater harvesting can provide water during water shortage and can curb flooding, India made rainwater harvesting compulsory in many parts of the country. Last year, the Rainwater (Compulsory) Harvesting Bill 2006 reached Lok Sabha, the upper house of the Indian Parliament. If the bill is accepted, rainwater harvesting will be compulsory to everybody in the country.

Existing compulsory harvesting policies are mainly based on individual municipality. For instance, the Kerala Municipality Building Rules, 1999 was amended in 2004 to include rainwater harvesting structures in new construction. In Tamil Nadu, the Tamil Nadu Muncipal Laws Ordinance 2003 made rainwater harvesting mandatory for all the buildings, both public and private, in the state. The ordinance also cautions, "Where

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[11] http://twdb.state.tx.us/**...**/reports/**RainwaterHarvesting**Manual_3rdedition.pdf , May 10, 2007
[12] http://www.ci.austin.tx.us/watercon/rbsales.htm , May 10, 2007
[13] http://rainwater.org/rainwater_collection_local.html , May 10, 2007

the rain water harvesting structure is not provided as required, the Commissioner or any person authorized by him in this behalf may, after giving notice to the owner or occupier of the building, cause rain water harvesting structure to be provided in such building and recover the cost of such provision along with the incidental expense thereof in the same manner as property tax". It also warns the citizens on disconnection of water supply connection provided rainwater harvesting structures are not provided.

Besides this, few areas, especially commercial areas, made it compulsory together with incentives to encourage installation. In Indore, Madhya Pradesh, rainwater harvesting has been made mandatory in all new buildings with an area of 250 sq m or more. Together with this, a rebate of 6 % on property tax has been offered by the Indore Municipal Corporation (IMC) as an incentive to encourage and motivate the public for implementing rainwater harvesting systems.[14] Similarly, 6 % rebate in property tax in the year in which the construction of rain water harvesting facility has been completed to the building owner is also offered in Gwalior, another city in Madhya Pradesh.[15]

The steps taken by India to make rainwater harvesting mandatory shows the seriousness of its government to have an efficient water resource management in the country and to have a more sustainable use of its natural resources. The steps taken by the Kerala Municipality in amending its Building Rules can be an example of implementing a new policy in Malaysia.

6. Implication of Compulsory Harvesting in Malaysia

It is acknowledged that voluntary rainwater harvesting would not lead to a significant progress to the number of installation in Malaysia. As mentioned earlier only few agencies have adopted the system. Hence the move by the government to make rainwater harvesting compulsory is a very welcoming effort.

Be that as it may, to make rainwater harvesting compulsory as in India would result in some implications on the existing legal provisions. Compulsory harvesting would involve amendment of certain laws since this attracts some planning, environmental and health issues. As design and requirement of a building are legislated under the Uniform Building By-laws 1984, it will be the most affected laws in this area. The proposed amended By-Laws shall require new buildings to include system installation in the layout plan. For a start it should apply to the large buildings and it will be the responsibility of the Public Work Department to refuse applications that do not comply with the new requirement. Nevertheless, this could be easier said than done as the developers who will practically implement this new policy might have other concerns such as the cost and technical issues[16].

Besides this, there are other related agencies; hence regulations on the planning and water related issues. To begin with, the control of land development, which is closely related to water resource management for sustainable development, falls under the Town and Country Department. This requires the need to amend certain provisions of the Town and Country Planning Act of 1976. In addition, the task of enforcing water quality is shared between the Department of Environment and the Department of Local Government. In this regard, the Environmental Quality Act 1974 and the Local Government Act 1976 may require some review. Besides this, the Department of Local Government is also responsible for planning approval and urban drainage, hence some assessment need to be made on the Street, Drainage and Building Act 1974. In all, detailed examination is needed with all these Acts to go through[17].

If Malaysia were to follow Texas steps in providing Tax Exemption, the Inland Revenue will have to provide such exemption by amending the Income Tax Act 1967. Initially, this may also entails budget implication, as some revenue will be reduced. However in the long run, rainwater harvesting can save the country a great deal amount of money when less money is needed for flood prevention or construction of new reservoir.

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[14] http://www.rainwaterharvesting.org/Urban/Practices-and-practitioners.htm, April 16, 2007

[15] http://www.unchs.org/downloads/docs/4179_35990_Policy%20Paper-2.pdf, April 16, 2007

[16] Othman, et. al. (2007), "Policies and Incentives for Rainwater Harvesting in Malaysia". Paper presented at the Rainwater Harvesting Colloquium, 19-20 April 2007, Dewan Baiduri, Wisma Sumber Asli, Kementerian Sumber Asli dan Alam Sekitar, Putrajaya.

[17] *Ibid.*

7. Conclusions

It is recommended that a combination of the methods practiced in Australia, Texas and India to be implemented in Malaysia for a successful rainwater harvesting policy in Malaysia. This ranges from rating system and tax redemption. From a legal perspective, the Uniform Building By-Laws could be amended to include a requirement for rainwater harvesting installation in buildings for the authority's approval. While Malaysia has, from time to time, experienced droughts or water shortage, things have yet to come to a critical stage where the people have no choice but to rely on rainwater as a main water source. It is recommended that rain water harvesting is introduced, initially on a small scale, such as drought or flood prone areas or highly populated cities, to assess public reaction. Since Malaysians are known to be slow in accepting changes, drastic measures could cause rainwater harvesting to fail. Monetary or economic incentives like cash or tax rebates and subsidies in purchasing or installing rainwater harvesting devices should be introduced to attract interest of members of the public. Besides this, education and awareness campaigns should start from the early stages to instill a sense of awareness. This may be included in the water and energy conservation topics under the environment subject or living skill in the school curriculum. As a matter of fact, the younger generation is the generation of the future. Thus, they should be equipped with knowledge on energy and water efficient building, as well as environmentally sustainable.

Acknowledgements

Department of Irrigation and Drainage

Ministry of Housing and Local Government

Ministry of Natural Resources and Environment

Ministry of Energy, Water and Communication

National Hydraulic Research Institute of Malaysia

Town of Country Planning and Development

Universiti Putra Malaysia

Universiti Tekonologi MARA

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Guidelines for Installing a Rainwater Collection and Utilization System, Department of Irrigation and Drainage, p.1

National Urbanization Policy, Town of Country Planning and Development, Policy 18 Clause (vi)

Othman, et. al. (2007). "Policies and Incentives for Rainwater Harvesting in Malaysia". Paper presented at the Rainwater Harvesting Colloquium, 19-20 April 2007, Dewan Baiduri, Wisma Sumber Asli, Kementerian Sumber Asli dan Alam Sekitar, Putrajaya.

DEVELOPMENT OF SAFETY CULTURE IN THE CONSTRUCTION INDUSTRY: A STRATEGIC FRAMEWORK

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Abstract

The construction industry is unique among industries. Construction activities often take place outdoor under conditions not conducive for safety and health. Workers in the construction sites have to face constant changes in the nature of work, the location of work and mixed workers. The nature of construction work is inherently dangerous and injuries are more likely to occur compared to other sectors. Most of accidents show that the construction industry is unique, involved with human behaviour, different construction sites, the difficulties of works, unsafe safety culture, dangerous machinery and equipment, and involvement with many procedures. Studies show that an accident and injury at the worksite are the result of workers' behaviour, work practices or behaviour and work culture. Safety and health culture are more related to workers' safety practices. An efficient safety management system, ought to be based on the safety awareness that become a culture in the construction industry where involving all the parties. The efficient safety culture and management system should be shown to the public, and as well as healthy and safely in environmental value business. This paper discusses the strategic framework in social aspects for the development of safety culture in the construction industry to ensure that construction industry (which is known as one of the dangerous industry) provides a safe working environment as well as become a safe and promising career. By understanding that safety culture is one of the alternative for the increment of competition mainly in international level, thus construction industry must have a safety culture in order to reduce number of accidents, fatalities and injuries that involves workers. Research finding show that for a long time, the construction industry which has been labelled with a poor occupational safety and health culture, can be improved through a strategic framework in management and leadership roles. As a result, there is a need for a major paradigm shift regarding attitudes on occupational safety and health in construction sites through the leadership roles and commitment.

Keywords: culture in construction, construction industry, safety culture, organizational culture

1. Introduction

The construction industry is unique among other industries as the activities of construction often take place in the outdoor under conditions not conducive for safety and health. Workers in the construction sites have to face constant change in the nature of work, the location of work and the mix of workers. The nature of construction work is inherently dangerous and injuries are more likely to occur compared to other industries.

By considering the situation of economy of construction industry, there are main issues facing the construction industry, namely; low quality, low productivity level, image, low level of ethics, lack of skilled labour and highly prone to of accident (Loosemore *et al.* 2003; Abdul Rahman, 2003). Most of the people tend to relate construction industry by dangerous working environment and high risk as compared to others. The reputation of construction industry is relying on the expertise of implementation and management of safety and also how it can be completed safely and meet the consumer's requirements (Hayes *et al.* 1986; CoVan, 1995; Mills, 2001; Loosemore *et al*. 2003; Root, 2005; Goetsch, 2005). A recent study on industrial accidents show that the frequency of injuries and fatalities occurring within the construction industry ranks amongst the top. Hardly a position to be envied. The construction industry has a disproportionately high number of industrial injuries.

One of the actions that can be undertaken in order to develop good or better image of construction industry is by providing safe working environment (Mohamad Khan *et al.* 2005). High accidents in construction industry are causing losses in number of labour and also losses in millions of ringgit of properties for every year in the country (CoVan, 1995; Alves Dias and Coble, 1996; Singh *et al.* 1999; Fong, 2000). If this situation is not reduced or prevented, it will disturb the country's economic growth to be a developed country in year 2020 (CIDB, 2000).

Nowadays, quality and safety are two main issues in construction industry. ISO 9000 has been promoted in construction industry to ensure the quality of construction work done by a contractor. Apart from quality, a safe working environment is necessary to put aside the current industry pictures of high risks in construction works. Construction safety is a standard of quality that is indicated in the contract and required by the client (Alves Dias and Coble, 1996). As projects become more complex, safety has become a main focus for ensuring safe both life and properties. There are developed countries such as UK and Australia have enforced practice safety rules in contractor's works on site. Revolution and changes in safety system management has become as a mandate in practicing safety action that can be managed interminable (Low and Sua, 2000). The worldwide construction industry is still practicing work process by labour intensive where based on wet trades. This factor contributes to the low quality of work due to the workers are lack of expertise and training and also exposed to the accident easily (CIDB, 2000).

Based on Human Factors Accident Theory, it shows that it is a link of events which are caused by human faults. In this theory three general factors that are causing human faults namely; overload, irrelevant response, and irrelevant activities. While based on Heinrich Theory, accidents are caused by main factor that can be predicted such as human faults, unsafe environment, or dangerous of mechanical (Goetsch, 1998). These accidents and injuries can be avoided by putting aside these factors. Current research shows that construction industry has been labelled as an industry that contains low safety culture and healthy. Compared to other industries, this industry has been indicated among having the highest accidents. The efforts of improving the safety and healthy of work for this industry will become useless until the safety and healthy culture could be improved (CIDB, 2000). The changes have to be undertaken by the construction industry towards establishing the paradigm of safety and healthy culture which may improve the safety and healthy level in line to the safety and healthy in construction industry entirely.

Most of the parties in the construction industry and consultants still do not realize the importance of safety management and unclear about the concept of safety system. The same goes to clients who only think the safety system as mere contract requirement. Most of the consultants are only following the instruction given by clients. They will just consider safety guarantee as a main priority without the ability to fully implement the safety system. The project financial management does not seem to regard safety system as priority. The main cause being that they cannot accept and agree to the reduced cost for safety management in order to abide by legal provisions and safety requirement, also the development of safety culture in construction site may not be fully implemented (Smallwood, 1996; Mohd Saidin *et al*. 2003).

The agreement to develop safety action among the parties requires changes of culture in construction industry (Lee, 2003; Mohd Saidin *et al.* 2006a). Nevertheless, it is uneasy and the process are limited. Besides procedures problems, other problems may exist such as refusal to execute changes and implementing the rules that has been stated in the safety management system (Stewart, 2002).

The concept of culture was first known to represent, in a very broad and holistic sense, the qualities of any specific human group that are passed from one generation to the next. This includes religion, way of life, values and beliefs of people. This is known as 'social culture'. People born in a particular culture are expected to believe and behave differently from others (Shamil Naoum, 2001). Similar to social culture, each organization has its own culture dominated by its values and behaviour. This is known as 'organizational culture'. According to Booth (1995), the term safety culture was introduced to the nuclear safety debate by the International Nuclear Safety Advisory Group of International Automatic Energy Agency (IAEA) in their analysis of the Chernobyl disaster. IAEA (1986) defines the safety culture of an organisation as the product of individual and group values, attitude, competencies and patterns of behaviour that determined the commitment to, and the style and proficiency of an organisation's health and safety programmes. Overall safety culture can be described as a set of beliefs, norms attitudes and social technical practices that are concerned with minimising the exposure of individuals, within and beyond an organisation, to conditions considered dangerous or injurious.

Cooper (2000) theoretically defined safety culture is a sub-facet of organizational culture, which is thought to affect member's attitudes and behavior in relation to an organization's ongoing health and safety performance. He argued that defining the product of safety culture is very important to clarify what a safety culture should look like in an organisation. He added that this could also help to determine the functional strategies required to develop this product. It could provide an outcome measure to assess the degree to which organisations might or might not possess a 'good' safety culture. This outcome has been severely lacking in construction.

This paper discusses the strategic framework in social aspects for the development of safety culture in the construction industry.

2. Issues and Problems in Safety Culture

Jones (1997) stated that safety is part of important aspects which should be given an attention and guidance to improve the stated safety management to stronger safety culture. Some can be used like the method to improve safety management, plant and equipment, and workers involvement. Two fairly distinct approaches to managing workplaces safety have competed for attention and have generated a considerable amount of debate and controversy during the past decade. The first of these approaches, behavior-based safety, focuses on the identification and modification of critical safety behaviour, and emphasizes how such behaviors are linked to workplace injuries and loses. The second approach, in contrast, emphasizes the fundamental importance of the organization's safety culture and how it shapes and influences safety behaviors and safety program effectiveness. Adding to this mix, each movement has recruited its own persuasive proponents and vocal detractors. On the surface at least, the two approaches appear to be indirect opposition to each other and represent two entirely different world views of injury causation and safety management (Dejoy, 2005).

Safety culture in construction community can be very low. Looking at that weakness in these characteristic and human attitudes, it can be concluded that to protect from accidents need changing of paradigm in the characteristic and human attitudes. Previous reactive and bad attitudes be a norm, should be changed to positive and proactive culture (Mohd Saidin *et al.* 2006b).

An organization's upper-level management has long been recognized as playing a critical role in promoting organizational safety culture (Dedobbeleer & Beland, 1991; Fleming *et al.* 1996; Flin *et al*. 2000; Gordon *et al.* 1996; Yule *et al.* 2001; Zohar, 1980; 2000). Organizational commitment to safety refers to the extent to which upper-level management identifies safety as a core value or guiding principle of the organization. An organization's commitment to safety is therefore reflected in the ability of its upper-level management to demonstrate an enduring, positive attitude toward safety, even in times of fiscal austerity, and to actively promote safety in a consistent manner across all levels within the organization. When upper-level management is committed to safety, it provides adequate resources and consistently supports the development and implementation of safety activities (Anderson, 2000; Marlow and Weyman, 2004). An organization's commitment to safety is therefore ultimately reflected by the efforts put forth to ensure that every aspect of its operations, such as equipment, procedures, selection, training, and work schedules, are routinely evaluated and, if necessary, modified to improve safety. Safety culture is a culture based on the premise that safety is the priority, the way of life. All activities and processes are accomplished with safety in mind (Helmer, 2002).

3. Safety and Organizational Culture

Culture is defined as those practices common to a group of people. In this context, safety can be expressed in simple direct terms as behavior affected by culture. Note that this topic encompasses both management behavior (action or inaction) and employee behavior (Eckhardt, 1996). Culture is further defined as missions interacting with work processes and corporate values to generate behavior (McSween, 2003). How a company’s mission is understood, followed by expectations and processes, determines behavior.

Organizational or corporate culture as defined by Handy (1993) is the 'pervasive way of life or set of norms and values that evolve in an organization over a period of time'. Norms are unwritten but accepted rules which tell people in organizations how they are expected to behave. They may be concerned with such things as how managers deal with their staff (management style), how people work together, how hard people should work or the extent to which relationships should be formal or informal. Values are beliefs on how people should behave with regard to such matters as care and consideration for colleagues, customer service, the achievement of high performance and quality, and innovation.

It should be noted that the proposed definition of safety culture is stated in neutral terms. As such, the definition implies that organizational culture exists on a continuum and that organizations can have either a good or poor safety culture. However, not all definitions in the literature make this assumption. Some suggest that safety culture is either present or absent within an organization. Nevertheless, it is clear from the initial introduction of the term within various operational environments that safety culture is assumed to be a component of an organization that can be improved rather than simply instilled (IAEA, 1986; Cox & Flin, 1998). Obviously, such a distinction is important when it comes to both measuring and changing safety cultures within organizations. More specifically, safety culture is seen as a subfacet of organizational culture and exists at a higher level of abstraction than safety climate. It seems plausible that safety culture and safety climate are not reflective of a unitary concept, rather, they are complementary independent concepts (Cooper, 2000).

4. Cultural Change

Cultural change aims to change the existing culture of an organization. Organizational or corporate culture is the system of values (what is regarded as important in organizational and individual behaviour) and accepted ways of behaviour (norms) which strongly influence 'the way things are done around here'. It is founded on well-established beliefs and assumptions.

Organizational culture is significant because it conveys a sense of identity and unity of purpose to members of an organization, facilitates the generation of commitment and helps to shape behaviour by providing guidance on what is expected. It can work for an organization by creating an environment which is conducive to high performance. It can work against an organization by encouraging unproductive behaviour. Strong cultures will have been formed over a considerable period of time and have more widely shared and more deeply held beliefs than weak ones. Strong cultures are only appropriate if they promote desirable behaviour. If they do not, they are inappropriate and must be changed (Armstrong and Stephens, 2005).

5. Safety Culture: A Strategic Framework in Social Aspects

Glendon and McKenna (1995) stated that effective safety management is both functional (involving management control, monitoring, executive and communication subsystems) and human (involving leadership, political and safety culture sub-systems paramount to safety culture). The concept of safety culture emerged from earlier ideas of organisational climate, organisational culture and safety climate. They described safety culture as the embodiment of a set of principles, which loosely defines what organisation is like in terms of health and safety.

In this approach, safety is looked into from the culture point of view of shared characteristics of a group dynamic relating to a system (e.g. group, community, race, nation, religion) which include beliefs, values, attitudes, opinions and motivations. Glendon and McKenna (1995) pointed out that building a safety culture on so many diversities is not an easy task. But it had been proven that organisations with good safety cultures have employees with positive patterns of attitude towards safety practice. These organisations have mechanisms in place to gather safety-related information, measure safety performance and bring people together to learn how to work more safely. Ostrom *et al.* (1993) looked at the employees' perceptions of safety culture as follows:

- management attitudes towards safety;
- perceived level of risk;
- effects of work pace;
- management actions towards safety;
- status of safety adviser and safety committee;
- importance of health and safety training; and
- social status of safety and promotion.

Safety culture involves the participation of everyone in the organisation. On site, it involves everybody from the project manager to the general worker. In order to cultivate the positive beliefs, practices, norms and attitudes among all in organisation, it is important to know the characteristics of safety culture.

Booth (1995) listed the characteristics of safety culture as follows:

a) The many separate practices interact to give added effect and, in particular, all the people involved share similar perceptions and adopt the same positive attitudes to safety - a collective commitment.

b) The synergy of a positive safety culture is mirrored by negative synergy of an organisation with poor safety culture. Here, the commitment to safety of some individuals is strangled by the cynicism of others. The whole is less than the sum of the parts.

c) The dominant themes for safety culture are:

- the crucial importance of leadership and the commitment of all chief executives;
- the safety role of line management;
- the involvement of all employees;
- openness of communication; and
- demonstration of care and concern for all those affected by the business.

Creating a culture of safety means that the employees are constantly aware of hazards in the workplace, including the ones that they create themselves. It becomes second nature to the employees to take steps to improve safety. The responsibility is on everyone, not just the management. However, this is a long process to get to that point (Dilley and Kleiner, 1996).

Safety and health culture within a company is closely linked to the workforce's attitudes in respect to safety. They share the company's risk, accidents and incidents. According to Glendon and McKenna (1995), effective safety management is both functional (involving management control, monitoring, executive and communication sub-systems) and humanizes (involving leadership, political and safety culture sub-systems paramount to safety culture). The role of management and the involvement of all employees as important key players in safety and health culture are important in order to cultivate the positive beliefs, practices, norms and attitudes among all in the company. Building a safety culture on so many diversities is not an easy task. But it had been proven that companies with good safety and health cultures have employees with positive patterns of attitude towards safety and health practices. Companies need to gather safety-related information, measure safety performance and bring people together to learn how to work more safely. Glendon and McKenna (1995) also identified four critical indicators of safety culture. They are:

a) Effective communication, it leads to commonly understood goals and means to achieve them at all levels.

b) Good organizational learning, whereby organizations are able to identify and respond appropriately to changes.

c) Organizational focus upon health and safety, how much time and attention is essentially paid to health and safety.

d) External factors, including the financial health of the organization, the prevailing economic climate and impact of regulation and how well these are managed.

The theoretical and empirical development of safety culture and climate has followed the pattern set by organizational culture and climate, although to a lesser extent. As stated previously, most efforts have focused on the empirical issues surrounding safety climate although it is possible to identify theoretical development of concepts within the safety culture literature. Also, the terms safety culture and safety climate have been used interchangeably in the literature (Cox & Flin, 1998). Cox and Cox (1996) also demonstrated this point by likening culture to personality, and climate to mood. Conducting a survey will assess the current mood state of an individual. Some responses may be indicative of the individual's stable underlying beliefs, constructs and personality but overall, the survey will reflect how the individual feels at that point in time. The comparison between culture and personality seems attractive because personality is relatively stable over time whereas climate and mood can be susceptible to short-term fluctuations (Pervin, 2003).

Creating a safe and healthy work culture requires the inculcation of safe and healthy practices as part of everyday life, at work and at home among all the workers in Malaysia. Culture means doing something automatically, spontaneously, without having second thoughts about it. In occupational safety, a safety culture means automatically correcting a hazardous act of job task or eliminating a hazardous condition. In occupational health it means automatically undertaking measures to ensure protection from health hazards at the workplace using personal protective equipment and without having to be told repeatedly to do so (Lee, 2003).

6. Concept of Safety Culture in Construction Industry

Today, the changes in safety management have opened a new outlook to war safety. It is no longer being treated as secondary in the business context rather it is treated as a culture. More emphasis is being put on ensuring everyone understand the importance of safety and changing the attitude and behaviour is the hard task. Safety is not only the manager's responsibility but everyone must play part (Stewart, 2002). Fig. 1 shows the strategic framework of safety culture development. The development of safety culture based from the framework that views the overall of individual to group responsibility that develops the total value of safety culture which support from the organisational culture. Everyone must play part in the organisational culture to ensure everyone understand the importance of safety and changing the attitude and behaviour through the instrinsic and extrinsic element of the culture. Organisational culture will be transmitted to all organisation activities which involved intrinsic and extrinsic elements of the organisation. This will in turn be transmitted to every member in the organisation. All instrinsic and extrinsic elements of culture will affect the organisation culture throughout the development of safety culture. Consequenly, it makes the concept of safety culture more acceptable and receives wider attention. It does not mean that the safety system nowadays is not relevance for practices, but this system will function well when the organization have developed safety culture. The reason can be seen from different aspects: the existence of barrier in safety system which may be less if the organization can develop strong safety culture.

For a long time, the construction industry has been labeled with a poor occupational safety and health culture. Efforts to improve occupational safety and health performance will not be effective until the occupational safety and health culture is improved (Mohd Saidin *et al*. 2006a). As the result, there is a need for a major paradigm shift regarding attitudes on occupational safety and health in construction sites (Glendon and Stanton, 2000). Widening the understanding of behaviour increases insight into possible targets for improvements, for example better planning, more effective job design, or more comfortable personal protection. Human behaviour influence on safety performance is enermous. Therefore this root problem must be managed effectively.

The legislation has changed over the years with more emphasis on safety at work. Still today the rules and regulations are being improved to make the working environment safe. Besides the effect of laws, many safety activism factors also influence the decision of modern managers regarding health and safety such as the active role of the trade unions, consumerism and the legal battle by accident/incident victims. All these factors are forcing managers to change their attitude towards safety. It is clear that working environment safety is going to be better. Managers are now adopting proactive approaches towards safety.

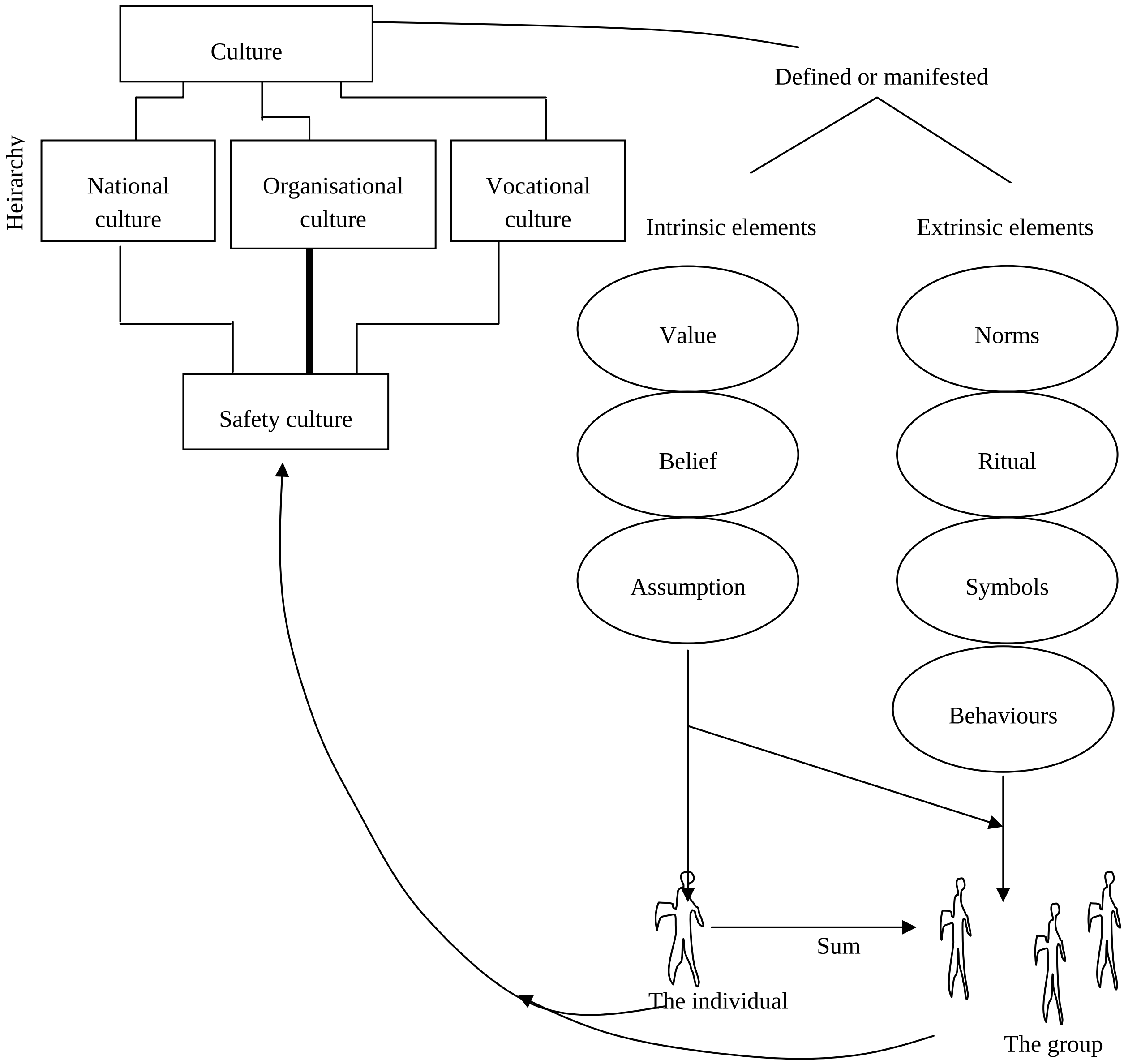

Fig. 1: Strategic framework of safety culture development.

7. Conclusions

In summary, there appears to be considerable evidence suggesting that organizational and contextual factors are important in terms of a variety of workplace safety related outcomes. However, current definitions of safety culture remain rather vague and variable, and current knowledge does not permit precise statements about which factors are most important in which organizations or situations. Also, systematic studies evaluating field-based interventions specifically targeted to safety culture change are conspicuous in their absence. But this is perhaps not that surprising given current conceptual and measurement limitations. It is also worth noting that intervening into the culture of an organization is difficult under the best of circumstances, because it requires that the organization be willing to look at itself and make fundamental changes in the way it pursues its core activities. These limitations not withstanding, the importance and usefulness of organizational culture as it pertains to workplace safety appears to be broadly accepted by researchers and practitioners alike.

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A PRELIMINARY SURVEY OF THE APPLICATION OF INDUSTRIALISED BUILDING SYSTEM (IBS) IN KEDAH AND PERLIS MALAYSIAN CONSTRUCTION INDUSTRY

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Abstract

Statistic shows that between 1995 to 2020, Malaysia will need a total of 8,850,554 houses, including 4,964,560 units of new housing to cater for an increase in population during this period. In the 7th Malaysia Plan, the country intended to construct about 800,000 units of houses for its population. Indeed, 585,000 units or 73.1% were planned for the low and low medium cost houses. Industrialisation is a process of social and economic change whereby a human society is transformed from a pre-industrial to an industrial state. It is a part of wider modernisation process through the technology system and one of the solutions for this increasing housing demand. One such technology is the industrialised building system (IBS). In Malaysia, since 1998, the Construction Industry Development Board (CIDB) has been actively promoting the use of IBS in the local construction industry by deploying large funds for research, developing standards as well as implementing various training and promotional programs. Although the IBS system improves the quality of projects, easier to control, reducing rectification work and lowering the total cost of construction, the trend of IBS usage in Malaysian construction projects are still below the national target. This paper highlights the application of the IBS among developers in Kedah and Perlis areas, the types of system used, and the barriers behind the low usage of IBS among developer companies in those areas. Solutions for encouraging the use of IBS for the construction industry have also been identified.

Keywords : Industrialisation, IBS, quality, housing developers, construction industry.

1.0 Introduction

Between 1995 to 2020, Malaysia will need a total of 8,850,554 houses, including 4,964,560 units of new housing to cater for increase in population during this period. In the 8th Malaysia Plan, the country intended to construct about 600,000 - 800,000 units of houses include the low and low medium cost houses for its population. Unfortunately, only 1,382,917 units were constructed under the 6th (1991-1995) and 7th (1996-

2000) Malaysia Plan. The achievement are somewhat disappointed with only 20% completed houses reported despite numerous incentives and promotions to encourage housing developers to invest in such housing category (Ismail, 2001). Majority of the developers and contractors are still using the conventional building system method which could not cope with the huge demand. Therefore, the former system must be replaced by an industrialised building system (IBS) which has immense inherent advantages in term of productivity, indoor quality, durability and cost (IEM, 2001).

2.0 Definition and Classification of IBS

The Industrialised Building System (IBS) is a construction process that utilises techniques, products, components, or building systems which involve prefabricated components and on-site installation. (CIBD, 2003).

An industrialised building system (IBS) may be defined in which all building components such as wall, floor slab, beam, column and staircase are mass produces either in factory or at site under strict quality control and minimal on site activities (Rollet, 1986; Trikha, 1999).

Comprehensive definition of IBS was explained by Junid (1986), IBS in the contruction industry includes the industrialised process by which components of a building are concieved, planned, fabricated, transported and erected on site. The system includes a balanced combination between the software and hardware components. The software elements include system design, which is a complex process of studying the establishment of manufacturing and assembly layout and process, allocation of resources and materials and definition of designer conceptual framework. The software elements provide a prerequisite to create the conducive environment for industrialised building system to expand.

The hardware elements are categorised into three groups. These includes frame or post and beam system, panel system and box system. The framed structures are defined as those structure that carry the loads through their beams and girders to column and to the ground whilst in panel system load are distributed through large floor and wall panels. The box system include those systems that employ three-dimensional modules (or boxes) for fabrication of habitable units that are capable of withstanding load from various direction due to their internal stability.

From the structural classification, there are five IBS main group identified as being used in this country. There are Pre-cast Concrete Framing, Panel and Box Systems (Pre-cast coloumn, beam, 3-D components (balconies, staircases, toilets, lift chambers), permanent concrete formwork), Steel Formwork Systems (Tunnel forms, beams and columns moulding forms, permanent steel formwork), Steel Frame System (Steel beams and columns, portal frames, roof trusses), Prefabricated Timber Framing Systems (Timber frames, roof trusses), Block Work System (Interlocking concrete masondry units (CMU), lighweight concrete block).

3.0 Benefits of IBS

The IBS construction method is more favorable for the construction of apartments especially in the midst of labor shortage. It offers better cash flow, speed and quality, consistency and better safety features or measures during construction.

The system is labor efficient, thus reducing the use of general labor at construction stage and splitting the construction sequence into two sites; slab casting and wall casting. Precast methods use less labor (30 %) than that of conventional method. (SP Precast, 2003).

IBS offers improved cash flow to developers as they could claim the costs from purchasers as early as two weeks upon erection of building panels comBased on the standart SPA, IBS concrete precast offers a claim of 45% from purchasers within a period of two weeks upon the erection of panels. In comparison to a period of at least ten months for the conventional method.

The IBS system is faster compared to the conventional construction for large volume of apartment construction. The speed of construction is governed by the speed of production. The client's requirement on fast delivery can easily be met by increasing the production capacity of the precast yard.

IBS offers safety features and procedures which are easily complemented during construction stage.

Others benefits of IBS include :

a) The repetitive use of system formwork made up steel, aluminium, etc and scaffolding provides considerable cost savings (Bing et al. 2001).
b) Contruction operation is not affected by adverse weather condition because prefabricated component is done in a factory controlled environment (Peng, 1986).
c) Prefabrication takes places at a centralised factory, thus reducing labour requirement at site. This is true especialy when high degree of mechanisation involved (Warszawski, 1999).
d) An industrilised building system allows flexibility in architectural design in order to minimise the monotony of repetitive facades (Warszawski, 1999).
e) An industrialised building system component produces higher quality of components attainable through careful selection of materials, use of advanced technology and strict quality assurance control (Din, 1984).

4.0 The Implementation of IBS in Northern of Malaysian

The industrialised building system's application in Malaysia began with two government pilot projects. The first IBS project use were constructed at Jalan Pekeliling which included the construction of 7 blocks of 17 storey flats, and 4 blocks of 4-storey flats and 40 storey shops lots (W.A.M. Thanoon, et al. 2003). The second pilot project was built in Penang with the construction of 6 blocks of 17 storey flats and 33 blocks of 18 storey flats along Jalan Rifle Range. The project used French Estiot System (Din, 1984).

In Northern Malaysia (Kedah dan Perlis), the usage of the IBS in the construction project is still small. Based on the survey amongst housing developers around Kedah and Perlis, statistic shows that majority of respondents have not use IBS in their projects. Out of 76 developers, only 24 of them have used IBS systems whilst the remaining still using the conventional method.

Based on the statistical results, most of the IBS projects were implemented in the developed area such as Alor Setar (30%) followed by Sungai Petani (30%), and Kulim (30%). The remaining 30 percent were implemented in Jitra and Changloon (15%) and Kangar and Arau (15%). The IBS system was used to build College Matriculation Center, schools, high institution centers, and government quarters. Studies on system types show 25% used framing system and steel formwork system. Steel frame systems are popular due to government's policy in encouraging the use of steel trusses in government buildings and housing. The third popular IBS system is concrete precast system (24%) and followed by timber frame and blockwork system.

5.0 Barrier to the Adoption of IBS

Based on the survey conducted in 2004 to 2005 in Kedah and Perlis, the adoption of IBS within the construction industry is small. There are several general reasons for the slow uptake including:

a) Fully prefabricated construction system requires high construction precision. Malaysia's labour forces still lack skilled workers. Many of foreign skilled workers had left the country after the wide spread crackdown on illegal foreign workers on July – September 2002. The new batches of foreign workers do not possess the required skill and have to be retrained.

b) Developers prefer to use the conventional method of building system because it is far easier to lay off workers during slack period and requires no retraining of IBS skill. Statistic show that 21 % of the respondents agree to conventional method which they regard as easier to use compared to IBS.

c) The construction industry is so fragmented, diversified and involved many parties. Consensus is required in the use of IBS during planning stage. However, the owners, contractors and engineers still lack scientific information about the economic benefits of IBS. Based on this survey, this is a top barrier factor contributing to the slow uptake of IBS.

d) Lack of incentives and promotion from government in use of IBS. Many architects and engineers are still unaware of the basic element of IBS such as modular co-ordination. This statement was supported by 21 % of the respondents from the survey which admit to the lack of exposure in IBS. The economic benefits of IBS are also not well documented.

e) Small and limited construction project. Most of the construction industry project in Kedah and Perlis especially housing projects, are of maximum 200 units with majority if them being single storey houses. Hence, it is not efficient to use IBS in those areas.

f) Internal barriers factors such as the company policies. Out of the total of 32 developers being surveyed, 5 respondents agree that company policies serve as one of the barrier.

6.0 Solutions and Improvements of IBS Implementations in Malaysia

Based on the research and views of experienced people involved in the IBS construction system, the following recommendations for improvements are proposed:

a) Buyers or costomers often complain about the poor quality of house that they have bought. To solve this problem, manufacturers must ensure that, the components of IBS design should pass the quality control measures/department before sending to the site. The installer should be an expert or experienced.

b) The government should be ready before deciding the use of IBS as a new contruction method. The government must ascertain that IBS are applied in according to the project requirements. The should identify capable suppliers or manufactures to supply products (panel) until completion of the project

c) There is the perception that precast housing is not flexible in term of renovation works. A hybrid system that caters for client who often renovates but at the same time keeping the structure intact was developed by Setia Precast Sdn. Bhd. This system offers much less wastages and provides speed to the contractor at no costs and extra headroom, a consistent finish and flexibility for renovation.

d) As the building height increases, crane capabilities and costs become a major concern. For taller buildings tower cranes are found to be more cost-effective, however this limits the sizes of precast components that could be handled. Alternative methods involving combination of walls, columns, beams and modular half slabs have been developed by the industry, to facilitate highrise construction.

7.0 Conclusions

This paper provides an overview of the application of industrial building system from the developers' perspective. Recommendations for solutions and improvements are given so as to encourage the use of IBS in Malaysia. In conclusion there is still a considerable amount of efforts to be done by the various authorities and government to encourage the use of IBS in th construction industry.

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GREENING ENGINEERING EDUCATION FOR SUSTAINABLE DEVELOPMENT

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Abstract

The success of sustainability in design and in the built environment relies on how institutions of higher learning respond to the ideas generated as a result of widespread interest in sustainable development. If sustainability is to become an essential aspect of society and economical development then it has to become an essential part of education.

The paper highlights existing engineering education in construction, opportunities for change and their challenges towards achieving a greener engineering education. Clearly, studies showed that a complete integration of sustainable development across the curriculum, i.e. in all modules and parts of relevant subjects and activities through all phases is needed in encouraging sustainable practices in civil engineering fields. The fundamental idea is that when sustainability is to become essential for all activities within society and all sectors of economy, it cannot remain as an isolated field of expertise but must form mindset for everyone

For a real sustainable development oriented engineer / designer, students must be trained to handle systems approach for finding sustainable solutions and implementation options for the short and for the long term and these require multi-disciplinary and lateral thinking.

Keywords: Sustainable development, education, engineering, multi-disciplinary

1. Introduction

The main goals of sustainable design are to avoid depletion of resources including energy, water, and raw materials; prevent environmental damage caused by buildings and facilities throughout their life; and create building environments that are livable, healthy, and productive. A sustainable building design aims to:

- Optimize Site Potential
- Minimize Energy Consumption
- Protect and Conserve Water
- Use Environmentally Preferable Products
- Enhance Indoor Environmental Quality (IEQ) and
- Optimize Operational and Maintenance Practices

Sustainable building is a challenge for the engineering community, as it is multi-disciplinary. Ideally, all of engineering graduates working towards careers such as designers, managers or researchers, should be prepared for the challenge of sustainable development and as such, they should leave university able to make sustainable development operational in their designs and daily practices.

Teaching engineering students how to incorporate sustainability in their work is not an easy job, as there was a lack of teaching experience and study material. To tackle this lack, various approaches were developed. As time went by, a fast growing number of institutions are struggling with the same problems.

The paper highlights existing engineering education in construction, opportunities for change and their challenges towards achieving a greener engineering education.

2. Challenges in engineering design

Designing and constructing safe and secure buildings have always been primary goals for owners, architects, engineers, and project managers. However, since the tragedy of September 11, 2001, there is increased concerned on safety design issues.

For designing the new generation of buildings engineers/ designers must no only strive for the sustainability objectives and also safe-security objectives. At the surface, it may appear that secure/safe design has very little relationship to sustainable design. Yet, security and safety measures, such as those for anti-terrorism must be considered within a total project context, including impacts on occupants and the environment irrespective of the level of protection. Hence, it is therefore necessary to provide engineers/ designers with an understanding of the interaction between security/safety and sustainability objectives.

A successful balance between economic, social and environmental effects can only be achieved by an overall approach to building design –whole building approach. The understanding of the whole building approach to engineers/designers is vital as it takes into consideration the interaction of the whole building structure and systems, and its context. In the past, research into isolated building components did not take into account how individual systems affect other systems.

Whole buildings design not only examine at how materials, systems and products of a building connect and overlap but also look at how the building and its systems can be integrated with supporting systems on its site and in its community. Incorporating this perspective into the designing, planning, and building stages can have significant effects on the outcome. For example, efficiency improvements that might be hard to justify on their own accord are seen in a different light when they result in a smaller heating and cooling system for the building. Synergies such as these are common in building designs, but are often overlooked. Such consideration of potential synergies will foster the use of advanced building technologies that incorporate solar and other forms of renewable energy; and an integrated approach both to new-building construction and old-building renovations. Hence, the fundamental challenge of whole building design is to understand that all building systems are interdependent.

Designing for a secure/safe and sustainable facilities for buildings must be planned from the conception stage. The level of security/safety and sustainability incorporated in a facility varies greatly from project to project. Tall and iconic buildings have greater security risks will have to be given a comprehensive analysis on the various threat, vulnerability and risk assessment before security requirements can be identified and the appropriate reasonable design responses are integrated into the building design. Technical buildings benefit from whole building design where the integration of building systems contribute to the overall performance of the building during operations and emergencies.

Since the World Trade Centre tragedy, there is increasing emphasis for a holistic approach to design taking into consideration all aspects of safety including structural, egress and fire safety to enhance building performance in emergencies. The interaction of professions in design are crucial whereby the structural, fire protection, mechanical, architectural, blast, explosion, earthquake and wind engineering communities need to work together to develop guidance for vulnerability assessment, retrofit and to mitigate the probability of progressive collapse of tall buildings under hazard scenarios. (FEMA, 2002)

One of the challenges of designing a sustainable and safe/secure building will require the ability to think on trade-offs and synergies and creative solutions to achieve effectiveness in designs. Daylighting, natural shading, energy efficient, photovoltaic facades, wind power systems and sky gardens within buildings add up to a significant shift towards a more sustainable design of buildings. Balancing any these sustainable features with safety/security needs will be a real challenge to engineers/designers especially for a given budgetary constraint.

Most of the building stock existed even before the sustainable building agenda arise and therefore they present some of the best opportunities for implementing sustainable construction practices, particularly to improve energy efficiency. In this respect designers will have a choice to consider and balance the benefits of converting existing buildings (rather than demolishing and rebuilding them) in terms of reduced materials use and waste against the opportunities for designing a new building with low energy requirements, and using renewable energy.

Currently, best practices on sustainable building construction which view building construction in a holistic way is lacking. Such is needed to provide engineers/designers with examples of effective design which presents the whole–life picture in a cradle to grave or cradle-to-cradle assessment. The support from a new generation of designers equipped with a multi-disciplinary knowledge on building systems will compliment to these efforts in achieving designs which are attractive, cost effective, energy efficient and flexible in meeting the needs of the occupants.

3. Implications on Engineering Design Education

3.1 Sustainability

The success of sustainability in design and in the built environment relies on how institutions of higher learning respond to the ideas generated as a result of widespread interest in sustainable development. If sustainability is to become an essential aspect of society and economical development then it has to become an essential part of education.

A complete integration of sustainable development across the curriculum, i.e. in all modules and parts of relevant subjects and activities through all phases is needed in encouraging sustainable design in buildings. The fundamental idea is that when sustainability is to become essential for all activities within society and all sectors of economy, it cannot remain as an isolated field of expertise but must form mindset for everyone (Venselaar et al, 2002).

Each course, project and other activity in the normal curriculum takes care of the issues relevant for sustainability connected with its own subject such as materials use , energy, design approaches, economics, etc.

Students must be trained to handle systems approach for finding sustainable solutions and implementation options for the short and for the long term. It requires multi-disciplinary and lateral thinking. The attitude and the competencies to do that are essential for a real sustainable development oriented engineer/designer.

3.2 Whole building education

The construction industry is fragmented where designers, engineers, and contractors perform their respective tasks without regard to the project whole. Similarly, most existing construction programs use the modular approach to education that provides well-conceived individual classes however fail to provide students with a complete understanding of how building systems are integrated.

The development of a whole building approach to design and construction education that will allow students to understand not only the parts of a building, but also whole building operations are vital. New curricula and techniques are needed for whole building education emphasising on how buildings are developed and designed, and how interdisciplinary teams can be used to maximize energy efficiency, reduce resource waste, and improve the environmental quality of the buildings being constructed.

3.3 Curricula

An implementation of the whole building design approach can be introduced into design classes. Innovative building materials and specifications can be incorporated into construction materials classes. The whole building education will provide holistic, integrative experiences for undergraduate students. This will respond to the increasing demands from the building industry for a more integrated approach to education as a means of securing closer and more effective collaboration among building design professionals (Jones,1998).

Based on the whole building system, energy efficiency and indoor air quality can be used to guide the curricula of Electrical and Mechanical classes. By using software tools like DOE 2 students can understand how equipment decisions affect energy performance. Whole building thinking can also be easily integrated into design build curricula.

Design through modeling and predictive simulation should be an important part of the design curriculum program to assist in the understanding of integrated design.

3.4 Collaborative learning

Since building systems are inter-related and that many design solutions may lead to other design problems therefore the design concept advocates to the use of inter-disciplinary teams that focus on systems approach to building design and construction. In order to create a successful performance building, an interactive approach to the design process is required. It is necessary for the people responsible for the building design to interact closely throughout the design process and that everyone involved in the use, operation, construction and design of the facility must fully understand the issues and concerns of all the other parties.

Many improvements are necessary in the orchestration of the complicated process, in order to take benefit of available technologies and products. A collaborative learning approach introduced to students will expose them to real problems of building design. The recommendations for cross-disciplines seemed the best solutions for effective designs and therefore should be addressed accordingly by educational institutions so that future designers are able to respond to the industry needs.

3.5 Performance-based design

To date, many countries have already undertaken the development of performance-based specifications. Later, these specifications will likely be preceded by the development of performance-based building codes. Different stakeholders will benefit from performance based specifications. These specifications will improve the reliability of buildings and build in guarantees to reduce their environmental impact. Owners and manufacturers will benefit from the increasing opportunities to apply new materials and new technologies. (Augenbroe et al, 1998)

The wide spread adoption and implementation of the LEED rating system is closely linked to performance based standards. LEED rates the environmental aspects of a building and the behavior of its occupants to arrive at a final score that results in a platinum (highest level), gold, silver, or bronze plaque being awarded.

A wide range of issues are evaluated to include energy and water use, indoor health, recycling for occupants, access to mass transit, materials impacts, landscaping, construction waste management, building sites and maintenance.

The LEED benchmarking system for sustainable design is one way of tracking and quantifying the potential sustainable savings and is rapidly gaining recognition by the design community as a viable convincing mechanism.

Introducing performance based design in the design curriculum and use of evaluation methods applied by industries to assess building performance will provide qualified professionals relevant to industrial needs.

4. Industry education and Professional development

Industry education is needed to increase the awareness of stakeholders and professionals on current design practices and to facilitate mainstreaming of sustainable building design and construction. Current barriers to implementations of sustainable/high performance buildings include the lack of knowledge about the economic and environmental benefits of such buildings, as well as a dearth of familiarity with sustainable building concepts and practices.

Currently, the Green Building Council (GBC) from various parts of the world, the International Initiatives for Sustainable Built Environment (iiSBE), the International Council on Research Innnovation in Building Construction (CIB), The United Nations Environmental Programme (UNEP) and the United Nations Sustainable Building Construction Initiatives (SBCI) are promoting the sustainable building agenda. The United States Green Building Council trains designers, builders, owners, and operators of public and private facilities to implement green strategies. The manual offers step-by-step guidelines for energy-and resource-efficient building during predesign, design, construction, operations, and management. It also includes chapters on sustainable building economics and future issues and trends. These provides guidance for engineers, design professionals, contractors, product manufacturers, building owners and tenants, facility managers, utilities and management towards sustainable building practices.

5. University- industry research

An important implication to engineers is the substantial need for applied research in sustainable buildings to support the industry needs and performance improvement in buildings.

Engineers/ designers in industry would benefit if research produced tools, methods and theories that add structure to complex design processes and reduced design iterations. It is increasingly necessary to apply structured, methodical approaches to design projects. There needs to be an increased emphasis on robust design methods and validation. Better mechanisms for team decision-making are needed, including decision-making under risk and uncertainty [NSF (1995), Steemers (2003)].

6. Conclusions

Sustainability along with whole building thinking should be considered across the construction and design education curriculum to lead future tall building designers into a rapidly changing design and construction industry. The reform in engineering/design education to incorporate collaborative learning and lateral thinking is essential to respond to the increasing demands from the building industry for a more integrated approach to education and, a means of securing closer and more effective collaboration among building design professionals.

Industrial education is equally important to increase awareness in stakeholders and professionals on current design practices to encourage implementations of sustianbale buildings designs which are economical, social and environmental friendly.

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GREEN BUILDINGS AND SUSTAINABLE DEVELOPMENT: U.S. ENVIRONMENTAL INITIATIVES, RESEARCH, EDUCATION AND THE MALAYSIAN APPLICATION

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Abstract

The green building movement has gained considerable headway in the American landscape partly due to the steady increase in energy prices, concern over global warming and the health of building occupants. The Leadership in Energy and Environmental Design (LEED) rating system, developed by the U.S. Green Building Council (USGBC), is the de facto measure for green buildings in the U.S. By February 2007, 715 buildings were certified at various levels and 5300 projects registered in 12 countries worldwide. The success of USGBC/LEED rating system has catalyzed a series of initiatives in the government, educational institutions and the private sector. The U.S. federal government is passing various tax laws to encourage green construction. States, counties and cities are creating their own green building mandates in addition to offering financial incentives. Universities are leading the way in green buildings R&D. Elementary and secondary schools are increasingly incorporating hands-on environmental education into their curriculum. Lessons learned from the American experience could be adapted to the Malaysian context with support from the Government in collaboration with various universities, NGOs, and the private sector. This green building agenda could spawn economic growth with the development of new non-traditional businesses and at the same time create a healthy and sustainable future.

Keywords: LEED, green legislation, environmental education, green business, environmental stewardship, Eco-City

Introduction

In 1987 the World Commission on Environment and Development, under the direction of Norwegian Prime Minister, Gro Harlem Brundtland, defined sustainable development in the following terms: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." (Brundtland et. al., 1987). In the U.S., however, environmental issues only seem to be in the forefront of the public awareness in response to somewhat adverse events. In 1962 the awareness was heightened from the publication of Rachel Carson's "Silent Spring". Possibly the founding text for the contemporary environmental movement in the West, the book illustrated the impact of pesticides on human and environmental health, specifically the poisoning of larger animals and humans in an attempt to poison insects. In 1973, the OPEC oil embargo and skyrocketing energy prices prompted the U.S. government to establish the Federal Energy Office, Federal Energy Management Program, Federal Energy Administration Act (1973) and the Department of Energy (1977) to address energy use and conservation. Consequently, buildings were built tighter and better insulated yet no considerations were given to the building material properties such as toxic off-gassing which in turn compromise the health of the occupants.

Buildings fundamentally impact people's lives and the health of the planet. Green design makes a positive impact on public health and the environment in addition to reducing operating costs, potentially increasing occupant productivity, and helping create a sustainable community. The U.S. Energy Information Administration estimates that buildings have a significant impact on resources and the environment, representing 35% of total energy use, 68% of electricity consumption, 35% of greenhouse gas emissions, 35% of raw materials use, 30% of waste output and 12% of potable water consumption.

Leadership in Energy and Environmental Design: LEED

The U.S. Green Building Council (USGBC) is established to promote high-performance, energy-efficient, healthy building with minimal impact to the environment. It is a nonprofit coalition of nearly 3,000 companies and organizations from across the building industry. The USGBC developed the Leadership in Energy and Environmental Design (LEED) rating system as a voluntary standard to support and validate successful green building design, construction, and operations. LEED building certification ranges from LEED Certified, to Silver, Gold or Platinum level.

There are currently six distinct LEED rating systems to capture different building types, operation and development concepts. LEED-NC, the foundation of all other LEED ratings, is intended for commercial and institutional projects, with a focus on office buildings. LEED-EB measures and ensures sustainable operations and maintenance on existing buildings. LEED-CI is applicable to tenant improvements of new or existing office space. LEED-CS covers base building elements, such as the structure, envelope and building-level systems, such as central HVAC and other central systems. It is designed to be complementary with LEED-CI. LEED-Homes promotes a healthier and more comfortable home for the occupants in addition to using less energy, water, and other resources. Finally, LEED-ND promotes environmentally responsible and sustainable development by integrating the principles of smart growth, urbanism, and green building.

LEED-NC, the foundation of the LEED rating system, is divided into 6 different categories: Sustainable Sites, Water Efficiency, Energy and Atmosphere, Indoor Environmental Quality, Materials and Resources and Innovations in Design. The primary goal in "Sustainable Sites" is to minimize the impact of the development on the local ecology, neighborhood and the surrounding community. Building development and construction activities often contribute to the destruction of the surrounding environment as well as pollute the air and water, produce stormwater runoff, advance the loss of habitat along with other negative impacts on wildlife and the microclimate.

In the US, approximately 340 billion gallons of fresh water are withdrawn per day for residential, commercial, industrial and recreational purposes. Water conservation and efficient water use in buildings plainly lower water and sewage bills. In addition, lower demand for potable water supply and lower sewage output reduce the use of chemicals to filter water for human consumption and treat sewage for discharge into the waterways and ground filtration. Water efficient landscaping by using native plants or non-invasive adapted species, on-site water treatment, such as composting toilets, and constructed wetlands, and low-flow fixtures and waterless urinals could be employed to reduce potable water consumption in buildings.

Energy efficiency is central to achieving a green building. Renewable energies, generated both on and off-site, will minimize power demand from traditional forms of electric power generation, which contaminate and emit toxic fumes and large amounts of CO_2 to the atmosphere. Energy efficiency measures need to start with passive strategies through proper building massing and orientation, maximizing daylighting and natural ventilation in conjunction with a high-performance building envelope. These strategies may downsize or completely eliminate the need for a building mechanical system. Integrated designs and systems integration is key to achieving energy-efficient buildings with high levels of comfort for the occupants

The environmental impacts of the extraction, manufacturing, transportation and disposal of building materials are far-reaching. These activities lead to air and water pollution, destruction of natural habitats and depletion of natural resources. Construction and demolition waste alone contributes to approximately 40% of the total solid waste stream in the U.S. Sustainable strategies to minimize these negative impacts include re-using existing buildings, managing construction waste, using salvaged materials and recycled products, using local materials, rapidly renewable materials and wood products that are sourced from forests that practice environmentally responsible management.

Concerns over the quality of the indoor environment and sick building syndrome have prompted the need for optimal indoor environmental quality (IEQ). Minimum indoor air quality standards ensure the comfort and well being of building occupants. IEQ parameters include ventilation and thermal comfort strategies, offgassing from building materials, electric and day lighting and access to the outdoors. Green design strategies that greatly exceed or are not addressed by any LEED prerequisite or credit are acknowledged in "Innovations in Design" category. This category serves to accommodate emerging green technologies and R&D in building science.

Government Green Building Initiatives

Green buildings and sustainable design initiatives span from the federal and state levels to local municipalities and cities. Federal agencies including the Department of Energy (DOE), the Environmental Protection Agency (EPA) and the General Services Administration (GSA) have instituted programs toward greener and more sustainable federal buildings. The GSA is the largest building owner in the United States, managing space in over 8,000 buildings for over one million federal employees. GSA was USGBC's first federal member. The Agency's commitment to building green includes: LEED Silver for all new construction, cooperation with other federal agencies to promote sustainable building practices and products, incorporation of sustainable design language in GSA's design guide, training associates in sustainable design, increasing the purchase of green power, funding research in green buildings

GSA is currently funding the Center for Building Performance and Diagnostics at Carnegie Mellon University to study the link between the built environment and human satisfaction, health and productivity. Other agencies that adopt LEED or other green building rating systems into their building projects include the Department of Agriculture, the Department of Health and Human Services, the Department of Interior, the Department of State and the National Aeronautics and Space Administration (NASA). The US military; the Air Force, Army and Navy, are also incorporating LEED or similar or adapted rating tools into their building projects.

21 out of 50 American states initiated different sets of executive orders, legislation, tax credits and other forms of financial incentives to encourage sustainable design. Most of the states require a certain level of rating, with LEED Silver as the highest requirement at present. Oregon's Business Energy Tax Credit is tied to the achieved LEED certification level. A building earns more than 25% tax credit if it achieves a Gold certification instead of LEED Silver. For a hypothetical 100,000 square foot building, the value could amount to a tax credit of $140,000 for a Silver certification and a $177,485 for a Gold certification. Pennsylvania offers state funds in the forms of grants and loans, for energy efficiency and renewable energy projects. New York State Energy Research and Development Authority provides low interest loans (4% below market rate) for energy efficiency measures and building materials that meet LEED or other generally accepted green building standards.

Counties, municipalities and cities, devise various forms of initiatives to promote green buildings and sustainable development. Arlington County, Virginia, requires that all site plan applications for commercial projects include a LEED Scorecard and have a LEED Accredited Professional on the project team regardless of whether or not the project intends to seek LEED certification. In addition, all projects must contribute to a green building fund for countywide education and outreach activities, those contributions are refunded if projects earn LEED certification.

Scottsdale, Arizona, Portland, Oregon and Vancouver, British Columbia in Canada require that all new city buildings achieve LEED Gold. Scottsdale boasts being the first city in the US to adopt a LEED Gold policy. Montgomery County, Maryland even goes further by requiring buildings in the private sector of at least 10,000 square feet to achieve a LEED Certified or equivalent standard. San Francisco, California and Sarasota County, Florida give priority permit review for green buildings and sustainable developments.

A significant number of universities are adopting the LEED guidelines. While most of these universities are requiring LEED Silver certification for all new building projects, a few universities are, at a minimum, using the rating system as a standard of reference for construction and renovation projects. Montgomery County and the state of New Jersey Public School systems are incorporating LEED Guidelines in their building projects. Pennsylvania Public Schools provide a financial incentive to public school districts that achieve LEED Silver certification.

Federal Tax Incentives

The Energy Policy Act of 2005 provides tax incentives for conservation and energy efficiency programs. The regulations and guidelines required to implement a series of energy efficiency tax provisions for commercial buildings and homes were enacted in response to skyrocketing energy prices. The provisions include tax deductions and credits for energy efficient commercial buildings, construction of new energy efficient homes, non-business and residential “energy property”, energy efficient appliances, business installation of fuel cells and microturbine power plants, and business solar investment tax credit.

For implementing energy efficient measures, a tax deduction of $1.80 per square foot of property can be obtained for commercial buildings that consume 50% less energy and water compared to a baseline building. New homes that achieve 30% reduction in heating and cooling energy are rewarded with a $1000 tax credit and a $2000 credit for a 50% reduction. “Energy property,” such as insulation material or reflective roofing receives a tax credit of 10% of the materials purchase price. Energy efficient furnaces and hot water heaters receive a tax credit ranging from $50 up to $300. Tax credits for energy efficient appliances range from $100 for dishwashers and washing machines to $125 for energy efficient refrigerators.

In residential applications, photovoltaic panels garner a maximum tax credit of $2000, a maximum $2000 for solar water heaters and $500 for each 0.5 kilowatts of power generated by fuel cell. For commercial applications, on-site power generation technologies such as fuel cell can get a tax credit of $500 for each 0.5 kilowatts of power generated, micro-turbines earn a tax credit of $200 for each kilowatt of capacity. Power generation from on-site renewable sources such as solar and geothermal is also eligible for tax credits. The deductions and tax credits provide an incentive for consumers to use energy-efficient strategies and promote the development and manufacturing of green technologies.

Solar Decathlon Competition

The U.S. Department of Energy (DOE) sponsors a competition among universities to design, build, and operate the most attractive and energy-efficient solar-powered home. The solar houses are built at respective universities, disassembled for transportation to the National Mall in Washington, D.C., where they are re-assembled to form a solar village. The teams compete in multiple competitions in categories ranging from architectural and engineering design solutions to effective building appliance, hot water and lighting systems, occupant comfort and market feasibility, to determine an overall winner. Carnegie Mellon University is a long-standing participant in the Solar Decathlon competition. International universities from Canada, Spain and Germany have also participated in Solar Decathlon since its inception.

DOE sponsors Solar Decathlon in partnership with its National Renewable Energy Laboratory. This federal initiative is successful due to its collaboration with professional associations and the private sector such as the American Institute of Architects, the National Association of Home Builders and British Petroleum. The Malaysian Government could support a Solar Decathlon team or sponsor a regional competition, starting with South East Asian countries, focusing on green buildings using renewable energies suitable for tropical climates.

University Green Building Initiatives

In addition to governmental efforts in green buildings and environmental sustainability, universities across America are forging the way in green building practices, education, research and development. At Carnegie Mellon University, the "Green Practices" Committee was given the charge by the President to "develop university practices that improve environmental quality, decrease waste, and conserve natural resources and energy, thereby establishing Carnegie Mellon as a practical model for other universities and companies". The areas of focus for the Committee include, but are not limited to, the following aspects of campus life such as dining services, recycling efforts, landscaping, transportation and building renovation and construction. Various green initiatives being undertaken are: food composting at university kitchens, developing environmental criteria and guidelines for campus procurement, flexible parking arrangements and free bus passes to promote the use of public transportation, and incorporating green technologies and materials in classroom renovations and adopting LEED guidelines in construction projects on campus.

The Steinbrenner Institute for Environmental Education and Research at Carnegie Mellon was launched in 2003 with a $4 million gift from a local philanthropist. This institute serves as a catalyst and external point of contact for all of environmental efforts at the University. It helps to identify opportunities and creates synergies that will both bolster ongoing efforts and jump-start new, multidisciplinary initiatives. A few of Carnegie Mellon's research centers that are geared toward energy and environmental research efforts are the Brownfields Center, Green Design Institute, Electricity Industry Center, Center for Risk Perception and Communication, Center for the Study and Improvement of Regulation, Center for the Human Dimensions of Global Change, STUDIO for Creative Inquiry, Center for Building Performance and Diagnostics (CBPD), and Institute for the Green Oxidation of Chemistry

In addition, Carnegie Mellon also offers environmental education and research in the School of Architecture, Department of Civil and Environmental Engineering, Department of Engineering and Public Policy, and the H.J. Heinz School of Public Policy. The Masters of Science in Sustainable Design program at the School of Architecture was launched in 2002 with an enrollment of only 1 student. By 2006, full-time student enrollment climbed to 12. Last year, the program can only accept 14 students due to space limitation. The School of Architecture is also developing a parallel Executive Education program in Sustainable Design targeted towards practicing professionals. There is a strong need for professional education to develop competencies as the building industries adopt sustainable construction as common practice.

The Intelligent Workplace (IW)

Figure 1: Exterior view of the IW

Figure 2: Interior view of the IW

Completed and occupied in 1997, the Intelligent Workplace (Figures 1 & 2) is a rooftop extension of Margaret Morrison Carnegie Hall on the Carnegie Mellon campus. The 7000 square foot facility is a living laboratory of office environments and innovations. As a "lived-in" occupied office, research, and educational environment, the IW provides a testing ground to assess the performance of new products in an integrated, occupied setting. The facility enables the interchangeability and side-by-side demonstration of innovations in on-site power generation, HVAC, building enclosure, interior systems, and telecommunication components and assemblies.

The IW is envisioned as a dynamic environment for the teaching and evaluation of how integrated building components, systems, and assemblies affect building performance. In-house post-occupancy research is critical to validating predicted performance through simulation and to assessing the performance in the integrated setting. As a test bed of new ideas, and a demonstration center for building innovations, combined with innovative workplace concepts and environmental diagnostics, the IW is a unique living laboratory of office environments.

The Building As Power Plant (BAPP)

Based on the experience and success of the Intelligent Workplace, the CBPD is embarking on the Building as Power Plant (Figures 3 & 4) project, to be built on the CMU campus. Currently in the design, R&D stages, the BAPP will be a living laboratory for research, demonstration and teaching of high performance buildings. The BAPP project will integrate advanced energy-efficient building technologies with innovative on-site energy generation systems, therefore becoming a producer of energy instead of an energy consumer. Passive techniques and high-performance building enclosure will reduce the energy demand. Renewable energies such as solar photovoltaic, solar thermal and geothermal will be harnessed on-site. The extra demand for energy will be supplied by the "cascading energy system", that integrates a Combined Heat and Power (CHP) system using reject heat for generating electricity, heating, cooling and dehumidification.

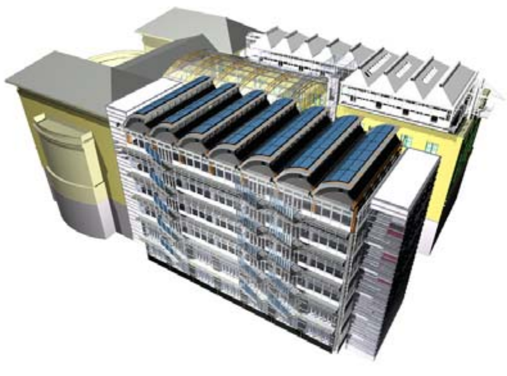

Figure 3: Aerial perspective of the BAPP

Figure 4: One-bay module of two floors of the BAPP

The central element of the on-site cascading energy generation system is a solid oxide fuel cell that will generate electricity and thermal energy in the form of hot water or steam. The thermal energy can be used either for a steam turbine and/or an absorption chiller. Reject heat from the turbine or chiller will be used for steam generation for space heating and domestic hot water. The integration of this unique systems design with on-site renewables, passive techniques and high-performance enclosure will enable the BAPP to be a net exporter of energy.

Other universities are also embarking on similar projects. The Lewis Environmental Center at Oberlin College is attempting to power the whole building using electricity from solar PV, in Ohio, at 41.3^0 N latitude. The basic building design incorporates passive strategies and an energy-efficient envelope to lower the energy demand, enabling the building to be completely powered by the sun.

The Carnegie Mellon experience is not an isolated case study of environmental and sustainable development practices and R&D. Most top ranked universities are leading the wave toward integrated and holistic approaches to green building and environmental sustainability. Similar programs in education and R&D in Malaysian tertiary educational institutions could be started and expanded through legislation and financial support from the government and collaborative efforts with international research universities.

Green Initiatives in Primary and Secondary Education

Environmental education starts early in many U.S. primary and secondary schools. Some schools are integrating their campus and building facilities as part of the environmental education curriculum. The "Solar Schoolhouse Project" provides living laboratories for students by incorporating solar panels into the school building and using smaller panels for class projects. Students and teachers are taught how to collect data from the system and upload into a central server. The web-based interface enables the schools to compare their solar power generation and energy consumption with other participating schools.

The "Edible/School Garden" program focuses on the cradle-to-cradle organic production of food while teaching the students concepts in life science, healthy nutrition and fitness. Other green features that could be incorporated in schools include, sundials, rainwater barrels, water habitat and on-site wind power turbines. Rapid growth in certain parts of the U.S. has created pre-fabricated construction companies that focus on green modular schools. Some of these design solutions are aimed for off-grid locations, by solely relying on on-site renewable energies, high-performance enclosure and passive strategies. These structures could also be mobilized to disaster relief areas where conventional power supply is disrupted. "Building as a Teaching Tool" is a concept that can be implemented into early education by incorporating interactive green design features into new school facilities and building retrofits.

Waste Management and Sustainable Development

Efforts to limit waste should not just be confined to the building construction industry. Recycling is one of the most easily identified environmentally sustainable practices. The practice should encompass all aspects of waste management, from household trash to discarded office paper and from rundown automobiles to industrial byproducts.

A study was performed by the California Integrated Waste Management Board to identify different types of wastes in California's landfills. Based on the samples, almost 90% of the total waste including paper, organics, metal, glass and plastics could be recycled or composted. With maximum recycling and careful separation of waste types, California could have 90% less landfill. Given the current real estate prices in California and concerns over groundwater contamination from landfills and other environmental issues, recycling and waste reduction are key to environmental and economic health.

Fortunately, waste recycling is widely practiced and often mandatory in American cities. Various unconventional strategies are employed to encourage or enforce recycling. Certain cities and counties are charging residents by the number of garbage bags that each household produces. RecycleMania is a competition among Universities to give recognition to the university that recycles the most. The separation of waste for landfills and collection of recyclables help municipalities with waste management costs by reducing the landfill tipping charges and the income from selling recyclables back to manufacturers. Recently, the mayor of the city of San Francisco signed a bill that would eliminate the use of plastic bags for groceries and other retail outlets. Paper bags made out of recycled materials and other agriculture by-products will be used in addition to encouraging shoppers to bring their own shopping bags.

Steps to encourage recycling can start with a national campaign promoting recycling. Recycling should be mandatory for municipal garbage and penalties could be assessed for non-recyclers. Areas for storage and collection of recyclables in neighborhoods and commercial buildings in addition to providing separate containers for recycling next to garbage cans can further promote recycling. A "Take-Back" policy requiring manufacturers of durable goods to accept the return of products for recycling will ensure manufacturers participation in the recycling program.

Recycling is important for its own sake. It is also the most widely practiced and easily recognized way that the environmentally conscious participate in "greening" the planet.

Green Buildings and Sustainable Development in Malaysian Application

Based on the experience and penetration of the LEED rating system and green construction and development practices in the US, similar incentives and strategies can be implemented in Malaysia to encourage green and sustainable development. Islam Hadhari promotes economic development and citizens' competitiveness through the mastery of knowledge, science and technology. The proposed steps are in-line with ideals promoted by the Government of Malaysia.

First, the Government of Malaysia can issue executive orders and pass legislation to promote green initiatives, ranging from the construction of green buildings to developing and promoting renewable energy and resources. In addition, financial incentives such as "green" tax credits and exemptions could be offered to individuals and corporations for initiatives towards environmental sustainability. Companies with cutting-edge green technology could be offered tax incentives to start new and expand existing manufacturing facilities in Malaysia. Malaysia could serve as the regional hub for the supply of green technologies. Similar to the development of the national automobile industry, technology transfer could jumpstart research and development in green technologies. Other types of financial incentives, such as below-market interest rates or no-interest loans and grants can further promote these initiatives.

Updating the national building energy code standards and guidelines to meet more stringent energy consumption and emissions will further support green building development. Lower energy consumption will be beneficial to reduce pollution from power plants consequently increasing the health of the citizens.

A vital component to the effort is to build cutting-edge green demonstration projects. These projects could be as small as a building project or as big as whole neighborhood developments and even Eco-Cities. A Malaysian Eco-City, among many environmentally sustainable strategies, would incorporate the following features:

- Neighborhoods that are designed to encourage walking to promote individual health, community building and reduction of automobile use, the single largest emitter of CO_2
- Multi-modal transportation system that includes light rail, busses, cars, and bicycles, integrated with sidewalks for pedestrians that are safe and accessible to all citizens regardless of age and physical ability.
- Buildings that are constructed to minimize energy use and provide healthy environments and the highest level of comfort for the occupants through energy efficient design and proper material selection.
- Energy supplied from renewable sources such as the sun for cooling and lighting or power generated from methane captured from landfill.
- Constructed wetlands to purify wastewater, provide habitat for wildlife, recharge aquifers and reduce stormwater discharge thereby help with flood control (an increasingly frequent phenomena in Malaysia)

Eco-Cities should incorporate vernacular forms and environmentally passive strategies to showcase the cultural and climactic factors of Malaysia and their applications to modern requirements and comfort standards. Cutting-edge and high-tech solutions will demonstrate locally developed technologies that are appropriate for buildings in similar climates. These demonstration projects will serve as teaching, research and showcase facilities.

Malaysia should take the lead in creating a Global Center for Tropical Sustainability. The Center would be the nucleus for sustainable initiatives encompassing the building sector, green policy and guidelines development, renewable energy and other emerging green technology development. Sponsored by the Malaysian Government, the Center will comprise various government agencies, universities, NGOs, and the private sector. The various constituents will bring their expertise from different backgrounds to form an integrated approach to green buildings and sustainable development. To propel the future of green and sustainable efforts in the country, the Center and its inventions and discoveries will serve both as a resource for curriculum and a source of inspiration for elementary and secondary schools that are designed using green technologies, creating awareness and participation of the new generation.

This broad-based national participation and commitment will position Malaysia globally in the forefront of environmental stewardship. Green buildings and sustainable development reflect a commitment to the reduction of urban sprawl and the preservation of the country's greatest natural resources – the coastline and primary forests – broadening the possibilities for Eco-tourism and safeguarding the environment for future generations of Malaysians and the world, one of the principles of Islam Hadhari, promoted by the Government of Malaysia.

Acknowledgements

The original concepts contained in this paper were presented at the "Malaysian Green Building Mission" Conference in Putrajaya in March 2007. The author would like to acknowledge the Department of Public Works and the United Nations Development Program for sponsoring the research and public presentation of these concepts.

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THE NEED FOR A CHANGE IN THE BUILT ENVIRONMENT CURRICULA IN MALAYSIAN UNIVERSITIES AND IN PRACTICE

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Abstract
The need for sustainable and energy efficient buildings in times of climate change cannot be further emphasized. Education is deemed to be the tool to bring about long term tangible results. The revamping of the tertiary level curriculum is vital in changing the mindset of budding building professionals. The process of transformation from conventional to sustainable building design is the underpinning factor in future architecture education, a process which would lead to a redefinition of the tropical architecture in this region. This paper presents the recommended process and doses of input of recommendations in the architectural education to incorporate sustainability awareness. It is also hoped that upon inculcation of modified knowledge to the students, they would be the agents of effective change later into practice. The model of reform made by USM is still in its infancy and too early to share its success story but should be exemplary to other architecture schools.

Keywords: Energy efficient building designs, University education curriculum, Sustainable architecture education

1. INTRODUCTION

The concept of sustainable design had been endemic in the last two decades. The official definition on sustainable development as first described by the World Commission on Environment and Development in the report on Our Common Future (commonly known as the Brundtland Report) is, "the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCOED, 1987). Based on this indication it recognizes that human civilization is an integral part of the symbiotic relationship between the natural and the built environment. The past concept of architecture stems from the basic need for shelter, "one that would adequately protect the inhabitants from the climate" but now the notion is that "it is the environment that has been seen as needing protection" (Williamson et al, 2004).

In most countries, buildings are the third sector after transportation and industries that produces greenhouse gases contributing towards global warming. As a nation Malaysia, together with other third world countries are amongst the highest energy consumers in comparison to Japan and Denmark by taking a comparative look at the energy intensity (consumption versus GDP) as seen in Figure 1 (KTAK, 2004). It is therefore crucial for the key players in building design to have more responsibilities towards sustainable buildings. In order to achieve this, they must first have a profound awareness and understanding on the whole spectrum of issues related to sustainable development and buildings.

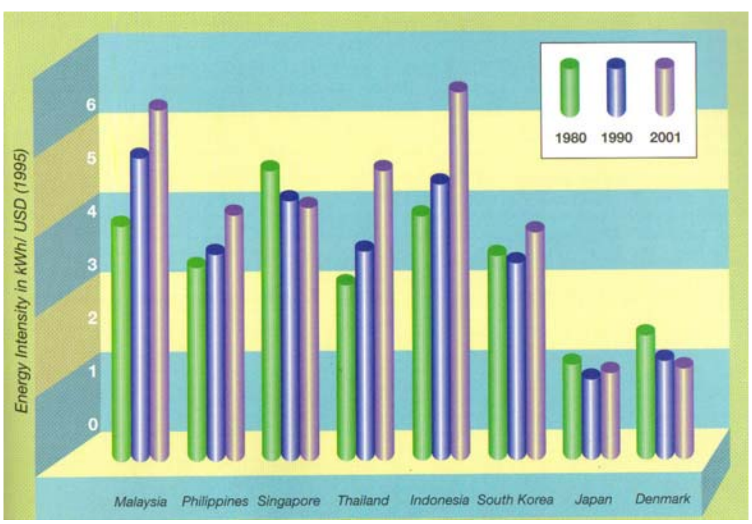

Fig. 1 Comparative Energy Use Intensity
(Energy intensity is a measure of energy consumption against GDP)
Source: Ministry of Energy, Water, and Communications, 2004

The plan of action following the discussions of sustainable theory in the Rio Earth Summit 1992 was detailed out in Agenda 21. It put emphasis on how the world communities can adopt and implement specific measures. On education, Chapter 36 of the Agenda underlines that (UN/DESA, 1992), "education is critical for promoting sustainable development and improving the capacity of the people to address environment and development issues....Both formal and non-formal educations are indispensable to changing people's attitudes so that they have the capacity to assess and address their sustainable development concerns....To be effective, environment and development education should deal with the dynamics of both the physical/biological and socio-economic, environment and human."

According to Shafii (2005) in her report on the Sustainable Building South-East Asia Conference, "participants highlighted that education about principles and concepts of sustainable buildings is most essential in main streaming SBC as it requires changing behaviour which in turn requires changing attitudes." In the context of architecture practice and education, UIA/UNESCO (1996) Charter for Architecture Education has declared that, "we, the architects, concerned by the future development of architecture in a fast changing world, believe that everything, influencing the way in which the built environment is made, used, furnished, landscaped and maintained, belongs to the domain of the architects. We, being responsible for the improvement of the education of future architects to enable them to work for a sustainable development in every cultural heritage."

Even though many architecture schools in Malaysia gain recognition from the professional bodies, the architecture programs are generally obscure in their pursuit of the statement and ideology that can give a huge impact on sustainable design and architecture of Malaysia. In the quality control of architectural education the body responsible on the accreditation process is the Board of Architects Malaysia. In its policy and procedure for accreditation of programs it stated that (BAM, 2000):
"Architectural education should ensure that all graduates have knowledge and ability in architectural design, including technical systems and requirements as well as consideration on health, safety and ecological balance; that they understand the cultural, intellectual, historical, social, economic and environmental context for architecture and that they comprehend thoroughly the architects' role in society, which depend on the cultivated, analytical and creative mind. The program of study should address the various issues outlined in Appendix A, amongst the 15 aspects of knowledge and skills, listed in Appendix A, the 1st and 6th are as below:

- Ability to create architectural designs that satisfy both the aesthetics and technical requirements and which aim to be environmentally sustainable
- An adequate knowledge of the means of achieving environmentally sustainable designs

Although the Board had already included sustainability as part of the knowledge to be acquired throughout the five years architecture education but the focus on sustainable issues and development is not coordinated in the curriculum in a systematic way. There are some inputs by many lecturers integrating sustainable issues and development but these inputs are piecemeal and do not give exposure to the students in broader perspectives. The education is only limited to single discipline with isolated topics based on the knowledge and interests of the lecturers. As mentioned by Jimmy Lim (1997) a local architect and planner, "this lack of concern for the environment cannot be allowed to continue. Society on the whole needs to be re-educated. Young professionals joining the industry need to be versed on their social responsibility of creating quality environment and housing for the people". The dire need for an education shift towards sustainability in Malaysia is in view of:

1. The present global scenario where societies and economies are oriented towards environmental awareness, widespread knowledge in sustainable issues and development is vital for meaningful participation in democratic, consultative and accountability process. The formulation of new policies and guidelines requires an overview from all key players in avoidance from overly beholden to experts, politicians, and technocrats in the decision-making process on the country's future development.
2. Knowledge in sustainable issues and development is important amongst future professionals who are able to make more open and effective contributions to the decision-making processes concerning the environment and development.
3. The preservation and management of our natural resources are done in a piece meal and haphazard manner. This situation needs to be address and in order to do so the mind-set of the main actors in the various fields should be retuned. If Malaysia is serious in joining other nations in promoting sustainable development there should be key players and stake holders willing to come to the forefront and spearhead the effort seriously. Malaysian graduates should be at the forefront in instilling awareness amongst the future actors in shaping of the environment in a sensitive manner.

In the quest for sustainable design, the work of a local architect Dr Kenneth Yeang had gained worldwide recognition for his 'bio-climatic skyscraper' in which he 'purposes the building enclosure as an environment filter' as shown in Figure 2 (Powell, 1999).

2. THE REVAMPING OF ARCHITECTURAL EDUCATION

As mentioned above the training of architects in Malaysia involves a wide array of objectives to be fulfilled. It has come a long way from merely to fulfil the three qualities of firmitas (strong or durable), utilitas (useful), venustas (beautiful) as mentioned by Vitruvius in his book "De architectura" (Wikipedia Encyclopedia, 2007). As mentioned by Abdul Samad and Abdul Rahman (2007), "besides functional and aesthetics consideration, architecture and buildings design are expected to tackle issues such as economic, cultural, societal, technological and even political. The current scenario sees the urgent need for architects to play the pivotal role in addressing pressing global issues." All this while, the five or six years training focused on the required range of skills and creativity in design, managerial, media, and technical expertise with core subjects or courses ranging from design, technology, history, theory, practice and environmental behaviour. The future architects should also be trained "to have profound empathy and understanding of how buildings relate to physical, cultural and social contexts, have knowledge of our architectural heritage and know how buildings may be energy and resource-efficient. They must have a clear understanding of how their role interacts with others to bring about good buildings and designs in many contexts (Architecture Committee, 2005)."

According to the National Pollution Prevention Center for Higher Education, University of Michigan (Kim et al, 1998) the ultimate goal of environmental education in architecture is to increase sustainability in the building sector with three levels of educational objectives as shown below:
Level 1: Creating Environmental Awareness
Level 2: Understanding Building Ecosystems
Level 3: Ability to Design Sustainable Buildings

Fig. 2 Mesiniaga Building by Ken Yeang

The inclusion of sustainable design in the existing curriculum in Malaysia should be not be seen as an extra syllabus that will increase the burden to an already outstretch credit hours of an architecture education. The AIA Committee on the Environment in their report on this matter has identified that "because the study of architecture is intensive and requires a large number of credits within the major, often there is very little opportunity to expand the curriculum to include more courses from other disciplines, even as electives" (COTE, 2007). Sustainable building design curricula can be implemented in various stages. The immediate stage is to include them into the existing curricula of all the architecture schools in Malaysia. The focus should be to assimilate the sustainable curricula as fundamental principles in all the existing subjects in the architecture program. If we look at the first level of objective which is to Create Environmental Awareness as mentioned above, this aspect can be incorporated conveniently into all the basic or introductory architecture subjects such 'Environmental Science' or 'Introduction to the Built Environment' already taught in most schools. There need to a redirection or shift in the focus of all these subjects towards awareness on sustainability. The primary aim for the early stage of education is to stimulate students' interest in environmental issues

The second level on Understanding Building Ecosystems can be integrated into core subjects such as Building Construction and Materials Courses, Building Technology, as well as Building Services to start off with. In the mean time specific courses outlining the Building Ecosystems such Energy Efficiency Design and other principles should be introduced to consolidate the understanding on sustainable building design.

The third level on Ability to Design Sustainable Buildings should be seriously implemented in the studio projects from the first to fifth year progressively. As discussed in the Report by The AIA Committee on the Environment "studio courses are the core of architecture education. When the environment is discussed only in "support" courses, students are likely to see it as inconsequential. Faculty who teach environmental courses are often not central to studio education, and vice versa. As a result, tenure may be difficult for them to achieve, and the school's commitment to environmental education becomes sporadic and weak (COTE, 2007)." To prevent these shortcomings in Malaysia, it is critical for the studio work to put emphasis on integration of sustainable objectives together with other learning outcomes. The design work should be closely monitored and assessed on attempts to fulfil sustainable issues apart from other requirements. Elsewhere, it is mentioned that the definition of sustainable buildings is constantly changing but there 6 accepted principles that constitutes sustainable which are: i) optimise site potential, ii) optimise energy use, iii) protect and conserve water, iv) use environmentally products, v) enhance indoor environmental quality and vi) optimise operational and maintenance practices (WBDG, 2007). Looking at these principles some of them are already integrated into present studio work for example optimise site potential, in most schools of architecture, students are already taught on the importance of context with the existing surroundings. Again emphasis should be placed on effects of the new development to minimize waste and destruction on the natural environment for example avoid unnecessary cutting of hills, etc.

3. THE EXPERIENCE OF ARCHITECTURE PROGRAM IN USM

The Architecture Program of the School of Housing, Building and Planning (HBP), Universiti Sains Malaysian had already made a leap towards implementing Sustainable Design Awareness in the Architecture Program. This concept of sustainable education was endorsed by the Vice Chancellor Professor Datuk Dzulkifli Abdul Razak (2004), of USM where he expressed that, "education is not about marks and a piece of paper to secure that high-paying job. It is not only about acquiring technical skills and knowledge to meet the needs of the industry or employment market. Education is about making Mother Earth a sustainable planet for all to live in for many generations to come. The larger goal and mission is towards humanity – to conspire to elevate ourselves to high ideals for a peaceful and harmonious existence between Man, Nature and the Almighty"

In the early turn of the millennium there was an urgent need to re-visit the curriculum in the school taking into consideration the progress in the industry. Each program in HBP was to review the curriculum and direction not only to be more relevant to the industry but more importantly to help shape the country in the right direction. There were two events that became the turning point in the architecture program's shift towards sustainable education, firstly, the set up of a Centre for Education, Training and Research of Renewable Energy & Energy Efficiency (CETREE) by the Ministry of Energy, Water and Communications based in USM in 2000. Secondly, the designation of the University of Science Malaysia (USM) by the United Nations University (a subsidiary of UNESCO) as one of seven universities in the world to be the Regional Centre for Expertise in Education in Sustainable Development in 2005. The other six are Barcelona, Greater Sendai Region, Okayama, Pacific Island Countries, Rhine-Meuse Region and Toronto and Toronto

The Architecture Program reached a consensus that sustainability should be the big umbrella that the committee must work under to fulfil the ethical and moral obligation to society. The committee (2005) produced an unpublished Report entitled 'Ecotecture, Architecture for the Future', to ascertain its role in producing future architects who are not only relevant but spearhead the sustainable development in the industry. HBP already has the expertise in the various aspects which should be exploited in a common theme or a niche that is cohesive in achieving this goal which is eco-friendly architecture. It would become a common denominator for everyone to contribute in their respective fields. The role is to bridge the gap between the public and professionals in the fields of sustainable construction, architecture and environmental protection (eco-professionals).

Once the goals were established the biggest challenge was for the expertise in the school to change the mind set towards sustainability due to the varied background in training. Every staff had to attune to this concept in not only the subject they teach but to incorporate them in the studio teaching as shown in Figure 3. A long term plan was to train future staff through the Young Lecturers Scheme in the various areas related to sustainability which was already implemented. It is the staffs, which first have to go through a learning process of adapting to the new sustainable perspective before imparting to the students. For some staffs this is already embedded in the training especially those in building services and environmental science but for others it means retooling, retuning or even re-educate oneself to suit the new goals.

According to AIA/COTE report on Ecological Literacy in Architecture Education (COTE, 2007) the "restructuring architecture education to embrace ecological literacy will require these issues to be addressed within the core curriculum of the school." The approach by HBP is to look at the current core curriculum and re-address them to adopt fundamental principles of sustainability or ecology. To revamp the system with a new curriculum would be very time consuming as they have to go through the formal process of getting approval from the university highest authority and involve a lot of red tape. Therefore the approach is to work within the existing curriculum. The whole strategy to education in sustainability should be conducted in a holistic manner with the end product manifestation in the studio or design work. On creating awareness subjects such as Introduction to the Built Environment, Environmental Science I, and II, gives emphasis on this. The awareness is enhanced in the 1st year studio which is conducted in integrated manner where all the disciplines (Architecture, Planning, Construction Management, Building Technology, Interior Design and Quantity Survey). The understanding on building ecosystems is introduced in a specific subject called the *Integrated Energy Building Design* introduced in 2004. To test the understanding and comprehension of all these theories the studio work from 2nd to 5th year thesis are assessed partly on the implementation of

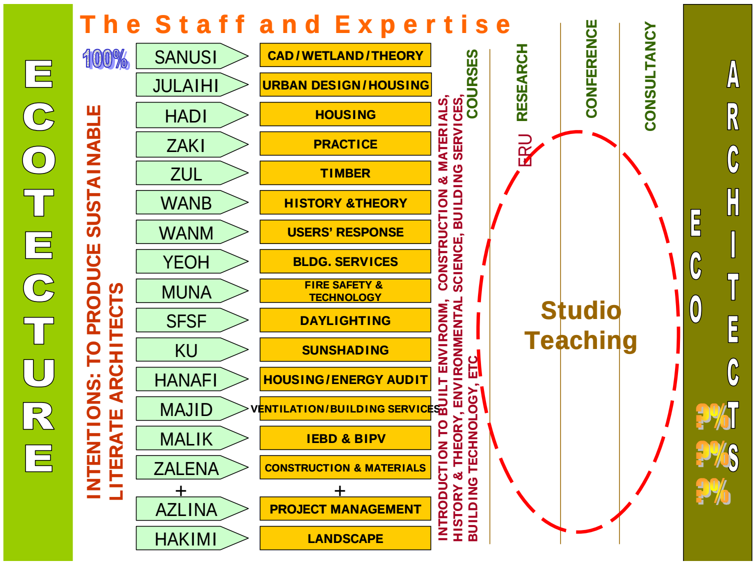

Fig.3 Roadmap of Architecture Staff and Sustainable Intentions

Fig. 4 Example of 1st Year Project: Basic Understanding of the tree and its ecology system

these issues. In the 5th year the Building Technology Subject also expose the students to field trips to completed buildings in the country as well as the to conduct case studies of a similar building typology to their thesis to make an appraisal on the issues pertaining to appropriateness of technology used. A seminar is conducted where the students would present their findings which can be benefited by others in the class.

"The integrated design process of working closely with all stakeholders and consulting experts at all stages of the project, including pre-design, implies a model of collaboration and that unfortunately is foreign to architects and students (COTE, 2007)." Contrary to this statement, in HBP the design is not taught alone in the studio by one teacher but instead by a group of lecturers with critic sessions done by a group of panels which cross the other disciplines. From 2nd to 5th (Figure 4 and Figure 5) emphasis are given to real projects from time to time and with site visits and meeting clients and/or end users.

The challenge in instilling this sustainable concept to students is how to overcome overemphasis on stylistic approach in design. Most students are influenced by the work of famous architects such as Frank Gehry, Zaha Hadid, Santiago Calatrava, etc. In the design exercises they would conjure up these iconic images of mega buildings publicised in the media or internet and try to imitate them. The sustainability approach on the other hand forces students to put more emphasis on context and locality and pragmatic solutions to produce good building designs. It can be almost contradictory to iconic portrayal of architecture as shown in the work of many famous architects. It is the task for educators to shift the students to emulate the work of sustainable architects who may not receive as much publicity or attention but are more meaningful to sustain our natural habitat. This problem is raised by Williamson et al (2004) in his statement, "the international strength of the disciplinary culture of architecture, with a small number of 'superstar' architects working concurrently in different parts of the world dominates local contexts."

3.1 SUPPORTING ACTIVITIES AND COLLABORATION WITH OTHER PLAYERS

"Sustainability goes far beyond energy and materials and involves land use, water, transportation, innovative engineering, landscape, and social justice. This broad array of issues and frameworks demands collaborative design and broad, multidisciplinary, linked thinking (COTE, 2007)." HBP is very fortunate to have multi disciplinary experts under one roof to accomplish collaborative effort such as seminars, workshops, and courses to promote the issue. In 2006, HBP organized an International seminar On Sustainable Housing which was successful in disseminating knowledge on global experiences in this aspect (ICSH, 2006).

Fig. 5: Final Year Project with EE considerations by passive methods and use of PV

In 2006, USM was nominated as one of the four Research Universities in Malaysia. This will ensure that the university will receive more grants from the federal government to conduct researches. An important milestone in HBP early this year was the set up of *Ecotecture* (eco-architecture) Research Unit, a unit to be responsible in collaborative research in any area relevant to sustainable issues (Architecture Committee, 2007). By setting up the unit, HBP has a better chance in obtaining government grants to undertake important researches on sustainable development and relevant areas. Findings from research can be assimilated in teachings, consultancy, and practice.

The School of HBP also works closely with CETREE in creating awareness to all levels of society especially in schools and professionals. CETREE task managers working together with representatives of the Ministry of Education have carried several workshops to incorporate and modify the contents of existing co-curriculum with exercises on sustainability of the environment (Abdul Rahman and Kandar, 2005). HBP can benefit by collaborating with CETREE as can be seen by the road map in Figure 6 (Abdul Rahman and Abdul Samad, 2006). This alliance is hoped to create a chain of events that will lead to better awareness not only to future architects but the practicing professionals.

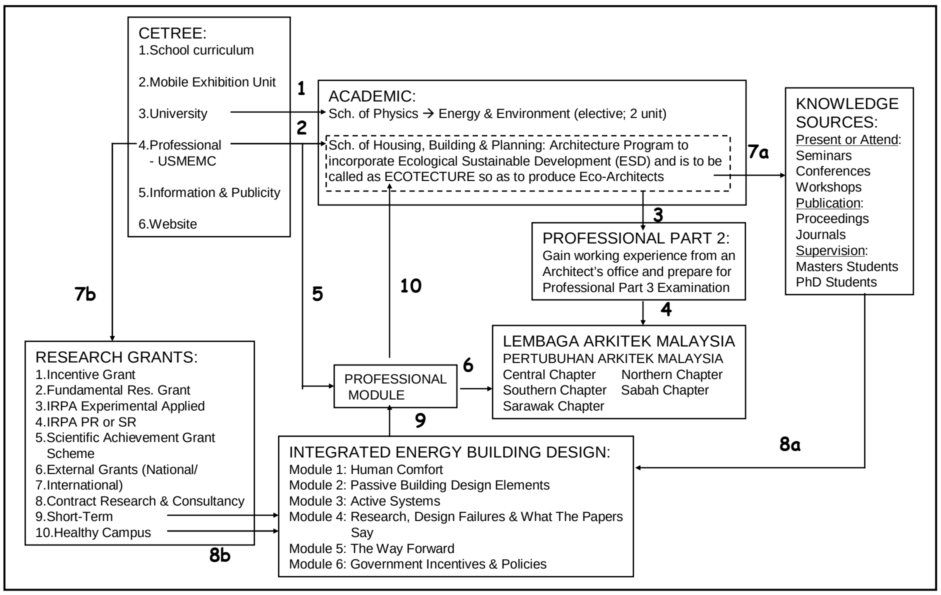

Figure 6 The CETREE-HBP-USM Strategy for Architecture Curriculum

4. DISCUSSIONS

"Many important stakeholders (contractors, manufacturers, developers) in South-East Asian construction industry are not even aware of the concept of sustainable building, and so are naturally resistant to change. Hence, the greatest barrier to implementation is the lack of understanding of the need for sustainable design (Shafii, 2005)." This is also a reflection of the situation in Malaysia. The Ninth Malaysian Plan (2007) an annual blueprint on the country's policy and implementation underlines in Chapter 19 on Sustainable Energy Development that "in ensuring efficient utilisation of energy resources and minimisation of wastage, the focus will be on energy efficiency initiatives, particularly in the industrial, transport and commercial sectors as well as in government buildings." In Promoting Environmental Stewardship, the Chapter 22 stated that "the Government will place emphasis on preventive measures to mitigate and minimise pollution as well as address other adverse environmental impacts arising from development activities. In addition steps will be undertaken to identify and adopt actions to promote sustainable natural resources management practices in relation to land, water, forest, energy and marine resources (Ninth Malaysian Plan, 2007)." In order to speed up the change in attitudes there must be concerted effort by the Government to revise the Legal Framework and Guidelines to fulfil the objectives in the Plan. Attempts at changing the policies on energy is already under way due to increase in energy tariffs especially petrol and electricity but have yet to be revised and gazette. Policies must also be followed by change in relevant laws such as Planning, Building Regulations or Building Bye-laws, Housing Developers Act, and other relevant acts or standards involving building design, construction and production of building material. All the relevant bodies related to the building industries such as Architecture, Planning, Engineering and other professional bodies, CIDB, Housing Developers Association and others should all be educated on sustainable practices. In England and Wales, the Local Government Association (2006), underlines what is covered in sustainable buildings which "is the environmental design and construction of the building and site, to meet the government's overarching environmental objectives to reduce resource use and environmental impact" and came up with Planning Policies on Sustainable Buildings outlining local strategies and implementation to guide planners, policy planners, development control officers, developers and architects. There should be similar framework for Malaysia, if more stringent policies are enacted in future there need to be guidelines for the law enforcement agencies such as planning and building approval authorities to enforce and monitor the execution on the ground.

There are many aspects that need to be integrated not only on spatial and climatic/thermal qualities but also on material and systems technology. Architects cannot design a building to completion and have other consultants to add on the building services systems later. The approach to sustainable and EE buildings is to integrate all the systems in the initial design stage. There need to be a revamping of all the education curricula involving civil, mechanical and the rest to have sustainable considerations as a priority. Another aspect is the building ecosystems and technology which is vital to sustainable buildings. Hard facts and data on the ecological properties, such as biodegradability, recyclable, reusability, toxicity, etc of materials in Malaysia are not comprehensive and widely available at present due the lack of sustainable considerations by building materials manufacturers. Again there need to be emphasis by the body such as Standard and Industrial Research Institute of Malaysia (SIRIM) that controls local products standardisation and quality to include sustainable criteria in their testing and in the Malaysian Standards for sustainable materials.

On the aspect of sustainable awareness the effort by The School of Housing, Building and Planning and the CETREE is to expedite the awareness to the future architects and the general public starting from schools so that changes can be achieved at a faster rate. Even if HBP is successful in producing future architects who are sensitive in sustainable issues and energy efficiency but as mentioned earlier architects cannot be the only player in this crusade. There are challenges in convincing other key players especially the practising architects who at the moment are not serious in adopting sustainable design again due to lack of enforcement in the current building by-laws and energy incentives to clients or building owners. It is not a priority due to lacking in stringent laws on energy audit on buildings in Malaysia. On renewable energy a study on RE in Malaysia shows that there is, "lack of policy framework (legal and financial) on RE – even though the potential of RE is enormous, it cannot be utilized without any legal and financial framework (Shigeoka, 2004)."

"Because ecological design should be required and integrated part of the entire design process, not merely an area of specialization, accreditation should require environmentally sustainable design principles (COTE, 1990)." And although it is part of Boards of Architects objective for schools of architecture to incorporate sustainable principles but the issue is not really given emphasis in the accreditation exercise which should be rectified to make sustainable education and practice a reality.

5. CONCLUSIONS

The moves towards sustainable design in buildings in Malaysia is lagging behind other developed countries such as Japan, UK, Germany and others by 20 years. In these countries energy efficient building design had been adopted since the 1980's. In the last decade the emphasis of sustainability in these countries has shifted further from the issue of low energy buildings to the environmentally sustainable neighbourhoods and more holistic approach to sustainable issues as described by Edwards (2000). In Malaysia, if the key players are still ignorant on these issues and law enforcement is slow to drive them in adopting sustainable strategies and actions, it is the vital role for educators to speed up this process through future professionals who are more aware and sensitive towards implementing them. The foundation must be implanted now to achieve a strong basis of knowledge on sustainable development and building design of the future. However in a long run and as mentioned again and again, there need to be concerted effort by all key players such as developers, government agencies, NGOs', other professionals especially planners, civil, mechanical and electrical engineers, the respective professional bodies, and the public at large to make sustainable developments a reality in future instead as merely rhetoric issues.

ACKNOWLEDGEMENTS

The authors would like to thank the organizations and individuals below:

- Professor Datuk Dzulkifli Abdul Razak, Vice Chancellor of USM for his far-sighted visions.
- Architecture Committee, School of Housing, Building and Planning, USM for the united effort in promoting sustainable design education.
- Dean and staffs of the School of Housing, Building and Planning, USM
- CETREE, USM
- Ministry of Energy, Water and Communications

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SUSTAINABLE OFFICE BUILDNGS IN THE TROPICS

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Abstract

An integrated approach is required in designing sustainable office buildings so as to come up with an optimal solution that balances all the important issues that have to be addressed. Various strategies have been identified for office buildings in the tropics. Daylighting has been identified as a potential source of energy efficiency measure because daylight is abundant in the tropics for most of the hours. Rainwater harvesting has also been identified as the most practical and economical method for providing alternative water supply to substitute potable water use in the tropics. In addition, the management of construction waste and use of sustainable building materials have also been outlined. Source control to ensure good indoor air quality through selection of healthy materials as well as regulating the ventilation rate to balance indoor air quality with energy efficiency are also important considerations in sustainable design. The impacts of transportation energy associated with office buildings are also highlighted so that measures can be taken to reduce the ecological footprint of the buildings.

Keywords: Sustainable buildings, tropics

1. Introduction

Sustainability in a building is more than just energy efficiency alone. There are many other important issues that have to be addressed in order to make the building sustainable. Designing sustainable buildings is an integrated process where the relevant issues have to be considered hand in hand in order to come up with an optimal solution. For example, more greenery is encouraged as an approach to reduce the heat island effect but more greenery may require higher irrigation demand so plants must be carefully selected. Designing for energy efficiency calls for more airtight building but the indoor air quality should not be compromised and so on and so forth.

The focus of this paper is primarily on office buildings in the tropical climate with examples mainly drawn from Singapore and Malaysia.

2. Energy Efficiency

Energy saving is without doubt the quickest, most effective and most cost effective manner for reducing greenhouse gas emission and for helping countries to meet their Kyoto target. Energy efficiency in buildings is one area where important savings can be made.

In the tropics, designing office buildings for energy efficiency is less complicated than that for buildings in the temperate climate. In the tropical climate, only cooling and dehumidification are required but not heating. Air-conditioning takes up about 60% of the total building energy consumption. In order to improve the energy efficiency of the building, the first and foremost task is to reduce the cooling load and this is done by keeping the heat out and reducing the internal heat gain.

2.1 Day lighting

In the tropics there is a lot of potential in utilizing daylight for improving the energy efficiency of buildings. The tropics enjoy an abundance of daylight throughout most of the hours. In Malaysia, for example, the average horizontal diffuse radiation is 15,000 lux or higher between 8 – 17 o'clock and only 300 lux is required for indoor office lighting. A proper daylighting design can therefore greatly reduce the electrical light usage in the perimeter zone of tropical office buildings.

Daylight is free of charge and therefore does not contribute to the energy consumption of the building as artificial lighting does. Moreover, daylighting has a higher lumen efficacy (i.e. carries less heat per light unit) than artificial fluorescent lighting – and can be more than double the lumen efficacy when spectrally selective glazing is used. Spectrally selective glazing lets visible light pass through and in turn reflects infrared and UV light out. Hence, the use of daylighting translates into a lesser heat load from lighting and consequently a smaller energy consumption for the chiller. Numerous studies have also shown that people working in daylit environments work more efficiently and experience an improved well-being. In other words, there are several benefits of using daylighting in buildings.

2.2 Air tightness

In the tropics there are no requirements for ensuring air-tightness of the building envelope, presumably because the temperature difference between indoors and outdoors is not very great. However, considerable energy can be saved by ensuring an air-tight building envelope, so that the hot and humid outdoor air does not infiltrate into the air-conditioned zone. A lot of energy is used by the air-conditioning system to dehumidify the hot and humid outdoor air if it gets into the air-conditioned building. In addition, air-tightness is a pre-requisite for using desiccant heat recovery on the air system (refer to section 2.3)

2.3 Desiccant Heat Recovery of Air

In tropical Malaysia and Singapore, about 50% of the outdoor air humidity content is removed to achieve a comfortable indoor climate. The latent cooling of outdoor air intake is considerably higher than the sensible cooling. Desiccant heat wheels allow the recovery of about 60% of the total cooling energy (latent and sensible) for the fresh air supply. For an efficient desiccant heat recovery to take place it is necessary to have an air-tight building so that the return air (dry and cool) can be directed through the desiccant heat recovery wheel and does not dissipate through a leaky building envelope.

2.4 Energy efficient equipment

Another potential area for energy consumption reduction is in the area of equipment energy use. Equipment energy use (plug loads) constitute a very big proportion of energy use in a typical office building. The energy consumption can be easily reduced by choosing energy efficient equipment in the first place. For example, a laptop only consumes 15-35W of power as compared to a PC with LCD monitor which consumes 70-90w of power. In addition, energy efficient printers, photocopiers, fax machines etc should also be chosen. Proper control of the usage of the equipment is also another way of reducing energy use. The equipments should only be used when necessary and should be switched off when not in use or put into sleep mode when they are on standby.

It is obvious that the selection of energy efficient equipment and proper control of usage require the cooperation of the client. The importance of the selection of energy efficient equipment to be put in the building has to be communicated to the client right from the start because this will affect the total building energy consumption.

3. Water Efficiency

Other than energy resources, water is increasingly becoming a scarcity issue in many parts of the world, including Malaysia. Plentiful water resources in the past are no longer so in the context of modern water demand and increasing populations, industries and agricultural production. The cost of supplying safe and clean water is increasing and if this problem is not properly addressed, it could lead to a water crisis.

Sustainable water management principles need to be incorporated into the building. Sustainable water management means reducing the demand for water usage through the use of very water efficient fixtures and appliances where possible and identifying alternative sources of water supply to substitute the potable water use.

3.1 Water Efficient Fixtures

Increasing the efficiency of fixtures can lead to significant reductions in water demand from end users. Many of these very water efficient fixtures are also available in the market now. In Singapore, the Public Utilities Board has launched the water efficiency labeling scheme for water fixtures. The efficiency of the various fixtures can be evaluated according to their water efficiency rating. Table 1 shows the improvement in water efficiency of the various fixtures over the conventional type.

Table 1: Water Efficiency Rating of various fixtures

Flush/Flow Fixtures	**Conventional (Poor)**	***Good**	***Very Good**	***Excellent**
Cisterns (L/flush)	9	>4 to 4.5 (full flush) >2.5 to 3 (half flush)	>3.5 to 4 >2.5 to 3	3.5 or less 2.5 or less
Urinals (L/flush)	4	>1 to 1.5	>0.5 to 1	0.5 or less Or waterless urinals
Wash Basins (L/min)	9.5	>4 to 6	>2 to 4	2 or less
Kitchen sinks (L/min)	9.5	>6 to 8	>4 to 6	4 or less
Shower Taps (L/min)	9.5	>7 to 9	>5 to 7	5 or less

(*Source: PUB, Singapore)

3.2 Alternative Sources of Water Supply

3.2.1 *Rainwater harvesting.* Rainfall is generally abundant in the tropical region and fairly consistent across the various months with occasional periods of drought. The average annual rainfall in Malaysia is around 2000mm. Rainwater can be harvested from the roof or from other paved areas in the building. Water collected from the paved areas is usually referred to as stormwater harvesting which will be touched on in the next section.

3.2.2 *Stormwater harvesting and management,* Stormwater harvesting is the collection of water from the paved areas of the building. Stormwater harvesting helps to reduce surface runoff and relieve the load on the drainage system during heavy rain to lessen the possibility of flooding. Minimizing non porous areas will minimize surface runoff hence by having landscaped area helps to reduce surface run off and promote infiltration into the ground.

3.2.3 *Greywater Recycling,* Grey water is the wastewater collected from showers, sinks, floor drains which although no longer clean, is not as contaminated as toilet water (black water). By intercepting grey water before it goes to the septic tank or the municipal wastewater system, and providing some treatment (in certain cases, no treatment may be required) the water may be reused to irrigate plants. More complex treatment is required if the grey water is to be used for toilet flushing. Grey water from the kitchen sink is not recommended to be collected. This is because the grey water that comes from the kitchen sinks tend to contain more grease, oil and other food particles which will require a higher level of treatment to recycle the water.

3.2.4 *Blackwater recycling,* Blackwater is the discharge from the toilet and the microbial contamination associated with blackwater means that the water needs to be treated to a very high level. This requires expensive technology like reverse osmosis.

3.3 Recommendations for the tropics

As rainfall is abundant in the tropics, rainwater harvesting is probably the most appropriate and perhaps less expensive alternative sources to substitute the use of potable water for toilet flushing and irrigation. This should of course be complemented with the use of water efficient fixtures in the building so that sufficient water can be collected from the alternative water sources to substitute the potable water use.

4. Waste Management

Construction and demolition debris frequently makes up 10-30% of the waste received at many landfill sites around the world (Fishbein,1998). In Malaysia, industrial and construction waste makes up almost 30% of the total solid waste generated. The recycling and reuse of construction and demolition waste can help to alleviate the pressure on landfills and natural resources. Waste minimization and avoidance must also cover the planning of the building such that wastes that are produced in the building during use can be separated and recycled.

4.1 Waste Reduction

The first step in a construction waste reduction strategy is good planning. Design should be based on standard sizes and materials should be ordered accurately. In addition, the use of high quality materials such as engineered products reduces rejects. The conventional construction method of extensive cast in-situ activities usually results in unnecessary waste hence new construction methods or technologies should be looked into. The adoption of prefabrication in construction is one way to reduce waste.

4.2 Re-use of materials

Identify potential re-usable or salvageable materials from onsite or offsite sources. Re-usable or salvageable materials may include bricks, tiles, doors, windows, furniture, plumbing fixtures, steel etc. By re-using materials salvaged from demolition sites eliminates the need for new resources.

4.3 Recycling of waste

For recycling of construction waste, the most important step is on-site separation. Initially, this will take some extra effort and training of construction personnel. Once separation habits are established, on-site separation can be done at little or no additional cost.

It is important to identify before recycling the waste, the people who will accept it. This helps to designate the type of waste to separate, and in making arrangements for drop-off or delivery of materials. Containers for material recycling must be set up on site and clearly labelled. Construction personnel must be trained in material sorting policy, and bins must be monitored periodically to prevent waste mixing as a result of crews or passersby throwing trash into the bins.

4.4 Waste management plan

A waste management plan has to be developed and should incorporate the following:

1. Types of waste materials produced as a result of work performed on the site.
2. Estimated quantities of waste produced.
3. Identification of materials with the potential to be recycled.
4. Cost savings accrued by recycling rather than disposing of waste in landfills.
5. On-site storage and separation requirements.
6. Transportation methods.
7. Destinations.

5. Use of sustainable building materials

Selection of sustainable building materials is one direct way of incorporating sustainable design principles into buildings. Selecting materials manufactured by environmentally responsible companies encourages their efforts at pollution prevention. In addition, by choosing products with recycled content (manufactured with post industrial or post consumer waste) helps to increase the resource efficiency of the building materials. The embodied energy content of recycled materials is much less than that of the virgin materials. Sustainable materials should be generally non toxic, recycled and recyclable, obtained from local sources (to minimize transportation energy), durable and long lasting. Figure 1 shows the output from the BEES program which is a program developed to help people select environmentally preferred materials. The output shows that it is better to choose the recycled PET(polyethylene terephthalate) carpet tiles over the nylon carpet riles because the environmental performance of PET tiles are better. The BEES program is developed for use in the United States and may not be accurate for the other regions. There is currently no program developed for use in Malaysia or the region. However, as many materials might be imported from US, BEES can still give us an indication of the performance between two alternative materials.

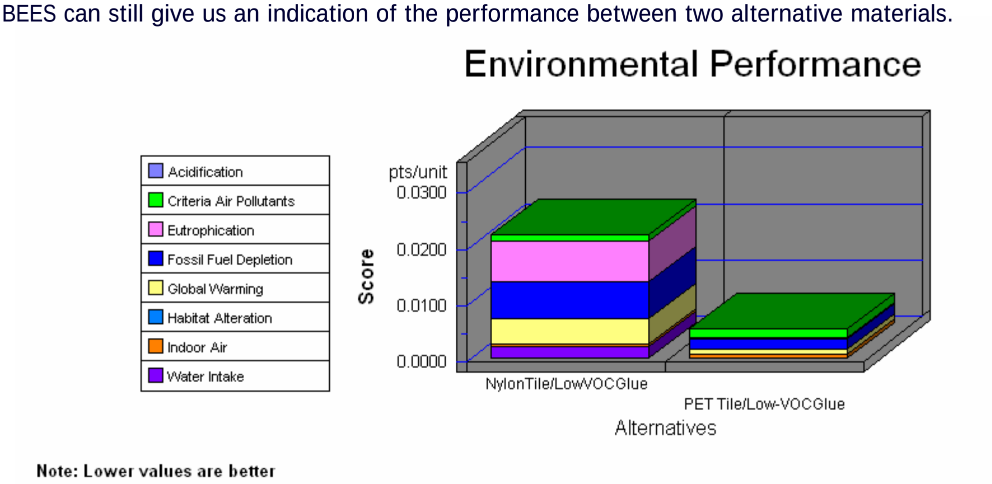

Figure 1: Selection of materials using the BEES program (example)

6. Indoor Air Quality

Indoor air quality (IAQ) has been increasingly gaining attention in office buildings due to its adverse effect on human health with the emergence of the Sick Buildings' Syndrome. The amount of pollutants in the office environment has a strong impact on IAQ performance as it can have an adverse effect on the health of the occupants. Source control for good indoor quality can be achieved by choosing healthy materials in the first place. Figure 1 shows that paints have great variation generally with high initial emissions that decay rapidly. Wool carpets have lower initial emissions but they persist over longer time. Particle boards have the lowest initial emissions but the decay is so slow that emissions can last for months or years.

To balance indoor air quality with energy efficiency, Carbon dioxide (CO_2) monitoring can improve indoor air quality and save energy when it is part of a demand control ventilation system. With CO_2 sensors connected to the ventilation system, the amount of fresh air supplied to interior spaces can be regulated to ensure that the CO_2 level does not exceed 1000ppm (the threshold limit). More fresh air is supplied when there is increased occupancy demand, and when there are less people, ventilation will be reduced to reduce energy consumption

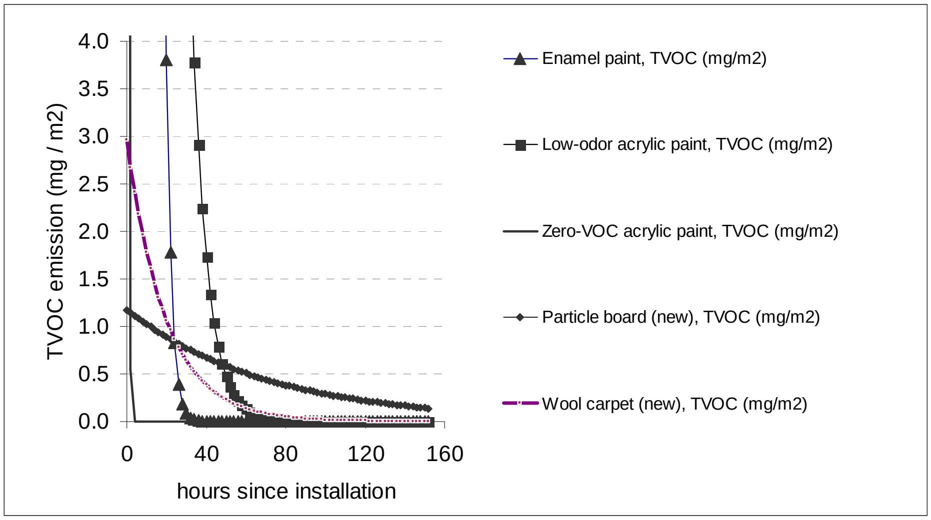

Figure 2: TVOC emissions from materials

7. Urban Heat Island Effect

Urban heat island is the built up of heat in the urbanized cities characterized with a higher temperature than the rural area. The high concentration of hard surfaces around the building could result in heat island effect due to the absorption of solar radiation by these surfaces in the daytime. This is a larger problem in the tropics because the outdoor temperature is already higher that what is preferred and any temperature increase in the cities is detrimental to outdoor comfort and also increases the cooling load.

Planting trees and vegetation is a simple and effective way to reduce heat islands. Strategic planting around buildings directly cools the buildings due to the shading effects provided, thereby decreasing air conditioning costs and peak energy demand. Trees and vegetation cool the air by providing shade and through evapotranspiration (the evaporation of water from leaves). A mature tree with 9m crown transpires approximately 150 litres per day and that corresponds to about 8000W of evaporative cooling or about $100W/m^2$ of tree footprint. Shade reduces the amount of solar radiation transmitted to underlying surfaces, keeping them cool. Shaded walls may be 5° to 20°C cooler than the peak surface temperatures of unshaded surfaces. These cooler walls decrease the quantity of heat transmitted to buildings, thus lowering air conditioning cooling costs. Cooler surfaces also lessen the heat island effect by reducing heat transfer to the surrounding air.

Green plot ratio can be used as a measure of greenery provision in building developments since provision of greenery has been shown to be an effective way to reduce heat island effect. This ratio takes into the consideration the 3-dimensional coverage of the foliage by plants (Ong, 2003). Green Plot ratio is basically the average leaf area index (LAI) of the greenery on site and the LAI can be considered as the ratio of leaves to ground covered. In other words, the higher the green plot ratio, the larger the total area of leaves exposed to the sun as compared to the area of the ground itself. This is beneficial in reducing the ambient temperature because the plants are providing a lot of shade to the ground and they will also cool down the surrounding through evapotranspiration. The Green Plot Ratio is used as a rating criterion in GreenMark-a green assessment system developed by the Building Construction Authority of Singapore.

7. Transportation energy

As buildings are designed to become more energy efficient, the energy required to transport the occupants of the building to their workplace becomes significantly larger in comparison to the building energy consumption. For a building to be considered sustainable, the transportation energy associated with the building has to be considered and reduced as well. Figure 2 shows the breakdown of energy consumption using a calculation example for buildings in Kuala Lumpur. The calculations were based on results of study conducted by CETDEM (2006). Figure 2 shows that for a reference building in Kuala Lumpur with an energy efficiency index (EEI) of 250kWh/m^2/yr, the transportation energy is about 80% as much as the total building energy consumption. As the building becomes more energy efficient (EEI of 80kWh/m^2/yr), the transportation energy is almost 2.7 times as much as the total building energy consumption. If 25% of the occupants take the public transport, the transport energy reduces to 2.2 times that of the building energy. And if 75% of the occupants take the public transport, the transport energy is almost the same as that of the building energy. It can be seen that the total energy consumed in the building and for using the building (transport energy) decreases significantly if commuting energy use is reduced.

The accessibility of the building to public transport is very important in reducing the need to drive. Sometimes the location is not within the control of the developer, the building owner can come up with various strategies such as providing company shuttle bus, offering incentives for carpooling etc.

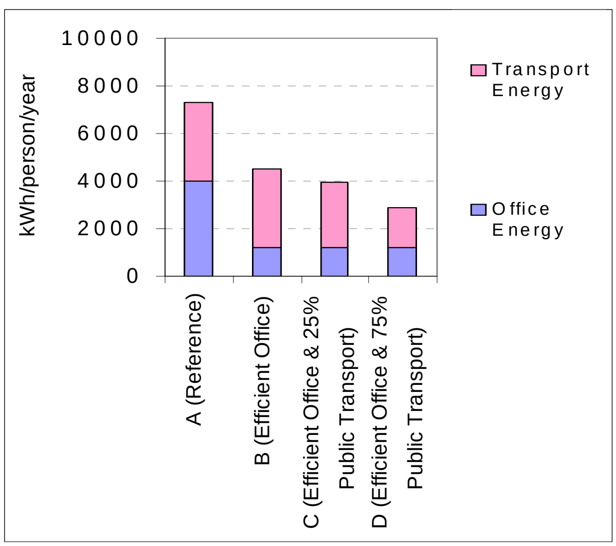

Figure 3: Breakdown of Energy Consumption (example from buildings in Kuala Lumpur)

Note: Assume transportation is by private car and public transport is by bus

Conclusions

It is important that all the issues mentioned above have to be considered, evaluated and optimized in order to come up with an office building that is sustainable, with minimal impacts to the environment.

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8 FUNDAMENTAL STEPS TOWARD ENERGY EFFICIENCY IN AIR-CONDITIONED BUILDINGS FOR TROPICAL CLIMATE

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Abstract

Energy efficiency in air-conditioned buildings for tropical climate has been a subject of much discussion, especially among the building construction practitioners such as the architects and building services engineers. Experience from designing two demonstration low energy building project in Malaysia (the Low Energy Office Building and Zero Energy Office Building) has exposed that there exist many myths about the effectiveness of various features in the building as energy flows in building remains largely unfamiliar to most. This is because even a simple building has a very complicated energy transfer process converting electrical energy into conveniences for the building occupants (lighting, computers, etc.) and then into heat, where electricity is used again to provide comfort by removing heat from the space and all this while, the climate outside is influencing the space by solar heat gain, conduction heat gain and infiltration of air into the building.

This paper addresses the need for an easy method of understanding energy efficiency in buildings by providing a simple and yet comprehensive picture of energy flows in buildings by providing the 8 fundamental steps for energy efficiency for air-conditioned buildings in tropical climate. This 8 fundamental steps covers all the energy components to achieve an energy efficient building, from architectural, mechanical, electrical and energy management point of view for an air-conditioned building. Steps 1 to 7 are building design steps that are prioritise according to the amount of energy consumptions in a typical air-conditioned building in tropics, while step 8 is for energy management. Step 8 is to ensure that step 1 to 7 is being practised correctly in the actual building after the completion of construction process. A detailed description of each fundamental step is provided to ensure that energy efficiency for air-conditioned building in tropical climate is easily understood and practised by all.

Keywords: Energy Efficient buildings, Tropical climate, Best practices, Passive Features, Active Features.

1. Introduction

The 8 steps towards energy efficiency for air-conditioned building in tropical climate is a resultant of the re-evaluation of the Overall Thermal Transmittance Value (OTTV) in Malaysia in 2005-2006.
The Overall Thermal Transmittance Value (OTTV) was first developed for Malaysia in 1987. The OTTV was developed using computer simulation to provide an easy method for architects and engineers to manually calculate the average heat gain that is being transmitted into a typical office building via the building fabric due to orientation, windows to wall ratio, wall properties and glazing properties. Since 1987 (a time when personal computer is not wide spread yet), there have been no re-evaluation of the OTTV until this study in 2005 undertaken by the Danida project for Energy Efficiency in Malaysian Buildings.

The re-evaluation of the OTTV was conducted using computer simulation to get a fundamental understanding of the behaviour of a typical building thermal and energy characteristic based on Malaysia's climatic data. The results of this study provided remarkable insight into the thermal and energy performance of air-conditioned buildings in tropical climate that not only provided valuable input for the updates of the Malaysian MS1525 (Malaysian Standard for Energy Efficiency in Non-Residential Buildings), but it has also provided a key summary of the steps required for an air-conditioned building to be energy efficient a tropical climate.

The re-evaluation of OTTV was conducted with a simulation of more than 40 case scenarios by varying different properties of the building. The development of the 8 steps towards energy efficiency for an air-conditioned building was largely based on the results of 3 case scenarios that vary the internal energy load of the building while keeping the building envelope constant as this would simplified the complexities of energy flow in building to a manageable analysis while providing enough useful information. The 3 selected case scenarios are:

- Worst Case Building Scenario
- Base Case Building Scenario
- Ministry of Energy, Water and Communication (MEWC)'s Low Energy Office Scenario.

2. The Ottv Model

Three (3) case studies were set up and simulated to get an understanding of how energy is used in a typical office building today. These case studies were:

Worst Case Scenario (2005)

Base Case Scenario (2005)

MEWC's Low Energy Office (2005) - calibrated to an air-conditioned space of 5,200 m2 instead of 19,000 m2

The worst case scenario describe a building with high energy consumption due to high internal load. An internal lighting load of 21 W/m² and a small power consumption of 24.5 W/m² is allocated for this building. In addition, this building is also assumed to have a bad energy management with an approximately 40% of lights and small power still running during non-occupied hours. It was also assumed that the building is very leaky with an infiltration rate of 2 air-changes per hour (ach).

The base case scenario attempts to describe a building with the most likely scenario of current buildings in Malaysia. It has a lighting load of 18W/m² and a small power load of 19 W/m². A moderate scenario of energy management is assumed for this building where approximately 30% of the lighting and small power load is still running during non-occupied hours. It was assumed that this building is also leaky with an infiltration rate of 1 ach as Malaysia do not have a culture of providing air-tightness in buildings.

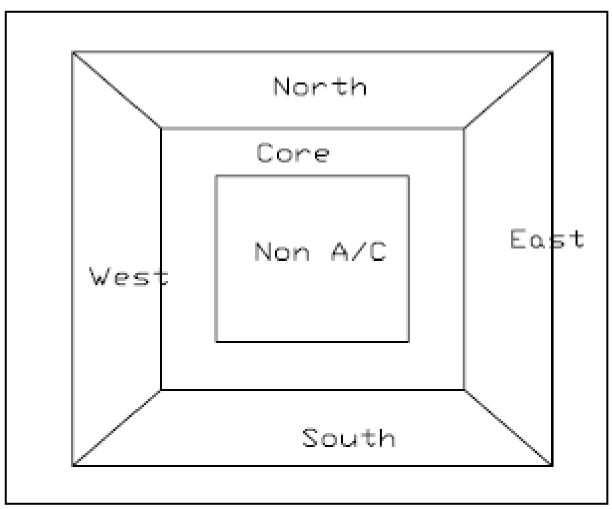

Fig. 1 Plan view of the Malaysian Base Case building with 10 floors

The Low Energy Office (LEO) scenario is based on the actual measurements obtained from the Ministry of Energy, Water and Communication's Low Energy Office building after approximately 9 months of operation. A lighting load of 5.5 W/m² and a small power load of 6 W/m² was measured in this building and is used for LEO case scenario. During non-occupied hours, approximately 20% of the lighting power is still being consumed, while the small power consumption during these hours represented approximately 54% of the peak daytime load. No measurement of air-tightness was made for the LEO building, however, based on the fact that fresh air is not required for the building from the system (CO_2 sensor controlled) and the measured CO_2 in the building range from 400-500 ppm, it is rational to assume that the infiltration rate is 1 ach for this study to represent a fairly leaky building.

The shape and properties of the Malaysian Base Case building in 1987 was retained in this initial study, while the internal loads were varied as shown in the table below. The base case office building shape and dimension of the simulation model in 1987 has the following properties:

Air-Conditioned Space	5200 m²
Core Space	1000 m²
Windows to wall Ratio	0.4
Shading Coefficient of the Glazing	0.69
Brickwall U-value	2.6 W/m²/K
Roof (Highly Insulated)	0.001 W/m²K
Lighting Load	21 W/m²
OTTV	66 W/m²
COP of Chiller	4.1
People Density	9m²/person
Small Power Load	5.35 W/m²
Infiltration	1 ach
Fresh Air	3.3 lit/sec/person
Variable-air-Volume Air Conditioning System	50% minimum flowrate

Table 1. Base Case Building. 10 Story office building.

The roof was simulated with very high insulated value to remove the effect of roof from the simulation, as the OTTV equation only describe the façade of the building excluding roof.

Descriptions	Proposed Worst Case (2005)	Proposed Base Case (2005)	MEWC LEO (2005)
Lighting Load (W/m2)	21	18	5.5
Lighting Operation Hours	100% 8am to 5pm 40% 5pm to 8am	100% 8am to 5pm 30% 5pm to 8am	100% 8am to 5pm 20% 5pm to 8am
People Density (M2/person)	10 as stated in UBBL	10 as stated in UBBL	60
People Working Hours	1% 7:30am-25% 8am 25% 8am-100% 8:30am 100% 8:30am-5pm 100% 5pm-5% 10pm 1% from 10pm-7:30am	1% 7:30am-25%8am 25% 8am-100% 8:30am 100% 8:30am-5pm 100% 5pm-5% 10pm 1% from 10pm-7:30am	1% 7:30am-25% 8am 25% 8am-100% 8:30am 100% 8:30am-5pm 100% 5pm-5% 10pm 1% from 10pm-7:30am
Small Power Load (W/m2)	22.14 W/m2	17.67 W/m2	4.5 W/m2
Small Power Operation Hours	100% daytime 45% nightime	100% daytime 29% nighttime	100% daytime 54% nighttime

Computer Load per person (W/person)	180 (18 W/m2) 100% Daytime, 35% night	150 (15 W/m2) 100% Daytime, 15% night	120 100% Daytime, 15% night
Server Room, Load/AC Area (W/m2)	2.5 100% 24 hours	1.5 100% 24 hours	1.5 100% 24 hours
Shared Office Load (W/m2)	0.5 100% 24 hours	0.25 100% 24 hours	0.25 100% 24 hours
Core Load (W/m2) of Core Area	5 100% Daytime, 50% night	4 100% Daytime, 50% night	4 100% Daytime, 50% night
Fresh Air	AC hours: 2 ach 20 l/s/person (10500 l/s) approx. 650ppm CO2 level Off AC: 1 ach	AC hours: 1 ach 10 l/s/person (5250 l/s) approx. 920 ppm of CO2 Off AC: 1 ach	AC hours: 1 ach 60 l/s/person (5250 l/s) Off AC: 0.5 ach
Fan Static Pressure	1250 Pa	750 Pa	250 Pa
Chiller COP	4.1	4.1	4.1
Air Delivery	VAV	VAV	VAV

Table 2. Description of input data for 3 different case scenarios.

Notes on the LEO case:

Lighting load of 5.5 W/m2 was based on actual monitored usage. Installed lighting capacity is 12 W/m2.
Occupant density in existing MEWC was approximately 60 m2/person.
Small power load of 4.5 W/m2 was also based on actual monitored usage.
Computer load of 120 W/person was assumed in this case as most staff in MEWC would be using flat TFT monitor instead of large energy inefficient CRT monitor.
Server Room, Shared Office Load and Core Load of MEWC were all calibrated based on actual monitored values in the current MEWC office.
Fresh Air intake is also calibrated to the CO2 sensor reading in the building. 1 ach rate is required to keep office CO2 reading below 460 ppm. Monitored CO2 reading in the MEWC is between 400 – 500 ppm in most areas.

3. The 8 Steps Toward Energy Efficiency in Buildings

The simulation results of the 3 case scenarios were tabulated in a bar chart (Fig. 2) to provide an overview of the various breakdown of energy consumption in a building.

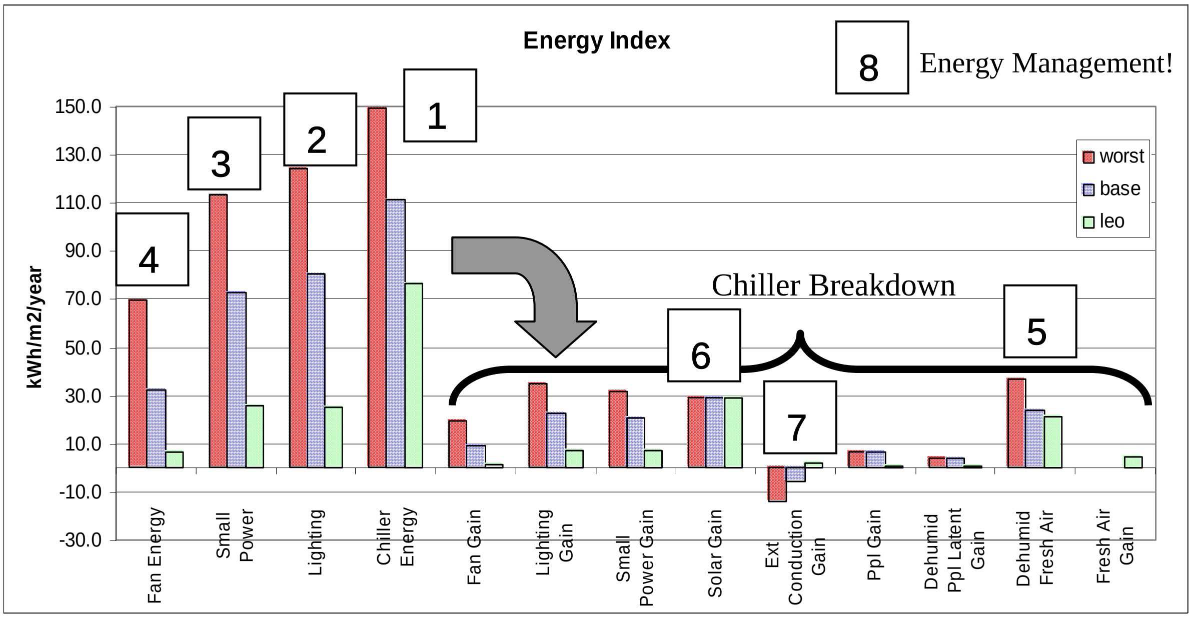

Fig. 2 Energy index breakdown of 3 different types of building scenario

The energy index breakdown in Fig. 2 shows that there are basically 4 major energy consumption in an air-conditioned building in tropical climate. These are:

1. Fan Energy
2. Small Power Energy
3. Lighting Energy
4. Chiller Energy

Usually the chiller energy and fan energy are combined and called as air-conditioning energy, however, for the purpose of understanding the energy flow in building, it is useful to it split up in order to provide a breakdown of chiller energy into each heat element that the chiller is required to remove from the building.

The chiller energy breakdown showed the following heat element that is removed by it from an air-conditioned space:

1. *Fan Sensible Heat Gain.* The fan have a motor that drives it. The motor would then generate waste heat. This heat is introduced directly into the air-conditioned space.
2. *Small Power Sensible Heat Gain.* All equipments that are plugged into the powerpoints constitute of small power energy use. As a law of energy conservation, all electrical energy used by these equipment will end up as heat in the air-conditioned space.
3. *Lighting Sensible Heat Gain*. Similar to the small power sensible heat gain, all electrical energy used by lighting will end up as heat in the air-conditioned space.
4. *Solar Radiation Sensible Heat Gain*. The heat gain due to solar radiation through the building windows are known as solar radiation sensible heat gain.
5. *Conduction Sensible Gain due to External Façade*. The heat gain due to conduction through the building façade excluding the roof space.
6. *People Sensible Heat Gain*. The sensible heat gain from people is the heat emitted by people in the air-conditioned spaces.
7. *Dehumidification of People Latent Heat Gain*. The latent heat gain from people is the moisture emitted by people in the air conditioned spaces.
8. *Dehumidification of Fresh Air Ventilation*. The infiltration of fresh air (outside air) into air-conditioned spaces bring along moisture content of the outside air.
9. *Fresh Air Ventilation Sensible Heat Gain*. The infiltration of fresh air (outside air) into air-conditioned spaces bring along heat/cooling content of the outside air.

The chiller energy is used to remove all the heat generated in the list described above in order to maintain the comfort temperature and humidity in the air-conditioned space.

The chiller energy is the highest contributor to the total building energy use for all the cases. The electricity used for lighting is consistently the second highest, followed by small power and lastly the fan energy that is used to deliver cold air into the spaces.

Fig. 2 is a very insightful chart. It shows that in the worst case scenario the heat generated by lighting and small power is higher than the heat from solar radiation or conduction heat gain in the building.

More interestingly is the fact that the worst case scenario, the net conduction gained over a year is negative, meaning that heat is being conducted out of the building more than being conducted in for a full year scenario.

This is due to the reason that in a worst case scenario, a significant amount of small power equipment and lighting system are still running during non-occupied hours (e.g. night time to early morning), at hours where the outside temperature is low. The air temperature in the office space during night hours would then be higher (due to the internal equipments and lighting that are still in operation) than the outside air temperature.

Therefore, heat is being conducted out of the fabric of the building, helping to cool the building during night time. This chart also shows that conduction gain is high for the base case in 1987 due to the reason that the building in 1987 does not have night load inside the building because it does not have equipments that are running during night such as computers, fax machine, server room, control room and etc.

The dehumidification of fresh air in the worst case scenario is also shown to contribute more energy to the chiller than the solar radiation heat again. This is largely caused by the high moisture content of a hot and humid climate such as Malaysia. In addition the removal of moisture from the air is phase-change process that requires large amount of energy to convert moisture in vapour form into water in liquid form.

It is also interesting to note that the air-conditioning that is used for the primary purpose of providing comfort to the building occupants (people). However, the sensible and latent heat gain from people represented only a fraction of the chiller energy use.

It is also shown in Fig. 2, that the heat generated internally by lighting and equipment (small power) represented a significant amount of heat removed by the chiller, clearly indicating that the reduction on energy consumption of internal loads such as lighting and equipments will also lead to significant saving on chiller energy consumption.

Finally the chart shown in Fig. 2 allows the following general interpretation to be made to provide a sort of checklist of priorities for energy efficiency features in building starting from the items that consumed that highest amount of energy to the item that consume the least:

Energy efficient chiller system. A low efficiency chiller system will increases the total energy use within a building significantly as it increases the energy used to remove heat from the air-conditioned space. The term 'chiller system' consist of the chiller, chill water pumping system, chill water piping system and condenser system such as the fans for the cooling tower and the pumping system of the condenser system. Energy efficiency of the whole 'chiller system' is required in order to gain efficiency in this area.

Reduce artificial lighting load. Natural daylighting is the best because it provide the highest amount of light with the least amount of heat. Other methods include the use energy efficient lighting system, proper zoning of lighting circuit and etc. Night lighting should be carefully considered and should never be over provided.

Reduce small power load. This would means that energy efficient computers, servers, and control system should be used. Nighttimes energy consumption of small power should be closely monitored.

Minimise fan power. The fan is used for the air-conditioning system. The energy use by the fan is mainly contributed by two factors, fan efficiency and ductwork total pressure. Selection of fan with high efficiencies will reduce the energy use by fan significantly, while larger duct sizes will have lower pressure loses and therefore lower overall static pressure and thereby reducing energy use of the fan.

Control of fresh air intake and infiltration. Air-tightness of building is now shown to be more important than preventing solar radiation heat gain as the infiltration of humid air into air-conditioned spaces contributes significantly to the energy used by the chiller. In addition, it is highly recommended to install CO_2 sensor in the air-delivery system to control the amount of fresh air introduced in air-conditioned building in this climate. The CO_2 sensor will ensure that the quality of air is maintained adequately without over providing fresh air via the air-delivery system to minimise the energy used to dehumifidy outside air.

Control of solar heat gain. Building orientation, exterior shading devices and glazing properties should be carefully considered by the architects to minimize heat gain from the sun.

Insulation of building fabric. Building fabric should only be well insulated when night load in the building is well controlled. Otherwise, the insulated fabric will trap the heat generated during night hours. It is also possible to use vegetation (greeneries) outside the building to help to keep the micro-climatic surrounding the building to be cooler.

A low energy building design need to address all these 7 steps, as these are the fundamental steps towards energy efficiency for air-conditioned buildings in tropical climate. It should also be noted that in each proposed step there are many possibilities to achieve the same intended objective as every building is built unique. It is up to the designer of the building to be creative to provide the most appropriate solution for their client while addressing these 7 fundamental steps for energy efficiency in air-conditioned building in the tropical climate.

Step 8 is energy management of the building after construction. This is to ensure that steps 1 to 7 are being practised in the building during the actual operation of the building to achieved the intended effect of a low energy air-conditioned building in tropical climate.

4. Summary

The re-evaluation of the OTTV offers an opportunity for an insightful analysis of typical energy consumption in buildings. As energy flow in building is often a matter of great complexity, this analysis simplified and put in perspective of the relationship and quantity of the possible energy saving potential of each element of a typical building into 8 fundamental steps. More importantly this analysis aided in providing a form of general checklist of priorities in the design of energy efficient buildings for the building designers such as the architect and engineer.

Acknowledgements

Special thanks to Prof. Kannan for sharing his experience on the building simulation study for the development of the OTTV formulation with us.

References

Prof. Kannan & Lawrance Berkeley Lab (1987), Building Simulation Study for the Development of OTTV formulation for Malaysian Climate.

CLIMATE RESPONSIVE BUILDING ENVELOPE TO DESIGN ENERGY EFFICIENT BUILDINGS FOR MODERATE CLIMATE

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ABSTRACT:

Buildings are either naturally ventilated or mechanically ventilated to achieve indoor comfort. Indoor conditions in naturally ventilated buildings are dynamic in nature and are static in mechanically ventilated buildings (air conditioned buildings). Selection of right building materials, thickness of walls, type of roof, orientation, percentage fenestrations, plan form etc are some of the parameters which help in achieving thermal comfort for both types of buildings. An attempt is made in this paper to understand and quantify the effect of different parameters like building materials, orientation, percentage fenestrations, Length/Breadth Ratio, height of the building etc on the building envelope for air-conditioned buildings. Heat loads are calculated for volumes ranging from 150cum to 180,000 cum and for two different combinations of materials; Heat loads are calculated for approximately 900 combinations of these parameters. This study led to some interesting conclusions which are useful to the designers. Design charts are developed for two combinations of materials with varying percentage glazing and plan form (L/B Ratio). These charts help the designers to try different combinations of these building parameters to reduce heat loads for a particular building. Design charts sensitize the architect/designer at the planning level as he is able to estimate heat loads. There is also a possibility of earning 10 points which are awarded in LEED rating for green buildings by reducing heat loads and hence an energy efficient building envelope design.

Keywords: BUILDING ENVELOPE, INDOOR COMFORT, ENERGY EFFICIENT, GREEN BUILDING, LEED RATING. DESIGN CHARTS

1.0 Introduction:

Buildings, as they are designed and used today, contribute to serious environmental problems because of excessive consumption of energy and other natural resources. The close connection between energy use in buildings and environmental damage arises because energy intensive solutions sought to construct a building and meet its demand for heating, cooling, ventilation and lighting cause severe depletion of invaluable environmental resources.

As the environmental impact of buildings becomes more apparent, a new field called **Green building** is gaining momentum. Green or sustainable building is the practice of creating healthier and more resource-efficient models of construction, renovation, operation, maintenance, and demolition. Research and experience increasingly demonstrate that when buildings are designed and operated with their lifecycle impacts in mind, they can provide great environmental, economic, and social benefits.

Figure 1.1 approximately shows the energy consumed in buildings. Heating, cooling and lighting consume enormous amount of energy. In tropical climates major amount of energy is consumed in cooling the building. Intelligent use of simple techniques such as orientation, percentage fenestrations, height and volume of the building, materials etc will reduce the energy consumption to considerable amount and improves the performance of the buildings.

One-way of assessing the building performance is to study the heat transfer through the building envelope. This paper considers the need to quantify the effect of various parameters like percentage openings, materials used, volume, orientation etc. An attempt is made to quantify the effect of these parameters and optimizing the parameters to design an energy efficient building.

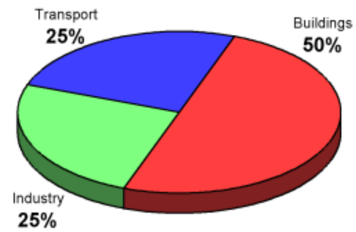

Fig 1 Energy Consumption

The author currently resides in Bangalore, India, and the work is focused on quantifying the above mentioned parameters at 12^{o} 58'N latitude, (Bangalore) with moderate climatic conditions. The temperature in peak summer is 38^{o} c and humidity lies between 50 to 70%.

2.0 HEAT TRANSFER THROUGH BUILDING ENVELOPE :

Heat gain or loss in buildings is due to heat transfer through walls, roof, ceiling, floor, and glazing etc., i.e., the building fabric or envelope. The load due to such heat transfer is often referred to as the envelope heat gain or loss. Majority of Heat transfer takes place in buildings through building envelope. Building envelope consists of walls, roof, and fenestrations (openings). Heat transfers through walls and roof is by conduction and is through conduction and radiation in glazing materials. Heat loads are generated through convection which is termed as ventilation load. There are also internal loads inside the building due to occupancy, lighting and heat loads due to air conditioning equipment if any, to maintain indoor comfort. In the present study heat loads due to Conduction, convection, radiation and internal heat load is considered and the method adopted to calculate heat transfer is equivalent temperature differential method. Heat loads due to infiltration, transmission gain through partition walls, ceiling, floor, etc, are ignored

3.0 PARAMETERS CONSIDERED IN THIS STUDY:

The various building elements taken for study which influence the transmission of heat loads are

- Orientation
- Building materials used on building envelope
- Volume
- Percentage glazing on building envelope
- Height of the building
- L/B ratio (length to breadth)

This study mainly focusses on the combined as well as the individual influence of these parameters on heat transfer in buildings. These parameters are varied and heat loads are computed to quantify the effect of each of these parameters.

- Heat loads are computed for North –South (NS) and East – West orientations (EW).

Two combinations of building materials are taken to study the effect of the materials used in building envelope.

- Combination 1 consists of brick walls, plate glass for glass area and RCC roof without insulation.

- Combination 2 consists of Fly ash blocks (Aerocon blocks) for walls, tinted glass for glass area and insulated with 50mm polystyrene sheets.

- Heat loads are computed for volumes ranging from 150 cum to 180,000 cum i.e., plan area ranging from 10 X 5m to 300 X 200m. 150 cum volume is the smallest possible volume for habitable area and 300 X 200 m plan area is very large and is fixed as upper limit.

Percentage glass area is assumed to range from 20% to 80% of the wall area. A maximum of 80% is assumed excluding columns, window frames and also corners of the building. The effect of percentage glazing on heat loads is calculated by assuming different combinations.

- ➢ All the four walls namely north, south, east and west walls are assumed to have 20% glass area initially and are increased to 40%, 60% and 80% for both the combinations and orientations.
- ➢ Percentage glass area is kept constant in east and west walls at 20% and varied in north and south walls from 20% to 80%. This is done to study the effect of glazing in north and south walls for both orientations i.e., north south (N-S) and east west (E-W).
- ➢ Similarly the percentage glass area is kept constant in north and south walls and varied in east and west walls for both the orientations to study the effect of percentage glazing in east and west walls.
- ➢ Further, to study the effect of percentage glazing area in each wall, heat loads are computed when percentage glazing area in three walls is kept constant at 20% in the first simulation and varied in the remaining walls.

For example, to find out the effect of percentage glazing in west wall two simulations are required. In the first simulation, percentage glazing in all walls is assumed to be 20%. In the second simulation, percentage glazing in west wall is increased to 80% and is kept at 20% for the remaining walls i.e., north, south and east walls.

- Heat loads are also computed when height of the building is assumed to be 3m and 4m for both combinations and orientations.
- Further, work is carried to study the effect of L/B ratio. The sample volumes of 150cum, 6000cum, 180,000 cum are studied for varying dimensions such that their L/B ratio is 1, 1.25, 1.5, 1.75, and 2.0 for the same plan area. This work is carried out for combination 2 also for both the orientations.

4. Results and discussion:

4.1 Effect of building orientation on heat loads:

It is observed from Table 1 that heat loads are lower in case of north south orientation when compared to east west orientation for all volumes. For smaller volumes like 150 cum, the heat load for combination 1 and percentage glass area 20% on all four walls, is found out to be 17.351KW for E-W orientation and found to be 15.628 KW for N-S orientation. It can be observed that heat loads are less in north-south orientation in comparison to east-west orientation for all volumes. Table 1 shows heat loads for combination 1 and only for 3 volumes.

- ➢ For 150 cum volume and 20% glazing area the reduction is around 10%. As the volume increases to 6000cum the reduction in heat loads for north-south orientation is around 0.78% and is 0.29% for 180,000cum.
- ➢ When the percentage glass area is 80% on all the walls the heat load for 150 cum is found to be 19.6% less in north-south orientation in comparison to east west orientation.
- ➢ Similar trend was observed for combination 2. The heat loads in north south orientation are reduced by 10% approximately for 150 cum in comparison to east west orientation. For larger volumes the reduction was found to be less than 0.28%.
- ➢ This shows that orientation plays an important role for smaller volumes and almost negligible for larger volumes. The main reason is due to the fact that as volume increases heat transfer through roof is very large when compared to heat transferred through the walls and subsequently through glazing.

Table 1 Heat loads in KW (Kilo Watts) for different percentage glazing and orientations

Percentage Glazing Area		20%	40%	60%	80%
Volume in cum	Orientation				
150	E-W	17.35	21.76	26.16	30.57
	N-S	15.62	18.61	21.60	24.59
15000	E-W	1064.64	1108.73	1152.82	1196.91
	N-S	1047.38	1077.29	1107.18	1137.06
180000	E-W	12084.16	12256.12	12393.61	12513.11
	N-S	12084.16	12193.24	12302.31	12411.40

4.2 Effect of building Materials on heat loads:

Table 1 and 2 show heat loads in Kilo Watts for combination 1 and combination 2. The following are the observations made:

- For 150cum volume and 20% percentage glazing area on all walls, heat loads are 17.351KW for combination 1 in E-W orientation. The heat loads are found to be 9.501 KW for combination 2 when the rest of the parameters are identical.
- This shows a reduction of 7.85KW (45%) in heat loads when combination 2 is used. The reduction in heat loads is approximately 47% for a volume of 180,000cum (large volume). This trend is observed for all volumes.

Table 2 Heat Loads in KW for Combination 2

Percentage Glazing Area		20%	40%	60%	80%
Volume	Orientation				
150	E-W	9.50	12.65	15.81	18.97
	N-S	8.59	10.95	13.29	15.64
15000	E-W	566.79	598.38	629.97	661.55
	N-S	557.82	581.28	604.75	628.21
180000	E-W	6426.47	6526.34	6626.21	6726.086
	N-S	6408.53	6492.15	6575.77	6659.39

- Similarly in N-S orientation for 150 cum volume and 20% glass area in all four walls for north south orientation the heat loads were found to be 15.628 KW for combination 1 and 8.593 KW for combination 2.
- The percentage reduction in heat loads when combination 2 is used is around 45%, and 47% for 180,000cum volume. This is due to the fact that the U-value for Aerocon block (flyash brick) is around 0.36 and that of brick is 3.2.Similarly roof without insulation has a U-value of 4.399 and with insulation is 0.3667. This explains the reduction in heat loads by 45 to 47%. It can be stated from the above observations that heat loads reduce by 35 to 45% for combination 2 (low U values) is used, **irrespective of orientation, volume and percentage glazing.**

4.3 Effect of percentage glazing on heat-loads:

Table 3 Shows heat loads in KW for different percentage glazing in east west orientation. As shown in table 3 percentage glazing in east west is kept constant at 20% of the wall area and varied from 20% to 80% in the north south walls. Similarly the percentage glazing is kept constant at 20% in north south walls and varied from 20% to 80% in east west walls. The following are the observations made:

- Percentage glazing area in east west is very sensitive and contributes significantly to heat loads, larger the glazing area, larger the heat loads.
- Increasing percentage glazing in north south walls doesn't contribute significantly to heat loads as it does in east west walls for both orientations
- For smaller volumes percentage glazing provided in the cardinal directions is an important design parameter in both NS and EW orientations.
- For larger volumes varying percentage glazing in east-west or north-south need not be a design parameter in both NS and EW orientations.
- By minimizing the percentage glazing to 20% in the west wall with 80% percentage fenestrations in the remaining three walls heat loads can be reduced approximately by 20-40% for small volumes.
- In N-S orientation north and south walls are longer than east and west walls, hence less percentage glazing in east and west walls. Despite this the percentage glazing in west wall needs to be kept low.
- However, for smaller volumes, the percentage variation is so high that openings in west wall even for north south orientation, are to be considered an important design parameter even in north south orientation.

Table 3 Heat loads in KW for variation in Percentage Glazing for E-W (east west) orientation, combination1

VOLUME cum	%GLAZING E-W	%GLAZING N-S		% VARIATION	%GLAZING N-S	%GLAZING E-W		% VARIATION
		20% in north south walls	80% in north south walls			20 % in east west walls	80 % in east west walls	
150	20 % in east west walls	17.351	18.916	9.03	20% in north south walls	17.351	29.010	67.19
15000	20 %	1064.645	1080.320	1.47	20%	1064.645	1181.241	10.95
180000	20 %	12118.623	12181.323	0.8	20%	13084.162	12468.412	3.18

4.4 Effect of increasing the height of the building

- Heat loads are marginally high when ceiling height is 4m when compared to 3m and hence need not be a design parameter.
- It was further observed that variation in heat loads for 3m and 4m ceiling height reduces as volume increases.
- This can be clearly be explained by the fact that as volume increases the major contributor to heat loads is the roof and not the walls. Hence increasing the height of the building from 3m to 4m increases the heat loads marginally.

Table 4 Heat Loads in KW for variations in Heights E-W, Combination 1

Plan area	Percentage glazing all walls	Height 3m	Height 4m	%variation
50 sqm	80	30.578	37.470	22.5
5000 sqm	80	1196.92	1265.83	5.75
60000sqm	80	12513.11	12747.55	1.7

4.5 Effect of L/B (length to breadth) Ratio on heat loads

- To minimize the heat loads in east west orientation the preferred geometrical shape of the building should be closer to a square. As the L/B ratio increases the east and west walls dimensions increase too and hence more glazing area. The lesser the L/B ratio the lesser are the heat loads.

Table 5 Heat Loads in KW for variations in L/B ratio for E-W orientation

Volume	Percentage glazing,all walls	1.0	1.25	1.5	1.75	2.0
150	80	16.616	17.170	17.895	18.470	18.977
15000	80	281.735	285.423	289.251	295.819	302.036
180000	80	6684.665	6713.120	6726.085	6750.204	6772.362

The desirable parameters from the above study are:

1) North south orientation,2) Minimum percentage glazing in east west walls, 3) Height of the building restricted to 3m, 4) Combination 2 which has low U values for building materials L/B ratio closer to 3, which reduces heat loads in north south orientation.

The undesirable parameters are

1) East west orientation, 2) Maximum percentage glazing in all the walls,3) 4m height of the building 4) Materials with high U values 5) L/B ratio close to 3(taken as 3 instead of 2 as L/B=2 increases heat loads marginally)

5.0 conclusions:

1. Orientation of the building plays an important role for small buildings. The effect of orientation on large volumes is insignificant.

Heat loads are found out to be high in E-W orientation when compared to N-S orientation. From the observations it can be stated that heat loads are reduced by 10 to 20% for buildings of small volume oriented N-S, depending on % glazing over E-W orientation.

2. Heat loads reduce by 35 to 45 % for combination 2 over combination 1

- Combination 1 is made of materials with high U values. (U for walls is3.2, U for roof is 4.4, U for plate glass is 5.9, solar gain factor is 1)
- Combination 2 is made of materials with low U values. (U for walls is .72, U for roof is .37, U for plate glass is 3.3, solar gain factor is .56)
- It can be stated that from the study that heat loads are reduced by 35 to 45% for combination 2 in comparison to combination 1 irrespective of orientation of the building, volume and percentage glazing. This conclusion is true for small and large buildings.

3. Heat loads increase as the building volume and percentage glazing area increase.

When the building volume increases the heat loads also increase. As the building volume increases percentage glazing area on each of the walls increases. It is due to the fact that heat transfer by direct radiation through the glazing area is more compared to conduction through walls. The heat loads are found to be substantially increasing even for large buildings.

4 Percentage glazing area in East and West walls is very sensitive and contributes significantly to heat loads in East-West orientation, for small volumes

5. Percentage glazing area in East and West walls is very sensitive and contributes significantly to heat loads in North South orientation, for small volumes.

6. Variation in heat loads is insignificant, in buildings constructed in N-S and E-W orientation, for larger volumes.

7. The percentage increase in heat loads is 35% higher when percentage glazing in west wall is to be considered an important design parameter for small volumes.

8. The percentage increase in heat loads is 11% when percentage glazing in west wall is at 80% with 20% glazing in the remaining walls. This may be considered as a design parameter for larger volumes.

9. Rating is given to all the walls based on the percentage glazing. It is based on which wall causes significant effect on heat loads for each of the orientations. The order given below is from high to low.

East West orientation	North South orientation
West	West
East	North
North	South
South	East

10. The heat loads are always more when the height of the ceiling is 4m when compared to 3m for all volumes.

11. To minimize the heat loads in east west orientation the preferred geometrical shape of the building is close to a square.

12. To minimize the heat loads in north south orientation the preferred geometrical shape of the building is a rectangle with a higher L/B ratio.

13. Desirable and some Undesirable parameters are listed based on the study for Bangalore moderate climate.

If any proposed building is designed as per the desirable parameters mentioned in this study, that building may earn all 10 points in LEED rating for GREEN buildings.

14. Design charts are developed for small volumes for different L/B ratio and percentage glazing. These charts are prepared for East West and North South orientations. For any particular volume, U value (combination of materials) and L/B ratio these charts help the designer to estimate the heat loads. These parameters have significant effect on small volumes and hence are developed for small volumes only.

Graphs 1 to 4 represent heat load variations for combination 1 for 150cum, 600cum, 1800 cum and 6000cum respectively.

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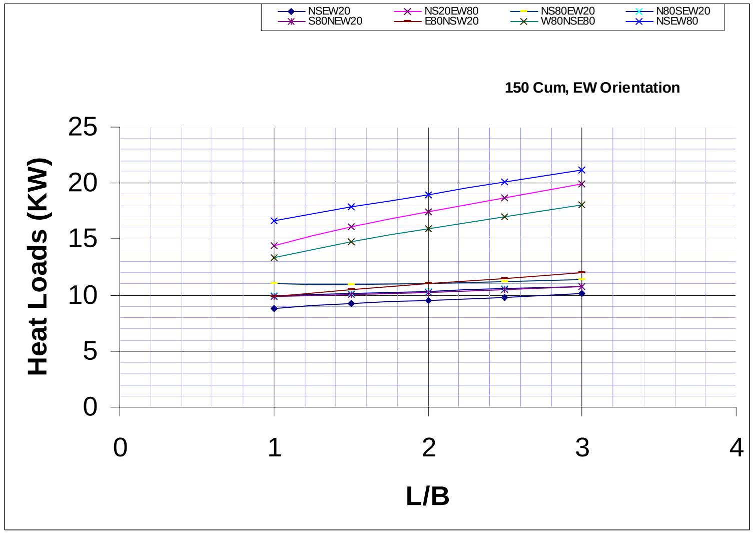
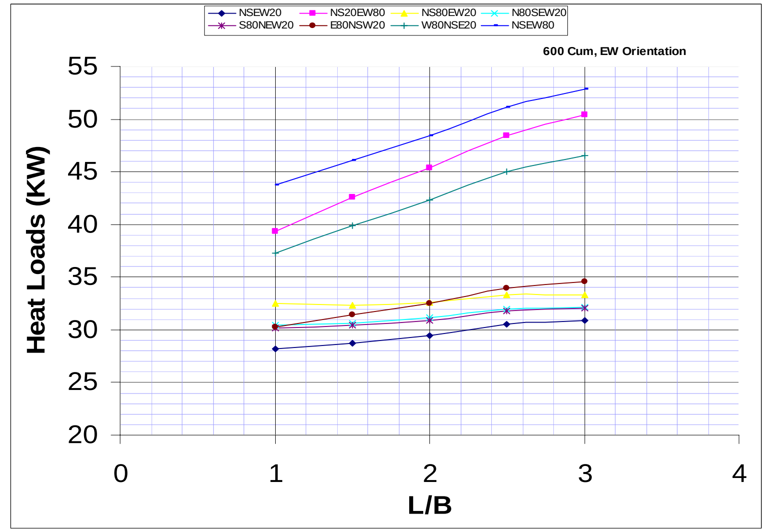
8.0 Acknowledgements:

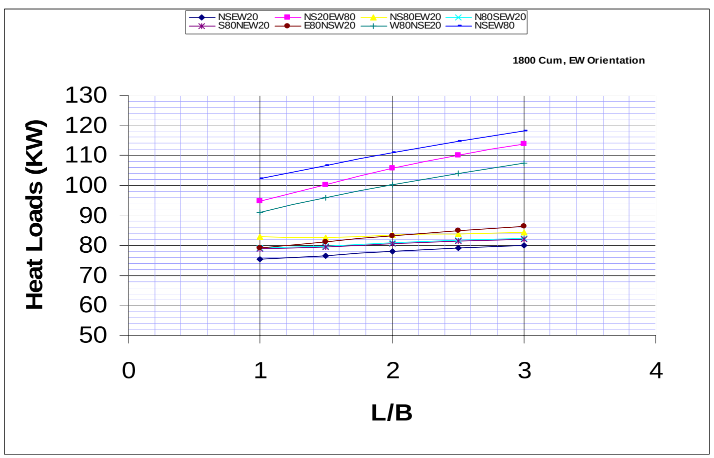
I would like to thank my father Prof P Venugopala Rao and, Prof P M Damodaran, Prof M.V Seshagiri Rao for their continuous support in carrying out this work



Design chart 1



Design chart 2



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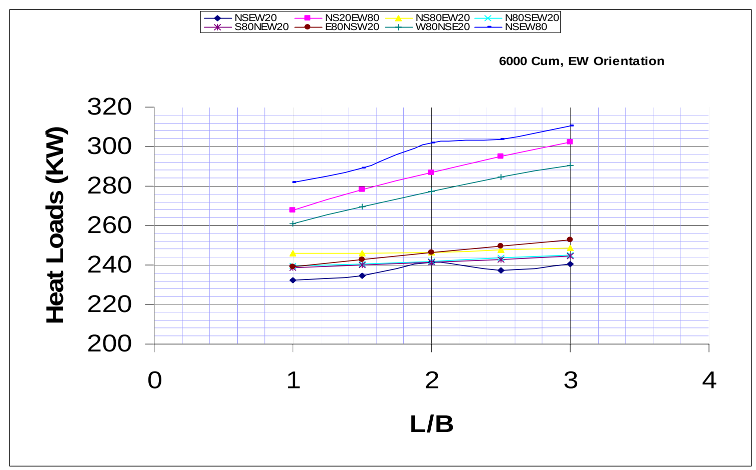

Design chart 4

ENERGY EFFICIENT UNDERGROUND COMMERCIAL BUILDINGS IN THE TROPICS

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Abstract

In recent decades, the rapid depletion of the environment and an exponential increase in energy consumption has forced man to be more environmentally conscious. This is evident in the development of passive and low energy concepts in buildings especially in the area of cooling and ventilation. Exploration in this area has resulted in underground buildings being re-looked as an energy efficient alternative to buildings on the surface. Most of the research and physical development of underground buildings have taken place mainly in temperate or hot and arid regions. Although, underground buildings in these regions have been successful, research into energy efficient underground buildings in the tropics has been limited. In hot and humid regions, commercial buildings are commonly air conditioned and the energy consumed accounts for up to 60% of the total building's energy. This paper explores the possibility of passive and low energy cooling of underground buildings in hot and humid climates as a means of energy conservation. Existing passive and low energy cooling strategies are considered to determine their feasibility within the context of a hot and humid climate. The achievable thermal comfort levels for each strategy are then examined against the acceptable thermal comfort levels in the tropics. Feasible approaches are subsequently selected and developed into hybrid low energy cooling strategies specifically for underground commercial buildings designed in the tropics.

Keywords: Underground buildings, Hot and Humid Climate, Desiccant Cooling, Evaporative Cooling, Ventilative Cooling

1.0 Introduction

In a bid for constant advancement, man has destroyed most of his natural environments with mega cities and used up natural resources at unprecedented rates. It has even been noted that at present levels of consumption, the human species requires about 3 earths to sustain itself, thus exceeding the carrying capacity of this planet, of which building consumes half of all fossil fuel energy and the totality of cities consume three-quarters (Edwards & Plessis, 2001). The main issue here is the rate of consumption driven by growth. Some environmentalist and policy makers have suggested non-differentiated growth. However, lessening growth or regressing to a stage of sustainability may be more of a utopian ideal then reality. Thus the issue presented is one of making our buildings and land more efficient, thereby reducing the need to take up additional energy or land mass which would otherwise be used for our natural environment.

The term underground buildings have been loosely used to describe a range of buildings that are in some degree covered by earth. More than 50 different terms have appeared in the international literature describing earth covered architecture. However, the appropriate terminology to describe an underground building is Geotecture, which could be further classified into two types namely Terratecture and Lithotecture. Terratecture refers to buildings constructed with a cut-construct and cover technique whilst Lithotecture refers to mined spaces enclosed by fully self supporting rock (Sydney & Baggs, 1991).

The interest in underground buildings and energy consumption stems from two issues. Firstly, with over utilization of land mass above ground especially within developed tropical cities like Singapore, developers and planning authorities have begun to explore space utilization underground. Secondly, the issue of sustainability and energy consumption has to be addressed as a matter of social responsibility in securing the environment for future generations. Furthermore, an energy efficient underground building would have a positive impact on the economy and environment. This can occur through increased developments of such buildings thus releasing land parcels for alternative usage; increased land utilization for residential or commercial activities or minimizing the impact on the physical environment. There are many existing examples of underground buildings in various cities around the world. Montreal's underground city, Shanghai's furniture exhibition hall, City Link mall and Dhoby Ghaut MRT station in Singapore and others are classic examples of successful underground developments. One of the reasons why the cited buildings in Montreal and Shanghai were built underground was due to climatic considerations; where it seeks to protect users from extreme temperature fluctuations of winter and summer. However, in tropical climates such as Singapore, it does not perform the same function as in temperate climates. The driving forces behind Singapore's underground buildings arise from economic and urban redevelopment gains. This paper aims to explore the climatic response in terms of "cooling of underground buildings" in the tropics and this work will assist the designers in establishing an appropriate response for cooling and ventilation of tropical underground buildings.

1.1 A Review of Available Energy Efficient Strategies Applied to Underground Buildings

Thermal exchanges between earth and the building are not the only methods of cooling an underground building. In certain instances, building underground is simply done to shelter the building from both solar radiations and higher ambient air temperatures rather than to use it as a heat sink or cooling source (Abrams, 1986). Nonetheless, the earth around an underground building both on and below the surface can be used as a cooling source for most climatic regions (Givoni, 1994). However, the performance levels of underground buildings are dependent on climatic regions. Extreme climatic regions with low humidity tend to benefit the most whist mild climatic and high humidity regions have lower benefits and its use may be unsuitable (Terman, 1985). Earth Cooling is observed to have the greatest effect on two types of climatic conditions. Firstly, it is effective in conditions where the differences between air and earth temperatures are wide. Secondly, in climates which have extreme surface conditions; for example unbearably high temperatures (Abrams, 1986).

General climatic conditions aside, the most important factor in determining the efficiency of earth cooling is actual soil temperature. Ideal soil temperatures can either be naturally occurring or induced through other passive means. For example evaporative and radiative cooling can be used to lower the soil temperature (Givoni, 1994). Earth coupling works by thermal transfer between the earth and the building through direct contact with the building envelope. The performance of this method is dependent on thermal resistance and thermal mass of both the soil and building envelope (Abrams, 1986). In addition, ground temperatures must be low enough in order for it to be of any use towards direct earth cooling (Abrams, 1986; Carmody & Sterling, 1983). This is because the internal surface temperature of the wall in contact with the soil will be close to the surrounding earth temperature. (Givoni, 1994). The limitation of this method is a slow thermal response time for external earth temperature to reach the internal space. This is because the external walls function as a buffer slowing the rate of thermal transfer. Alternatively, earth tube cooling has a more immediate effect on the rate of cooling for interior underground building space. Projects using this system have met with limitations of cooling capacity and humidity issues. Additionally, the costs of installing cooling tubes are almost similar to the air conditioning system; however it can not achieve the cooling capacity of the latter. Therefore earth cooling tubes are not recommended for use in residences or commercial buildings (Abrams, 1986).

Ventilative cooling (Givoni, 1994) is a process using air movement to cool a space or a person. Air movement in this case can either take place naturally or be induced mechanically. For example, opening a window to let air flow in is a natural process whilst turning on the fan to assist in the air movement is considered a mechanical means. Higher air speed increases the rate of sweat evaporation from the skin, thus minimizing the discomfort people feel when their skin is wet. Moreover, higher air speed extends the acceptable comfort range to higher temperatures up to 28^{o}C at an air speed of 0.8m/s (Givoni, 1994; Santamouris et. al., 1996). In some cases, physiological cooling increases the tolerable comfort temperature up to 30^{o}C even if the air is warm (Givoni, 1994). A study consisting of 256 people conducted at the Kansas State University concluded that psychological cooling effects were experienced at low to moderate wind speeds of 0.15m/s (Abrams, 1986). This is significant because an increase of wind speed between 0.15 – 0.27m/s can increase the comfortable temperature range by 1^{o}C (Abrams, 1986; Givoni, 1994). Therefore, the ASHRAE recommended maximum wind speed of 0.8m/s can increase the comfortable range up to 5^{o}C. However it is too limiting in dealing with cooling needs especially in non air-conditioned and extreme environments (Givoni, 1994). In such conditions, wind speeds of above 0.8m/s are required for effective ventilative cooling to take place.

Nocturnal Ventilative cooling functions by cooling the structural mass of the building interior by air movement from the cooler outsides during the night, and closing the building to the warmer outside air during the day (La Roche, 2002). There are two variations of Nocturnal Ventilative cooling. The first is a simpler process of ventilating a building during the night. As air passes through the building, cool energy is stored in the building's thermal mass and released directly into the space during the day. An example is an experiment conducted by Givoni. In this experiment, Givoni, ventilated a room during the night and closed during the day. It was discovered that this method of cooling can lower the maximum indoor temperature close to an outdoor daily average of 27.5^{o}C. This is in comparison to the experiment's maximum outdoor temperature of about 34^{o}C. The second method is similar to the above mentioned except it utilizes a dedicated thermal mass storage. During the night, air is passed through a storage mass such as a rock-bin or water tank. During the day the storage mass is used either as a radiator by ventilating air through the cool storage mass into the interior space, or using storage mass as a heat sink by absorbing heat generated or penetrating in the building (Givoni, 1994). The passive cooling system in Federation Square, Melbourne, Australia is an apt example. This system was possible due to the high diurnal temperature variations where labyrinths of concrete slabs were created and cool night is air pumped through the slabs. This process cools and stores thermal energy in the concrete slabs. A low velocity air displacement system is then used to circulate air through the concrete labyrinth of slab thus cooling the air. This cooled air is then delivered into the interior spaces. Studies have shown that the system is capable of cooling the interior space by up to 12^{o}C below the external ambient temperature. In order for nocturnal cooling to be effective, certain parameters must be met. High diurnal range with a night time temperature of below 20^{o}C is essential to cool the interior of a building sufficiently. This is so that peak temperature loads and maximum indoor temperature can be kept within a comfortable range (Givoni, 1994; Abrams, 1986).

Evaporative cooling is a thermodynamic process whereby heat from the air is absorbed by water which functions as a heat sink thus causing water to vaporize. Through this process of evaporation, either air or the water body is cooled, depending on which element has a higher temperature at the process's inception (Santamouris & Asimakopoulos 1996; Givoni, 1994; Killinger, 1999; Abrams, 1986). Research conducted by (Givoni, 1994; Abrams, 1986) established that the effectiveness of evaporative cooling is dependent on the wet bulb temperature. This is because temperatures produced through evaporative cooling are limited by the wet-bulb temperature. For example if the wet-bulb temperature is 25^{o}C then cooling by evaporative means cannot attain temperatures below 25^{o}C. Furthermore, evaporative cooling temperatures are generally 2^{o}C to 3^{o}C above the ambient wet-bulb temperature.

In the direct evaporative cooling method, Air passes through a wet body such as a water shower or wet fibrous pads. In this process, cooled air which is supplied to the conditioned space has direct contact with the water surface. Wet fibrous pads have been used in conjunction with a ventilation tower, commonly referred to as wind scoops (Battle McCarthy Consulting Engineers, 1999). This cooling method shares similarities to traditional Middle Eastern techniques where a water body like a pond is placed at the bottom of a wind tower. As the wind is redirected down the ventilation tower, it passes through the pond, which cools air by evaporative means before entering the ventilated space (Karaman, 1983). In a more contemporary version, Air enters the ventilation tower and is redirected into a chamber lined with an evaporative cooling pad where air is cooled as it passes through the pads. This cooled air then enters the building and eventually gets discharged out the building (Givoni, 1994;

Santamouris & Asimakopoulos, 1996). Results have shown that such methods can yield comfortable temperature results of 24^{o}C given conditions where the incoming dry bulb temperature air is 35.6^{o}C with a wet bulb temperature of 22.2^{o}C. (Santamouris & Asimakopoulos, 1996). These results are in line with La Roche's study establishing that direct evaporative cooling can reduce the difference between dry and wet bulb temperatures by 40 – 50%. Although research has shown that direct evaporative cooling can reduce air temperatures by substantial amounts, its use may either be an advantage or disadvantage depending on climatic conditions of the region. The water vapor content of the supplied air is increased due to the direct evaporative cooling process. In turn, the humidity of conditioned space is increased.

Unlike the direct method where a space is cooled through direct contact with humidified air, the indirect method works by cooling a heat sinking element such as a roof, wall, floor and others. When air from the space comes into contact with the heat sinking elements, heat is absorbed, thus cooling the space. Sheltered roof ponds and roof top sprays are simple passive ways through which the method is applied. By keeping the roof top wet, an evaporative process can take place throughout the day, therefore maintaining a constantly cooled roof. A space cooled using this method can yield temperatures 2^{o}C to 3^{o}C above the cooled ceiling temperature. The ceiling surface which has direct contact with the roof pond can achieve temperatures close to the wet bulb temperature (Givoni, 1994).

3.0 Limitations of Passive Cooling Strategies in the Tropics

3.1 Earth cooling

Buildings above ground receive direct exposure to the sun. This can cause internal heat gain through windows or heat build up through the exterior walls. This heat absorbed through the exterior wall is consequently released into the building throughout the day. Heat gained through external exposure accounts for a large percentage of energy required to cool internal spaces. This is especially common in the tropical context. Therefore, the most immediate and apparent benefit of placing a building underground is the exemption from direct UV radiation. The placement of buildings underground has presented new opportunities through the building's proximity to the surrounding earth. As a result, methods of using the earth as a cooling resource were developed. Successes of these methods are however subjected to the appropriate climatic conditions of temperate regions. During summer, the ground is cooler than the ambient air temperature as the ground acts a storage mass during winter. This process is subsequently reversed during winter. The tropics however, are subjected to summer temperatures all year round without winter periods to cool the ground. For instance, annual soil temperatures in tropical climates like Singapore ranges between 28^{o}C – 29^{o}C at depths of 1m (Meteorological services division, NEA Singapore). Similarly, in other tropical regions like Malaysia, the annual soil temperature at 1.22m depth ranges between 28^{o}C-30^{o}C depending on the location (Lapuran Mardi Report). This information has its limitations as data collected is derived from open ground conditions covered with grass, without shading interference from its surroundings (Todorov, 1980). Therefore, collected temperatures do not reflect soil conditions in urban areas where the ground is generally shaded by buildings and landscapes. Consequently, it is not possible to determine for certain the effective use of soil temperatures in high density urban areas as a means of earth cooling. Moreover, temperature data of more than 1.22m deep are not available. This is important as most underground buildings are situated at depths greater then 1.22m. With the limitations of present data, it is not possible to determine if earth cooling by means of direct contact with the soil at deeper levels will be sufficient in providing cooling needs of the tropics. However for depths of 1.2 and above, cooling through earth coupling is not a feasible strategy for cooling in hot and humid climates. This is because soil temperatures at these depths are not low enough for effective earth cooling. Existing literature suggest that even with naturally high soil temperature earth cooling is possible with cooling the soil through evaporative and radiation means. This is achieved by wetting the soil during the day to reduce the soil's ambient temperature. With lowered soil temperatures, earth cooling in the tropics is possible. However, the underground buildings with such techniques have to be located near the surface in order for this method to be effective. For buildings located at greater depths, this method will not be effective as cooling of soil through this process is limited to the surface.

In addition, other methods of earth cooling by means of cooling tubes are also not feasible as it requires a large temperature range between surface air and the ground temperature. This is because ground temperatures have to be significantly lower then the surface air temperature to cool it sufficiently as it passes through the ground before entering the building. The mean dry bulb temperature in Singapore ranges between 26.8^oC – 28.8^oC while soil temperatures range between 28.2^oC - 29.5^oC. This establishes that the temperature range between the ground and air is less than 3^oC. Without a higher diurnal range, air entering the cooling tube cannot be sufficiently cooled before entering the space. Therefore, cooling tubes is not a feasible strategy for hot and humid tropical climates.

3.2 Radiant Cooling at Night

Radiant cooling is a phenomenon whereby objects on earth losing its heat to the sky by means of thermal radiation emission. This is because the sky has a lower temperature than most objects on earth, for example buildings. In order for this process to take place, it requires an external surface of a building to be exposed to the sky, in which case, it is usually the roof.

The effectiveness of this strategy is dependent on the sky temperatures and studies have shown that this is very similar to the night ambient temperature. In hot and humid Singapore, the mean night temperature is about 26.7^oC (Singapore Meteorological department). This temperature is barely within the thermal comfort temperature for a tropical climate of 26.8^oC. Moreover, the low diurnal range in Singapore does not provide sufficient buffer for storing up cold temperatures during the night to address peak day time temperatures of around 31^oC.

Other elements making the radiant cooling process more efficient are operable roof insulations which are used during the day to block solar radiation heat gains, these operable roof have yet been proven reliable in actual building situations. Issues of reliability encountered by existing large scale operable insulations make it an impractical solution for the long term. Reliability problems encountered were due to the frequency of use as the roof has to be exposed and covered up on a daily basis. In addition, underground buildings that are too far from the surface would not have the opportunity of using the sky for radiant cooling. Any radiant cooling that takes place on the surface would not reach the building depending on the depth. Even if the cooling effect reaches an underground building, the transfer through layers of soil would diminish any cooling effectiveness. Hence, radiant cooling is not a feasible cooling strategy for underground buildings.

3.3 Nocturnal Ventilative Cooling

Nocturnal ventilative cooling unlike normal ventilative cooling does not require high wind speeds to be effective. It however, relies on two factors, high diurnal range and low dry bulb temperature during the night. Most hot and humid climates do not have the benefit of these factors. In Singapore, the diurnal range is about 6^oC with a night time low of 25^oC. Studies have suggested that the feasibility of nocturnal cooling requires a diurnal range of 8^oC with a night time temperature of below 20^oC. Without ample low temperatures, the nocturnal cooling system would not be able to store enough cold energy to deal with Singapore's day peak ambient air temperature of 31^oC. In addition to the ambient air temperature, heat generated in building interiors by lighting, people and machinery, may cause the temperature to rise above 31^oC.

4.0 Potential of Selected Passive Strategies for Tropical Underground Buildings

4.1 Ventilative Cooling

Ventilative cooling is most effective and commonly used passive cooling strategy in the tropics. It is almost instinctive to open the windows or turn on the fan when entering a hot room as wind blowing onto the surface of skin gives an immediate sensation of cooling. This is because air movement helps dry up the sweat from the skin through the evaporative process thus cooling the body down. The extent of human intuition has resulted in ventilative cooling strategies commonly found in traditional architecture within hot and humid regions. In South East Asia, traditional Malay houses are raised off the ground for two reasons. One for preventive measure against flooding and the other to allow air to pass underneath the house, keeping the floor cool. Another advantage of raising a house allows for prevention of heat gain through the ground as tropical grounds are often hotter than the ambient air temperatures. In the hot and humid climates of Sinamaica in South America, similar strategies were employed. Similarly, the Lacustrine village (Louisiana) have built their houses over the lake, allowing air flow between the building and water surface, removing internal heat and cooling the spaces through air gaps in the floor. It is interesting to note from the examples seen in different parts of the world suggest that such strategies are not culturally biased. This proves that air movement is an efficient passive means in addressing the cooling needs with hot and humid regions. However, not all air movement can effectively provide cooling. Studies have shown that a minimum air movement of 0.3m/s is required for effective cooling. It may be possible to apply ventilative cooling strategies in Singapore with a degree of effectiveness as data gathered shows an estimated of 50% of Singapore's Annual Wind speed is above the recommended air movement of 3m/s.

4.2 Direct Evaporative Cooling

Direct evaporative cooling does not appear feasible in hot and humid climates as this process increases the humidity levels. High humidity has an adverse affect on human comfort. However if temperatures yielded by direct evaporative cooling is low enough, the discomfort associated with high humidity is alleviated. Studies have shown that direct evaporative cooling temperatures are very close to wet bulb temperatures. That indicates that evaporative cooling temperature in Singapore can reach an average of 25.5^{o}C + 1^{o}C to 2^{o}C. This temperature is about 1^{o}C lower than the established acceptable comfortable temperature of 26.16^{o}C in the tropics (Cheong & Tan, 2002). However with higher humidity levels generated by this process, 27.5^{o}C (25.5^{o}C + 2^{o}C) may not be enough for optimum thermal comfort although this can be overcome with the assistance of increased air movement. Wind speeds of 0.3m/s can bring down the acceptance of a higher temperature by 2^{o}C. Therefore with ample wind speeds, the perceived cooling temperature can reach 25.5^{o}C (27.5^{o}C - 2^{o}C) below the acceptable tropical comfort level. An example for such a cooling phenomenon is when it rains. This evaporative cooling process is similar to a direct cooling tower except that it is on a larger scale. Whenever rain falls in the tropics, spaces that are natural ventilated often become sufficiently cooled. Spaces like commercial office buildings with air conditioning are often overcooled during periods of rain. It is not uncommon to see people in office buildings and on the street donning light jackets during rainy seasons in the tropics. Even with cooled environments resulting from direct ventilative cooling, the problem of humidity still remains.

4.3 Indirect Evaporative Cooling

A more appropriate strategy in combating humidity issues is by using indirect evaporative cooling. Indirect cooling is effective in hot and humid climates as it does not increase the humidity of conditioned air. However, cooling efficiency is lower than direct cooling as thermal energy is lost during a transferring process from the heat sinking element to the conditioned air. A loss of temperature in the range of 2 – 3 deg C is expected. For example if a ceiling, cooled by an indirect process, produces a temperature of 25^{o}C based on the wet bulb temperature, the resulting temperature of the ambient space would be about 27^{o}C – 28^{o}C (25^{o}C + 2^{o}C/3^{o}C). These temperatures would not be sufficient to meet thermal comfort levels required in the tropics. To generate better results solely through passive means would not be possible as resultant temperatures are directly linked to the wet bulb temperature of a region (Givoni, 1994; Abrams 1986). However, it is possible to make indirect cooling more efficient and applicable by lowering the wet bulb temperature with mechanical assistance (Desiccant systems). Hence, evaporative cooling is feasible in hot and humid climates with proper control of humidity levels and lowered wet bulb temperatures.

5.0 Selection of a Hybrid Strategy for Underground Buildings

Thermal Comfort levels for hot and humid climates differ from other climatic regions. This is because people living in hot and humid regions are accustomed to higher temperatures and humidity. Research in tropical regions has shown that building occupants are satisfied with temperatures at 26.16^{o}C (Cheong & Tan, 2002). This is much higher than studies results for acceptable comfortable temperatures in temperate regions. However, a simple fact remains that humans, regardless of the region they are from, are still governed by the same comfort factors of humidity and ambient air temperatures. Different strategies in cooling differ from region to region. The selection of correct cooling strategies is based on achieving the correct comfort levels within the boundaries of a region's climatic condition. Most of the passive cooling strategies presented above and in preceding chapters are not applicable in hot and humid regions. There are however two strategies that may offer an acceptable solution in meeting thermal comfort levels of hot and humid regions. They are ventilative cooling and evaporative cooling. Although both are potentially viable options, these cooling methods still possess inherent limitations that have to be overcome. Ventilative cooling, although creating a sensation of “coolness” does not deal with some problems associated with humidity, like “stickiness”. Stickiness is caused when perspiration on the body dries up with the effect of ventilative cooling. This can cause one to feel uncomfortable even though one feels the cooling effects of air movement. Evaporative cooling on the other hand is limited by both the wet bulb temperatures and humidity. Furthermore, evaporative cooling increases humidity levels depending on the type of evaporative cooling process whereas high humidity is not ideal for general comfort.

5.1 Indirect Cooling Method for Lithotecture

Fig. 1 shows a proposed indirect evaporative system with ventilative cooling as a variant method that can increase the distribution of cooled air and physiological cooling during peak temperature loads in underground buildings. The system works by introducing fresh air from the surface through a simple wind catcher device, which then passes through a liquid desiccant chamber. A solid desiccant wheel can also be used in this process to replace the liquid desiccant however as mention in the earlier section solid desiccants need a higher regeneration temperature. As air passes through the desiccant, the humidity is reduced from up to 87.2% (Singh, 1994). A post cooling heat exchanger is then required to cool down the dehumidified air as heat is gained during the dehumidification process. The post cooling heat exchanger used in this instance is a combination of mechanical refrigeration and cool water generated from the evaporative cooling process. Mechanical refrigeration is used during the start up of the system as the water from the system will not be low enough to sufficiently cool the dehumidified air. After running the evaporative system for awhile the internal water will be cool enough to take over the mechanical refrigeration. In other words the post cooling heat exchanger used to cool the dehumidifier air would run on a self generated coolant. The dehumidified air is then ventilated through a cooling tower where by water is sprayed from the top of the tower. Evaporative cooling of the water takes place as the dehumidified air passes up the cooling tower in order to elevate the water temperature close to the wet bulb temperature of air. This water is then collected and distributed by means of gravity or a pump into copper pipes acting as a radiator. These radiators can be located either on the ceiling or be embedded within the floor, with adequate care to avoid condensation. The low temperatures water in the pipes is then circulated by means of a fan which doubles up as a ventilative cooling device. The water, after passing through the radiator is then collected in a water balancing tank with a makeup water valve to add water lost through the evaporation process. Water from this tank is then recalculated back into the cooling tower where it is sprayed, thus restarting the evaporative cycle.

The temperature of the system can be controlled from two points. The first point of control is through the varying of wind speed in the cooling tower. By lowering or increasing the air movement it is possible to manage the rate of evaporation thus controlling the resultant cooled water temperature. The second point of control comes from the ventilative system. An increase in air movement will increase the perception of cooling for end users. Both control strategies when used together creates a system that is highly manageable in terms of temperature and comfort levels.

The proposed low energy hybrid evaporative cooling system is ideal for under ground buildings in the tropics. This is because it does not add humidity to the air as it works by means of indirect evaporation. Furthermore, the ambient temperature generated by the system is controllable. It is also important to note that the cooling tower does not take up space additional space within the underground building. The depth of the underground building allows for long cooling towers to be positioned between the earth surface and the building below. A deeper cooling tower makes the evaporative cooling process more efficient.

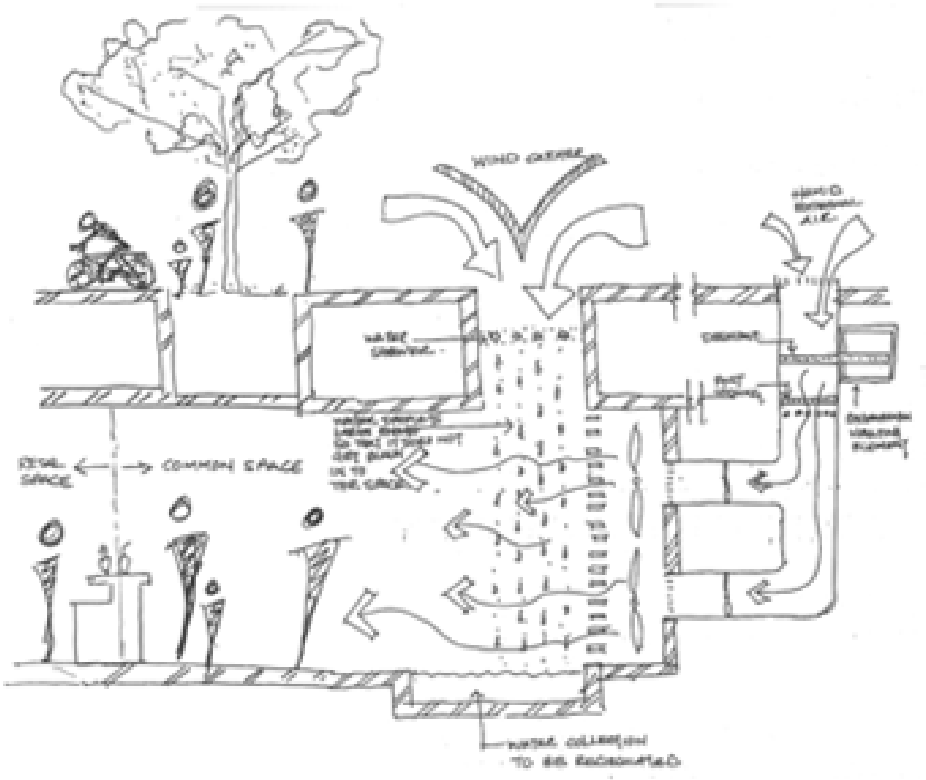

Fig. 1 A schematic application of the indirect cooling system for underground buildings

5.2 Direct Cooling Method for Terratecture

This system is less complex and does not require a cooling tower. However the cooling capacity is not as high as the indirect system. Direct cooling works similarly in a way that one feels cooled when the wind blows on a rainy day. The initial dehumidification process of air is similar to the indirect system. The difference comes after the post cooling where the dehumidified air is blown through a water shower directly into a conditioned space. This method relies on a higher air movement speed to present effective cooling to a space. Evaporative cooling here is used to improve the efficiency of the ventilative cooling. Direct cooling is ideal for smaller underground buildings nearer the surface like homes. The advantages of this system are that it requires less energy to cool a space. However, because of the direct evaporative cooling process the conditioned air increase the humidity levels of a space. Nevertheless, higher supplied air velocity cancels out the effects of humidity felt by the end users.

There are less control points in the Direct Hybrid Cooling System as compared to the indirect system. However, thermal comfort can likewise be controlled by increasing or decreasing the speed of the ventilation fan and rate of water flow from the ‘shower’ element (Fig. 1). By varying the air and water flow, more or less evaporative cooling will take place. This will result in an improved thermal comfort level for the cooled space. However controlling the rate of humidity is limited due to the inherent issues arising for all direct evaporative cooling methods.

6.0 Conclusions

This paper is an attempt to critically evaluate the possibility of extending the usage of the available passive cooling strategies to underground buildings in the tropics. Especially, with the growing population in Singapore and the limitation of available land, underground buildings are the most likely alternatives the country will move in future. Hence, it is necessary for considering extending the sustainability agenda even to these typologies. The paper has identified the limitations and the potentials of the various cooling strategies to tropical underground buildings and in turn has concluded with two simple hybrid strategies that could be attempted to cool the underground spaces. However, the actual efficiency of these proposed systems would in turn depend on environmental factors and design considerations of the wind catchers, site location and others apart from the system itself. It is also necessary to conduct tests to quantify the effectiveness of these methods. The impact of ground temperatures on the indirect system of cooling could be a potential issue to be resolved. Despite the limitations, the paper could still be considered as a starting attempt to explore possible solutions to the upcoming new prototype of sustainable underground buildings.

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A MARKOVIAN APPROACH TO THE MODELING OF SOUND PROPAGATION IN URBAN STREETS CONTAINING TREES

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Abstract

Urban streets normally contain trees mainly for their aesthetical function. However, it is also claimed that the trees may become a possible control method for noise in streets and hence contribute another step towards a sustainable environment. This paper examined the capability of an abatement scheme based upon trees in streets through a simulation model developed using the novel approach based upon Markovian techniques. The approach treats the sound propagation process as first order Markov process characterised by a matrix of transition probabilities relating to sound radiation between surfaces. The approach assumes that the facades lining the streets and the trees reflect sound diffusely. The trees are also assumed to absorb and transmit the sound. The paper begins with the development of the key element in the modelling process i.e. the transition probability matrix, source distribution, receiver functions and Markov process. The effect of the trees on the transition probability matrix is dealt with by means of the development of masking matrices for screening coefficients. The simulation of noise propagation in streets containing obstacles is first carried out and the results were then compared with the results obtained with a commercial hybrid ray tracing and image source model, RAYNOISE using the diffuse reflection option. The results showed that sound pressure level in a street containing obstacles relative to that in an empty street predicted by the Markov model was in good agreement with predictions obtained using RAYNOISE model. Within the scope and assumptions in this study, it is shown streets containing trees and absorbent building façade result in sound reductions typically less than 1.5 dB. Hence trees in streets appear to have only a slight effect on sound attenuation, and thus make no significant contribution towards producing a sustainable environment in this respect.

Keywords: Diffuse reflection, Markov process, Transition probability, Sound propagation, Noise control, Sustainable environments.

1. Introduction

A number of models of noise propagation in urban streets have been proposed based upon façade reflections which are diffuse [1]. In addition to their aesthetical function, trees in urban streets will affect the sound field and should be considered in the model. The importance of the effect of trees as well as other obstacles can be seen from the work of Steenackers et al [2] who compared their theoretical expression for sound field drop in smooth streets with field measurements of the decay of sound from a point source located in the street channel. They suggested that the presence of these scattering objects in the street was probably the reason the apparent coefficient of absorption for wider street is higher than for narrow streets. Recently, Kang has also suggested that diffusely reflecting façades and scattering objects including trees, street furniture etc may be possible noise control method for sound in streets [3]. However, current diffuse models generally assume that the street channel is empty and hence do not account for the effect of objects such as street furniture, vegetation or vehicles. In this paper the application of a particular stochastic method, the Markov chain, which can incorporate the effect of trees will be employed [4].

A Markov process involves consideration of states which change with time. The possible transitions between states can be described in terms of a probability or transition matrix where an element denoted by pij denotes the probability of a transition from state i to state j. The fundamental requirements for a Markov matrix are: i. All elements are non-negative and ii. The sum of each column is 1. Suggested by Gerlach[5], reverberation could be modelled as a Markov process because the energy falling on a surface of an enclosure will be reflected and distributed to all the surfaces in a room according to their “visibility” with respect to the reflecting surface. This can be interpreted in terms of probability where the fraction of the reflected sound energy reaching a particular surface is equivalent to the probability of reflected energy reaching that surface. Transitions correspond to orders of reflection. The possible transitions between states can be described in terms of a probability or transition matrix. The technique is applied to a parametric study of the propagation of sound in a street with distributed trees called scattering elements. Markov approach treats propagation of sound in street as a Markov process which requires the construction of a transition probability matrix relating to the radiation of sound between boundaries.

The model in this paper assumes that urban streets consist of building facades lining the street and trees planted within the streets. Both are assumed reflected sound diffusely. The paper begins with the basic modelling process i.e. the transition probability matrix, source distribution, receiver functions and Markov process. The effect of the trees is dealt with in the development of the transition probability matrix by means of masking matrices for screening coefficients. The result from the simulation of noise propagation in streets containing screen is compared with the results obtained with a commercial hybrid ray tracing and image source model, RAYNOISE[6] using the diffuse reflection option. The applicability of model to predict sound level for street containing trees are carried out through various abatement scheme and the results obtained compared with the results for a similar empty street.

2. The Modelling Process

The trees are assumed as 'screens' and which scatter the sound in all directions. This is also the assumption made by previous researchers working in the fields of urban noise propagation (Leschnick[7], Kutruff[8]) when treating the obstacles. Therefore, the trees in the street are modelled as a simple screens aligned in the same direction as the facades. The screens are also assumed to absorb and transmit the sound. The degrees of transmission is simulated by employing a transmission factor, TF which is zero for full screening, one for no screening and values of TF between 0 and 1 relate to partially transparent screens. The configuration of the model is shown in Figure 1. The thickness of the trees is ignored. Both surfaces of the screen are divided into a small patches of the same size as those on surfaces I_T and J_T. Surface $F1_T$ and $F2_T$ have patches defined by $f1_x=1,2...n_1$, and $f1_z=1,2....m_1$, and $f2_x=1,2.. n_1$, and $f2_z=1,2.. m_1$, respectively. In order to simplify the mathematics, the dimensions of all surfaces are integer multiples of the patch size including the heights of façades and screens, can be expressed by the integer numbers, m and m_1, respectively. A grid based approach is adopted with the grid dimension equal to the patch size.

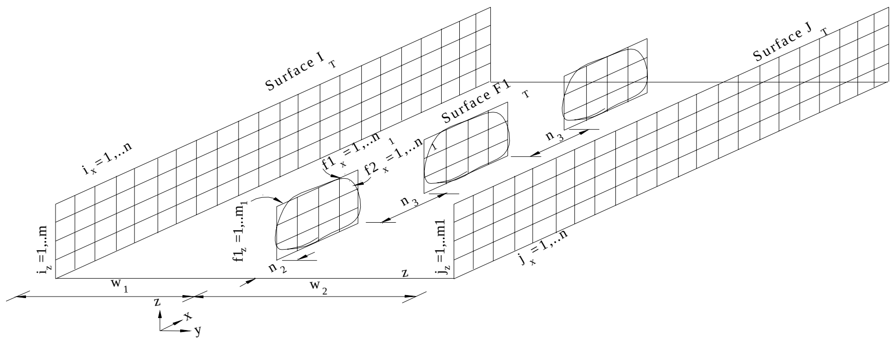

Fig. 1. – Trees are idealized as simple screen

For simplicity the source is assumed to be located in the ground plane which avoids the need to consider possible interference effects. This approach can be justified as the multiple diffuse reflections between facades can be expected to mask any interference effects. The initial radiation of sound is determined by the distribution to any patch on surfaces I_T, J_T and $F1_T$. The model assumes the patches then to act as point sources, thus the size of these patches have to satisfy the condition that the distance between any two opposite patches is greater than fives times the projected dimension of a patch. This requirement also applies to the distance between the source and any patch and any patch and the receiver.

The road is assumed to be specularly reflecting and reflections are taken into account by considering images of the facade and screen patches in the ground plane. The sound to a patch on surface J_T will have a direct path for radiation from surface I_T plus sound radiation from a patch on I_G reflected in the ground plane (Figure 2a), I_G; The sound to a patch on screen $F1_T$ will have direct path of radiation from surface I_T plus sound radiation reflected in the ground plane i.e. radiation from image in I_G (Figure 2b); Sound radiation from the patch on surface $F1_T$ back to a patch on surface I_T can be direct or reflected in the ground plane. Sound reflected in the ground plane can be treated by means of an image patch on $F1_G$ (Figure 2c).

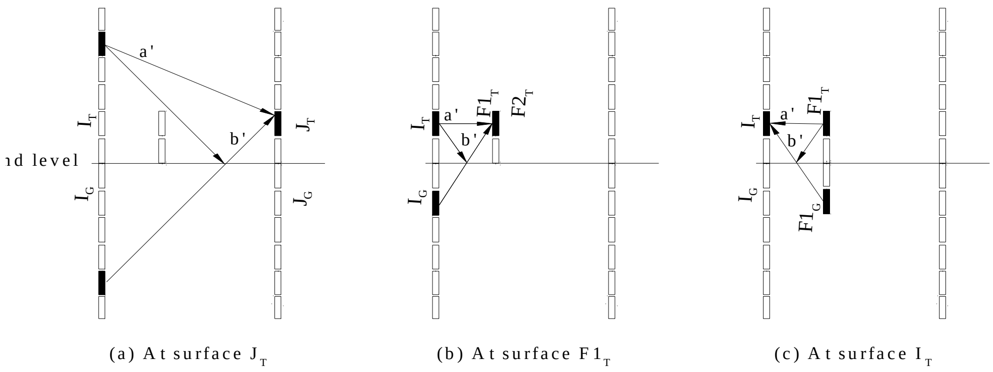

Fig. 2 Sound radiated by 2 patches due to direct path (a') and ground reflection (b')

The transition probability corresponding to the radiation of energy from one patch to another patch is equivalent to projecting the radiating patch onto a unit hemisphere centred about the radiating patch. The solid angle formed by the projected area is then divided by the total solid angle at the base. This is equivalent to the determination of the form factor in the radiosity method [1]. The transition probability matrix will consist of the following:

- Sub matrices for radiation of sound between patches on surfaces I_T and J_T, ($P_{I_T J_T}$ and $P_{J_T I_T}$)
- Sub matrices for radiation of sound between patches on surfaces I_T and $F1_T$ ($P_{I_T F1_T}$ and $P_{F1_T I_T}$)
- Sub matrices for radiation of sound between patches on surfaces J_T and $F2_T$ ($P_{J_T F2_T}$ and $P_{F2_T J_T}$)
- Sub matrix for radiation of sound from image patches on surface I_G to surface J_T, ($P_{I_G J_T}$)
- Sub matrix for radiation of sound from image patches on surface I_G to surface $F1_T$ ($P_{I_G F1_T}$)
- Sub matrix for radiation of sound from image patches on surface J_G to surface I_T ($P_{J_G I_T}$)
- Sub matrix for radiation of sound from image patches on surface $F1_G$ to surface I_T ($P_{F1_G I_T}$)

Masking matrices are devised to consider the effect of screening for radiation of sound between patches on I_T and J_T ($M_{I_T J_T}$ and $M_{J_T I_T}$) and for radiation from I_G to surface J_T ($M_{I_G J_T}$) and J_G to surface I_T ($M_{J_G I_T}$).

3. Distribution of Sound Energy From Source to Patches and Patches to Receiver

Before the Markov model can be run it is necessary to distribute the sound energy of a source to the patches which can then be regarded as sound sources, for example to a patch on surface I_T (Figure 3). The basic principle of the source energy distribution is that the fraction of energy from the source that is incident at each patch is the same as the ratio of the solid angle subtended by the receiving patch divided by the total angle into which energy from the source radiates. The normal intensity at the centre of a patch can be determined using the inverse square law which a point source at ground plane at (x_s, y_s, z_s) radiate hemispherical. The source properties (sound power spectrum) can be separated out from the geometry to obtain a source function, S. for example for patches on surfaces I_T;

$$S_{(i_x,i_z)_T} = \frac{\cos\theta_{(i_x,i_z)_T}}{2\pi d^2{}_{s,(i_x,i_z)_T}} \tag{1}$$

Where $d_{s,(i_x,i_z)_T}$ is the distance from the centre of a patch on surface I_T to the source and $\cos\theta_{(i_x,i_z)_T}$ is the angle of incidence of a sound ray from the source to the centre of a patch on surface J_T.

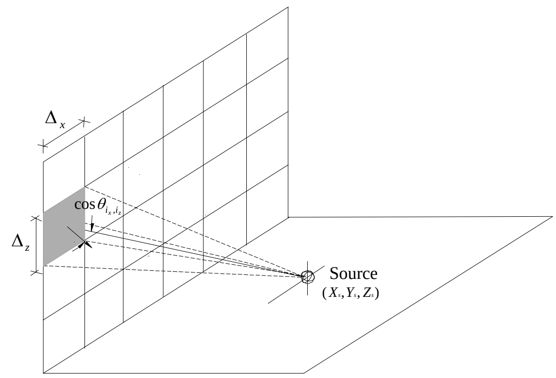

Fig. 3 Distribution of sound energy from a source to a patch i.

The source to patch distribution function vector can be written as;

$$S = \lfloor S_{I_T} \quad S_{I_G} \quad M_{SJ_T} S_{J_T} \quad S_{J_G} \quad S_{F1_T} \quad S_{F1_G} \quad S_{F2_T} \quad S_{F2_G} \rfloor \tag{2}$$

Where the sub matrices corresponding to radiation from the source to image patches such as S_{I_G}, S_{J_G}, S_{F1_G}, and S_{F2_G}, are null matrices and to radiation from the source to $F2_T$, S_{F2_T} is set to be zero because radiation to this surface is impossible. $M_{SJ_{TT}}$ is the masking matrix for sound radiation from source to patch on J_T. It can be determined by applying an integer and remainder method in the x and z directions.

The radiation of sound reflected diffusely from a patch and image patch to a receiver can be treated in the same way. The intensity at the receiver due to radiation from a patch can be calculated using the inverse square law to yield a receiver function and distribution vector similar in form to Equations (1) and (2).

4. Comparison Between Results From Markov and RAYNOISE Models

In order to check the validity of the 3D Markov approach, a RAYNOISE[6] model was developed in order to compare its predictions with results obtained using the 3D Markov method. The street length and width of 50m and 10m was employed. The point source was positioned at (5m, 2.5m,0m). Two screen arrangements of 4@1m x3m and 4@1m x10m were employed. The screen were assumed reflective with TF=0. To ensure that the source radiates in a hemispherical way, the source emission angle was set at H_{min}=-180° to H_{max}=180° and V_{min} and V_{max} equal to 0° and 90°, respectively. The ground was assumed to be fully reflecting with both the absorption coefficient and the diffusion coefficient set at 0. The facade absorption coefficient was set to 0.1 and the diffuse coefficient, d was set to 1 to obtain diffuse reflections. The calculation was carried out using 300,000 rays the triangular beam option and 12 reflections.

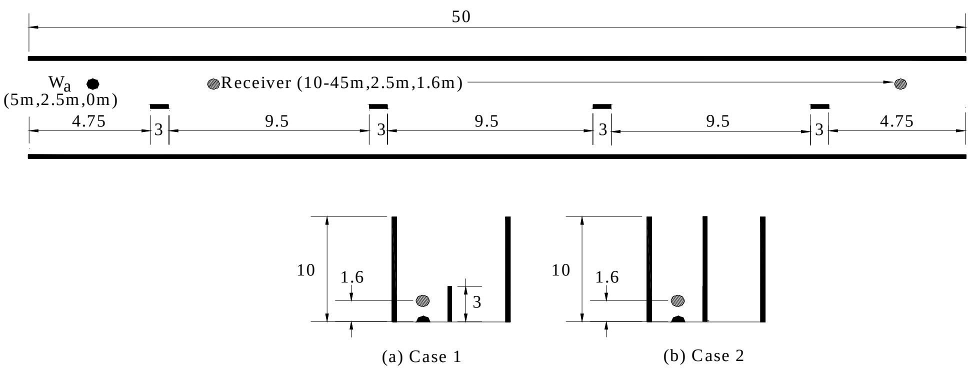

Fig. 4 Street configuration

The sound pressure level in a street containing reflective screens relative to that of the sound pressure level for the street without screens obtained from the 3D Markov and RAYNOISE models is shown in Figure 4. The results from both simulations show a very small effect (approximately a variation of -0.3 to 0.4 dB) and they are in agreement typically better than 0.2 dB.

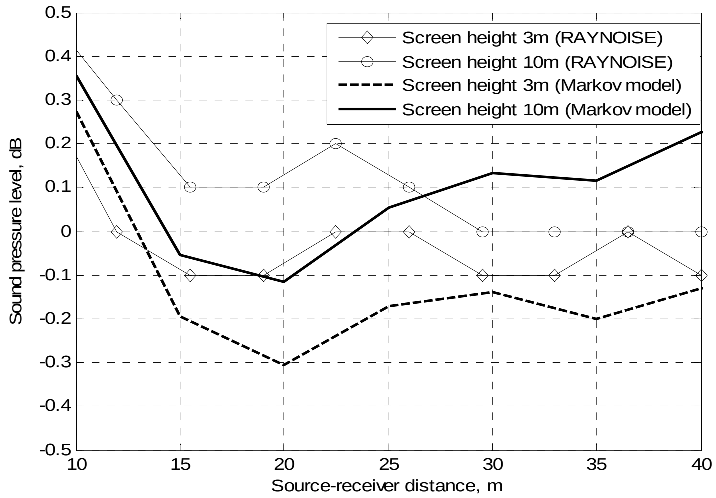

Fig. 5 Comparison sound pressure level in a street with reflective screens relative to that of the street without screens obtained from the RAYNOISE and the 3D Markov models.

5. The Effect of Trees and Absorption of Building Facades

The effect of trees were carried out by assuming that absorption coefficients of trees within 0.1 to 0.3. This is theoretically derived using equation $\alpha=Gf^{1/2}$ where f is frequency and G is a constant within the range 0.001 and 0.002[9]. Trees with dense leaves are assumed with a Transmission Factor TF=0.25. Seven noise abatement schemes as shown in Table 1, consisting of various treatments to both facade surfaces and screen surfaces are investigated. Case I was intended to study the effect of untreated facades containing screen other than trees which is absorptive. Case II was used to investigate when screen consisting of dense leaves trees (TF=0.25) and with absorption coefficient 0.1. The sum of the absorption coefficient and the transmission factor must be less than 1 to ensure that the law of conservation is not violated. Case III was intended to investigate the effect when the absorption coefficient of façade is doubled and the screen of densely leaves trees have greater absorption. Case IV was similar to Case III but was aimed to investigate the effect of absorption concentrated on one side of facade. Case V was used to examine the effect when the absorption coefficient of façade in Case III is doubled. Case VI was similar with Case I with the building facades more absorptive. Case VII was used to examine the effect of the screen with a transmission factor of 1.

Table 1: Absorption coefficient and transmission factor for each abatement case

Case	Absorption coefficient				Transmission factor(TF)
	Façade 1	Façade 2	Screen face 1	Screen face 2	Screen
I	0.1	0.1	0.9	0.9	0
II	0.1	0.1	0.1	0.1	0.25
III	0.2	0.2	0.3	0.3	0.25
IV	0.3	0.1	0.3	0.3	0.25
V	0.4	0.4	0.3	0.3	0.25
VI	0.4	0.4	0.9	0.9	0
VII	0.4	0.4	0	0	1

The results of each case were compared with that for the unscreened case with the absorption coefficient of both façades equal to 0.1. Figure 6 shows the sound pressure level variation relative to the unscreened case for source-receiver distances of 5m to 40m. Abatement scheme with reflective façade and densely leaves of trees with low absorption increase the sound pressure level up to 0.5 dB. While abatement scheme with absorptive building facades and the densely leaves of trees with absorption coefficient 0.3 and TF=0.25 (Case V) reduced approximately 1.5 dB. The reduction is similar to abatement scheme with absorptive building facades i.e without any screen. However, reduction due to abatement scheme consisting strong screen absorptions for both building facades and screens (Case VI) is higher than abatement scheme in Case V with the difference is approximately by 0.4dB. Also the effect of reduction of absorption concentrated on one side of facades is similar to the effect with the distribution of absorber evenly on both facades.

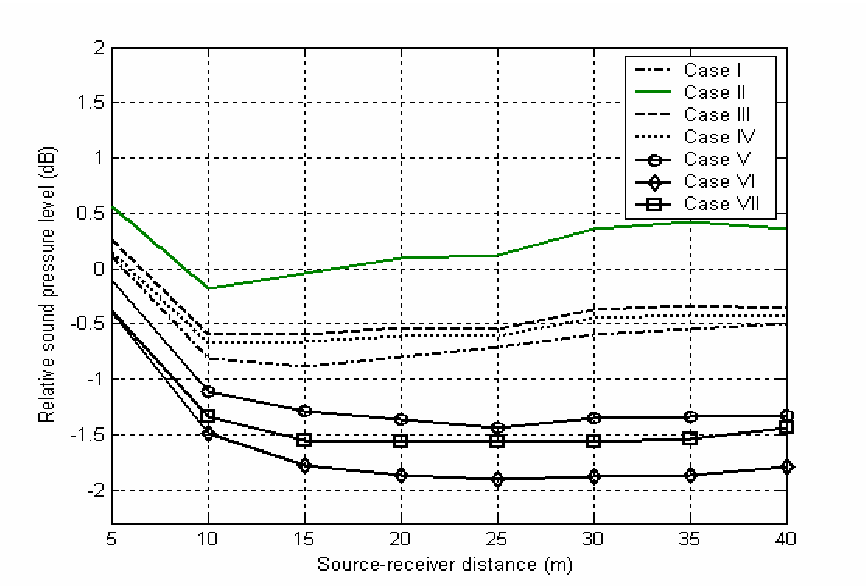

Fig. 6 Effect of building facades absorption and transmission factor (TF)

6. Discussion

It was found that the relative sound pressure level predictions obtained with the 3D Markov approach agreed with the RAYNOISE model predictions to within approximately 0.2 dB. This small difference suggests that 3D Markov processes produces results equivalent to those of the ray tracing algorithm. The results of investigations using both the 3D Markov model and RAYNOISE, the use of screens with a low absorption coefficient can result in a slight increase in the sound pressure level. The same trend shows with dense leaves trees with low absorption coefficient. The result is consistent with experiments using a scale model of sound propagation in a street containing pedestrian barriers with low absorption coefficient by Horoshenkov et al[10].

The reduction of up to 2 dB can be achieved when both the facades absorption are 0.4 and screens with high absorption coefficients of 0.9. When this screen is replaced by dense leaves trees with coefficient of absorption 0.3, it does not have a significant effect on sound attenuation in the streets. The maximum sound attenuation predicted along the street was less than 1.5 dB. Previous research by Kragh[11] also found from his experimental investigation that the effect of a belt of trees near the roads was less than 1 dB. Tang and Ong[12] also reported similar findings in the their work on the simulation of the effect of road side trees in an urban canyon on the sound field at ground level using the Monte Carlo method. The sound reduction is also affected by the distribution of absorber on facades and it is better to concentrate absorption on one façade as suggested by Kang [3].

7. Conclusion

A 3D Markov model for the prediction of sound propagation in streets containing trees has been described. It has been shown that the sound pressure level relative to the sound pressure level for unscreened case predicted by the Markov model is in good agreement with predictions obtained using RAYNOISE model. This shows that Markov approach has the potential to predict the sound field in more complex environments. The technique could also be developed to investigate sound propagation through a region combining a low density of buildings as considered by Leschnick [7] and Kuttruff [8].

Within the scope and assumptions of this study, it is shown the abatement schemes containing trees with dense leaves and absorbent building façades result in sound reductions that are typically less than 1.5 dB. Hence the trees with dense leaves in streets appear to have only a slight effect on sound attenuation, and thus make no significant contribution towards producing a sustainable environment in this respect. The results also suggest that any forms of screens with a low coefficient of absorption do not have a significant effect on sound attenuation in the streets and may actually result in a slight increase in noise level.

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A TYPOLOGICAL STUDY ON THE CREATIVE NUCLEUS OF MALAY HOUSES

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Abstract

Cultural sustainability can benefit from re-learning traditional houses that require systematic studies. This study attempts to explore the creative nucleus of Malay houses by a typological methodology. More than 200 cases were studied through the following operations: i). Encoding by typological description, ii). Finding variations in house-building, iii). Formulating typological rules, iv). Proposing "generating mechanism" and "screening mechanism" as the creative nucleus embedded in Malaysian architectural traditions.

In respond to the current urge of sustainable development, these studies highlights the heritage of Malay houses and the creative applications of its typological potentials in the contemporary context.

Keywords: Malay house, creative nucleus, typological study, house type.

1. Introduction

Paul Ricoeur, world reknowned philosopher, said in 1961 that universalization brought progress of human beings on one hand, and the destruction of creative nucleus of some great cultures on the other hand. This statement is particularly alarming in this century of globalization, in which we all experienced the dark side as well as the bright side of the universality. With this regards, this paper addresses the issues related to the notion of creative nucleus by presenting a typological method to the study, and the future development of Malay houses.

The house types in Southeast Asia, although lack no commonality such as raised footing, boat image, decorative gables, etc. (Waterson, 1990), have some obvious disparities, such as big roof vs. small roof, heavy wood vs. light wood construction, multi-family single building vs. detached houses etc. Within these various house types of Southeast Asia, the houses in Peninsula Malaysia exhibit some distinctive characteristics: the stilts footing, non-boat image, small roof, and light wood construction (as compared to Batak Karo and Tongkonan houses), and compound buildings with central main house for single family.

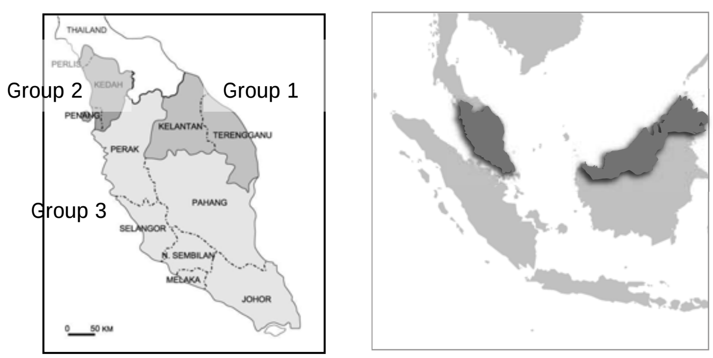
The main house (rumah ibu), the distinctive built volume in Malay houses, is always located at the front. The ridge of the main house is usually parallel with the street and perpendicular to the entry gate. The main house has largest volume and highest roof that constructed with two different slopes. Behind the main house locates one or more sub-houses with descending roof heights. The floor heights also decrease from the main house, sub-houses, to the kitchen (dapur), which is usually on the ground (Teh, 1996). There are three major spaces in Malay houses: *serambi* (reception area), *rumah ibu* (core space), and *dapur*. The spatial sequence in Malay houses is clear and strict: from outside to the inside in the order of *serambi*, *rumah ibu*, and *dapur*. Guests are only invited to *serambi*, while relatives can enter *rumah ibu*. Dining with the guests also takes place in *serambi*. Usually, the front half of the house (front yard and *serambi*) is the living space for male, and the back part (back yard and *dapur*) for female (Ariffin, 2001).

Spatial form and construction language are considered two fundamental aspects for house type studies. The two interact in various ways. Spatial form is deeply embedded in the culture while the construction language may travel from one culture to another. The change of spatial form, as results of the change of life demands or outside environments, may require transformations of construction languages accordingly, which may reciprocally entail related changes in spatial form. It is hypothesized that each culture has its house genotypes from which many typological varieties are derived (Wang, 2002). The methodological goal of the typological study is to formulate a set of rules that can account for all possibilities as well as existing houses of the culture under study. These typological rules may reveal the wisdoms that are congenial to the notion of *creative nucleus* of the culture.

2. Materials and Method

There are two sources of data in this study. One is KALAM Centre (Pusat Kajian Alam Bina Dunia Melayu, Centre for the Study of Built Environment in the Malay World) at the architecture department of Universiti Teknologi Malaysia (UTM), whose architectural research, surveying and mapping have been collected for decades. The other is the field survey on Peninsula Malaysia conducted in 2005 and 2006 by National Cheng Kung University group from Taiwan.

The house type data of the Peninsula Malaysia are classified into three groups: Group 1: Kelantan and part of Terengganu, Group 2: Kedah and Perlis, Group 3: Other than those mentioned in Group 1 and 2. Group 1 features the special courtyard space (jemuran) in Malay houses, and the combination of the derivative space and volume. Group 2 is a longitudinal longhouse which deserves a new category. Group 3 contains large number of cases, including the houses in Perak in the mid-north, Pahang, Selangor, Negeri Sembilan, Melaka in the middle, and Johor in the south. The paper focuses on the cases in the vast areas of the mid-north, middle, and south of Peninsula Malaysia in Group 3. (Map 1)



Map 1. Groups of Malay houses in Peninsula Malaysia

3. Malay House Types

There are two major methodological components in this typological study: 1). the descriptive system to encode all features significant to Malay houses, and 2) the generating mechanism capable of producing all possible cases of Malay house.

3.1. Descriptive System

A descriptive system is formulated for the Malay houses under study. The system addresses three aspects of the house type: house grouping, spatial structure, and construction. Shorthand names are used in the description.

3.1.1. House Grouping. “Twelve-column house (rumah tiang dua delas)” is the first and the main unit which has two spans in the front and 3 in depth. This 12-column form is considered to be the prototype of Malay house. In order to meet the needs of families of various scales and to show the characteristics of diverse regions, the extension of main house is essential during the derivation of Malay houses. The types of extension include increasing the span number in depth (E1), decreasing the span number in depth (E2) increasing the span number in width (E3), increasing floors (E4), increasing *anjung* (the extruding quantity in the front of the main house) (E5), increasing the width of *serambi* (E6), expanding *rumah tangga* (the staircase space at the entrance) (E7) (Lim, 1987). The sub-house unit, conceivably built after the main house, has independant structural system and is usually but not necessarily a single building. Attchment (At) is the structure that can be attached to the main or sub-houses but cannot exist alone (Fig.1).

There are connections between main house and sub-house, sub-house and sub-house, or house and attachment that are positioned in four different ways: 1). Eave to eave (C1): Connecting a gap between parallel eaves, with a gutter to drain rainwater out, forming a part of interior space. 2). *Pelantar* (C2): The separation of parallel eaves forms an outdoor space like an indoor courtyard. 3). *Selang* (C3): A corridor built by adding a longitudinal roof upon the larger distance between two roofs, serves as indoor or semi-outdoor space. 4). Attached shelter (C4): attach to the main unit or sub-houses. In addition, three possible locations of the joints: at central back (@p1), at side of back (@p2), at side (@p3). (Fig.2)

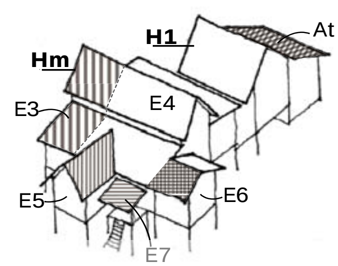


Fig.1 Extensions of main house

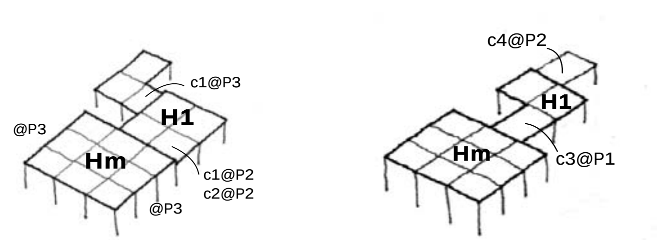


Fig.2 Connections of houses

3.1.2. Spatial structure. In addition to afore mentioned *serambi* (S), *rumah ibu* (RI), and *dapur* (D), other interior spaces that feature the Malay house type are as follows: *bilik tidur* (bedroom), *rumah tengah* (rumah ibu), *selang* (corridor), *pelantar* (inner courtyard), *anjung*, *rumah tangga* (stairway space). The spaces are positioned according to the following arrangement rules: 1). the main house is originally composed of *serambi*, *rumah ibu*, and *bilik tidur*. 2). *serambi*, *anjung*, and *rumah tangga* are located in the front of the house. 3). *selang* and *pelantar* are both connecting space. 4). *dapur* are located in the back.

3.1.3. Construction. Basically there are two types of construction.

Construction 1 (Cons.1): The original “six-column house (rumah tiang enam)” contains three columns at two sides, each with a flat-beam (beam with flat rectangular section) on top, and another 3 vertical flat-beams (level 2) at the 3 pairs of columns on top of these two parallel flat-beams (level 1). Locate the post in the middle of the three flat-beams (level 2) and put the oblique beams at the two terminals of the post and the flat-beam to form the prototype of the oblique roof (Fig. 3). In case of extension, one (3 columns) or two rows (6 columns) of columns parallel to the house ridge are added to expand one or two more spans. This is a technical way of building the attachment. The oblique beam that supports the roof of the attachment is connected to the added column, level 1 flat-beam or columns on the main house. The main house of such style contains the pitch roof with double slope, composed of one “six-column house” and “two attachments” and forms “twelve-column house” (rumah tiang dua delas). The roof in the middle of the house is more slanting than those of the sides. The preceding description is about the constructional prototype of the Malay houses.

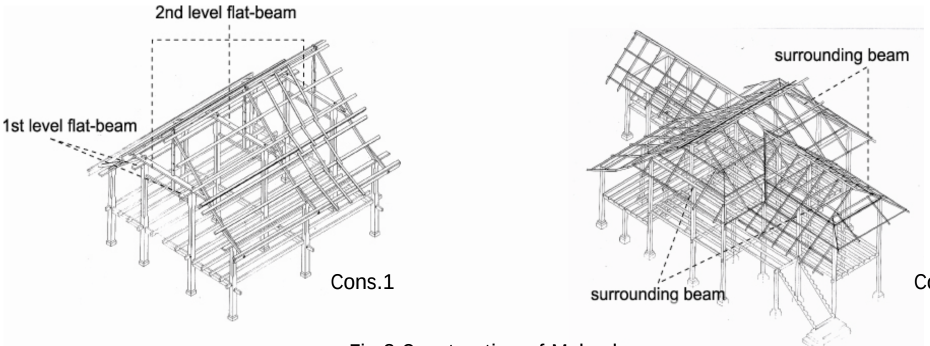
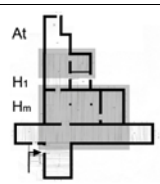
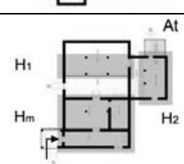
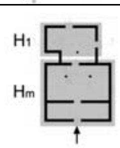
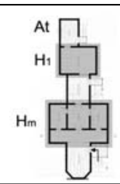
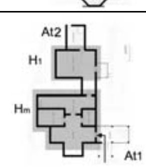


Fig.3 Construction of Malay houses

Construction 2 (Cons.2): This construction is without parallel flat-beams. The columns surrounding the house support the beams around. Horizontal beams are supported by the rows of columns, and the post on top of the beams supports the spinal beam. Because of the beams around, an oblique rafter can be put on each roof of elevation to connect the surrounding beams and spinal beams and form the hip roof. But this technique excludes the roof variation of double slope and adopts smaller slope, not resembling the image of the main house in Malay house prototype. (Fig. 3)

The middle, mid-northern, and southern parts of Peninsula Malaysia are the three main areas where the Malay house types are studied. From each of the following states one house is selected to demonstrate the typological features as analyzed above: Negeri Sembilan, Melaka, Pahang, Perak, and Johor. (Table 1)

Table 1. Descriptions of Malay houses. (grey parts represent the house volumes; white, the attachments)

Negeri Sembilan _Rumah Dato'muda Haji Omar Bin Lajim_1747		Hm (E3,E5,E6) 【C1@p2】 H1 【C4@p2】 At Cons.1
Melaka_Rumah Encik Husin Be_1900		Hm (E3,E6,E7) 【 C1@p1 】 H1 【 C2@p3 】 H2 【C4@p1】 At Cons.1
Pahang_Rumah Hajjah Zaleha BT. Haji Mat_1895		Hm (E3,E4) 【C1@p1】 H1 Cons.1
Perak_Rumah Haji Mohamad Jali		Hm (E2,E3,E5,E7) 【C3@p1】 H1 【C4@p2】 At Cons.2
Johor_Rumah Haji Ahmad_1918		At1 【 C4@p3 】 Hm (E3,E5,E7,E8) 【 C3@p2 】 H1 【C4@p1】 At2 Cons.2

3.2. Capacity of Variations

The main house unit can enjoy the freedom of enlarging and reducing through the rules from E1 to E7. The sub-house and attachment can be increased or reduced according to their position rules. There also exists flexibility for grouping different house units as vindicated by three places for connection (@P1, @p2, @P3) by four ways (C1~C4). *Rumah ibu* is a multi-functional interior space which is recognized by the free plan arrangement. As for construction, both Cons.1 and Cons.2 have their own technical freedom. In Cons.1, the main columns under the flat-beams can be put in the front or back to allow the column spans in the main house be adjusted flexibly. So are the column spans in the sub-houses. Observably, the roof structure of equilateral triangle will be maintained while the rafters can be placed freely. The slope of roof can be changed as free as the height of the floors.

In Cons.1, there are four components, columns, oblique beams, roofing, and floors, that can be placed in various ways. In Cons.2, only two principles are applied: the exterior columns outline the house with beams on top, and the interior and exterior columns support the roof structure collaboratively. In this way, the top of the roof structure defines the house ridge. Rafters are located between the roof ridge and the surrounding beam. With the same slope, various kinds of hip roof can be constructed. The placing of columns, roofing, and floors is quite free as the principles allow. In addition, various materials can be used. For instance, wooden boards, woven bamboo stripes, and palm leaves (atap) can apply both to the wall and roofing systems. Galvanized corrugated iron sheets often replace the palm leaves as the roofing material.

3.3. Typological Rule

Three main formal features can be identified in Malay houses: 1) the composition of space *serambi*, *rumah ibu*, and *dapur* as a generic whole; 2) the parallel flat-beams are adopted in Cons.1; 3) the double-slope pitch roof is designed to constitute a strong image of main house. These features can be viewed as typological rules which govern the production of Malay houses. Rules are layered to reveal their varieties in application.

From all the cases under study, it is found that the “S, RI, D composition” is the fundamental rule shared by Malay houses without exception. The second-level typological rules are “Cons.1 or Cons.2” and “main-house image”. For instance, Perak houses, while complying with the “S, RI, D composition” rule, adopt “Cons.2” and produce the “main-sub-house integrated image” as result. The rule regarding “back or side extension and connection” also belongs to the second-level. The constructors of Negeri Sembilan houses prefer the sub-houses to be in alignment with the sides. The sub-houses in Melaka can exceed the left or right side lines of the main house. The *selang* of Perak houses are connected with mid-back of the main house. The above arrangements, as spatial interpretations of “back or side extension and connection”, constitute the category of the third-level typological rules. Negeri Sembilan houses have Minangkabau-style bull-horn ridge, which are the result of applying “Cons.1” and “main-house image”. Minangkabau’s roof can also be considered as an instance of the third-level rules. The 3-bay façade of Perak houses with middle bay elaborated by *anjung* method is another case of the third-level rules. (Table 2)

In Johor area, there are houses as generated by the second-level typological rules of “Cons.1”and “main-house image” resemble those in the middle area. There are also Johor houses as produced by the second-level rules of “Cons.2” and “integrated main-sub-house image” resemble those in the Perak area. Nevertheless, *ruang tangga*, a special attachment to the sides of Johor main houses, represents the third-level typological rules. The short stilts of Johor houses can also be considered as the third-level rules.

Table 2. Typological rules

1st-level rule	2nd-level rules	3rd-level rules
Spatial hierarchy of S, RI, D	Back or side extension and connection Cons.1 with main-house image	Sub-houses exceeding the side line of the main house
		Sub-houses in alignment with one side Minangkabau's roof
	Back or side extension and connection Cons.2 with main-sub-house integrated image	*Selang* connected at central bay *Anjung* at front central bay
		Ruang tangga at main house's side Low stilts

4. Generating Mechanism

Malay houses have endowed with great capacity of variations by 4 different classes: the house grouping, the spatial layout, the construction methods, and the building materials. Each class has certain alternative choices, and all together can generate multiple combinations. The combination possibilities can be calculated in greater detail by the following parameters from X_1 to X_6:

x_1= E1~E7, main house extension;

x_2= C1~C4, connecting way of main house, sub-house and attachment;

x_3=@p1, ~@p3, connecting position;

x_4= more than 9 spatial elements;

x_5= column, obligue beam, roofing, floor (construction elements);

x_6=materials.

These 6 parameters constitute the generating mechanism of Malay house variations. The generating process of a Malay house may begin with the prototype, *rumah ibu*, also known as the main house, which triggers the generating processes to produce great amount of house groupings through the parameters, x_1, x_2, and x_3. The selected house grouping offers many spatial layout possibilities through the arrangements of different spatial elements as defined by parameter x_4. Each layout plan can be built by alternative construction systems as prescribed by the parameter x_5. Then, various materials as described by the parameter x_6 can be applied to complete the house.

Fig.4 is a demonstration of possible variations of Malay house by manipulating only parameter X_3: @p1, @p2, @p3, i.e. three different eave-to-eave connecting positions, under Cons.1 while fixing all other parameters. This demonstration shows only the tip of iceberg of all possibilities when the generating mechanism reveals its full power.

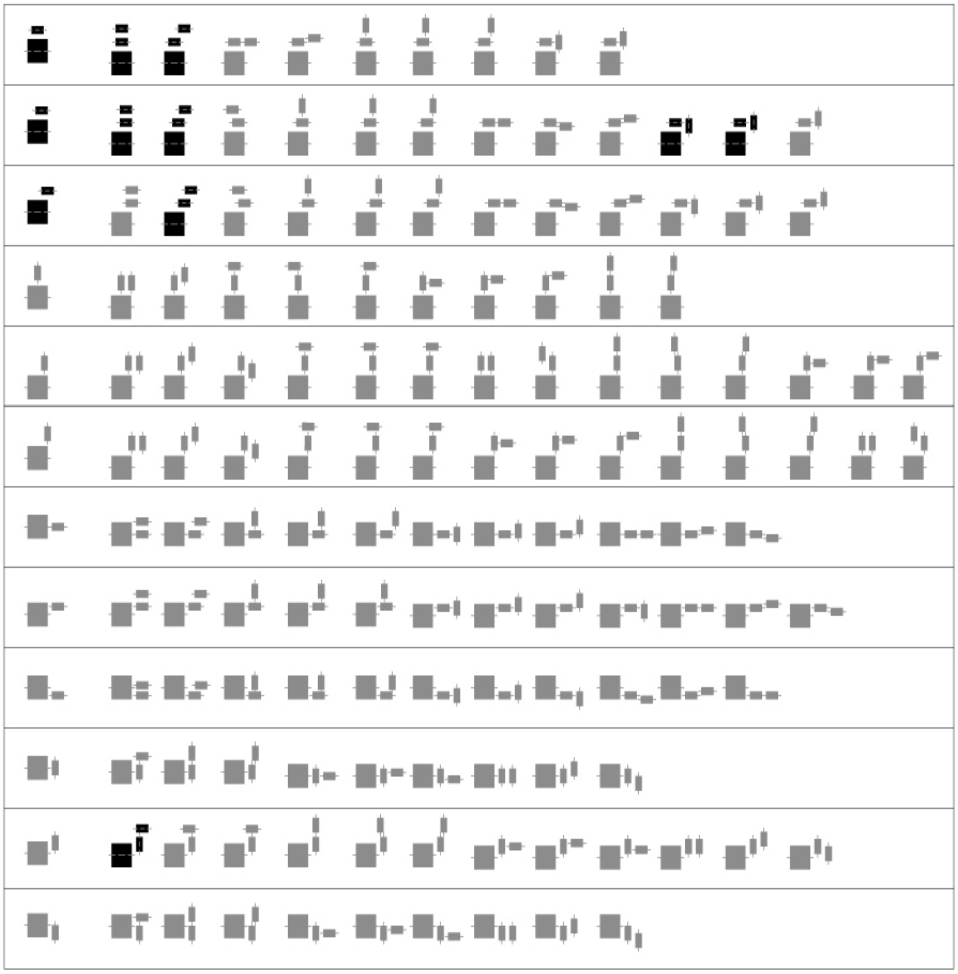


Fig.4 Generated cases by eave to eave connection at p1, p2, p3

In Fig.4, black diagrams represent existing cases, grey ones represent speculation cases which do not exist as yet either in literature or in field. Conceivably, a sort of *screening mechanism* may exist to prohibit certain variations from emerging, though they are admitted by the generating mechanism. What is the structure of this screening mechanism is a question that beyond this investigation and capacity. However, we can speculate that it might relate to two cultural factors: one is that there are certain inherent forbidden rules in the building process to exclude some variations. The other may be called 'system bias' or tradition preference which encourage only some variations rather than others.

5. Conclusion: Creative Nucleus of Malay Houses

Every Malay house has an innate genotype, which is basically described by the first-level typological rule. Houses are not Malay house if the first-level rule is violated. The various combinations of the second- and third-level typological rules can lead to different sub-types of Malay house. Take Acehnese house as an example. It conforms to the first-level rule but not the second- and the third-level rules, therefore, it becomes another sub-type of Malay house.

As observations turned away from Peninsula Malaysia, some interesting findings emerge. A domestic house at Kakunodate, Akida, Japan, as shown in Fig.5a, shares some characteristics of Malay house. By the afore mentioned *Descriptive System*, this Japanese house can be coded as a main house extension with Hm(E1, E3, E5, E7), five sub-houses (H1~H5), three attachment (At1~At3), four connecting ways (C1~C4), and three kinds of connecting points (@p1~@p3), as shown in Fig.5b.

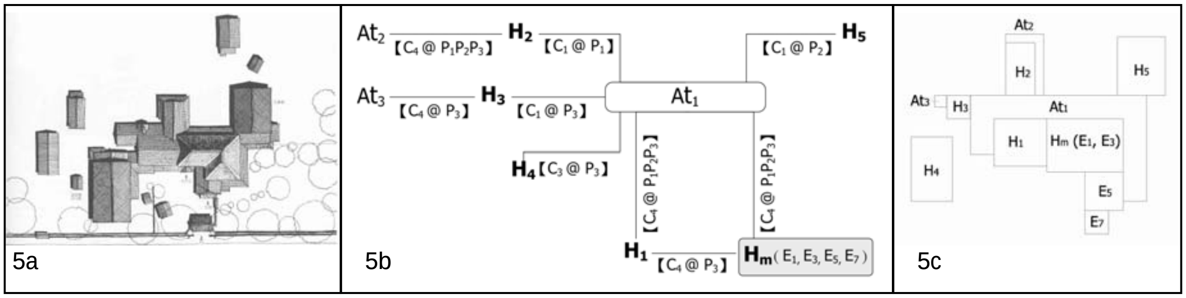


Fig. 5 Japanese house presented with the descriptive system of Malay house

Fig.5c shows the way of coding the Kakunodate house as those shown in Fig.4. By comparing these two codings, i.e. Fig.5b and Fig.5c, it is interesting to find that the Japanese house can qualify to be another type of Malay house if add three revisions to the descriptive system of Malay houses:

1). Change linear connection into network connection.

2). Define connecting positions more specific.

3). *Selang* may connect the houses perpendicularly and also in parallel as the veranda in Japanese house.

This example has no intention to compare the similarities and differences between Malay house and Japanese house, nor to search for the origins of these houses, although we may speculate their evolutionary relevance. This serves to demonstrate the productivity of the generating mechanism of Malay house, from which many variations can be generated even beyond our wild imaginations.

In respond to the current urge of sustainable development, this paper concerns not only the heritage of Malay house but also the creative applications of its typological potentials in the contemporary context. It is expected that more original researches will continue along this line to improve and refine the current findings. Hence the creative nucleus of the Malay house is opened for further discovery and exploration.

Acknowledgements

Appreciation is especially dedicated to the professors and professionals of KALAM Centre and Department of Architecture, Universiti Teknologi Malaysia, and the architectural students working on numerous measured drawings of traditional Malay houses. This study has been made possible with their consistent contribution since 1975.

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STUDY ON ROLES OF Non-Profit Organisation (NPO) FOR SUSTAINABLE INFRASTRUCTURE DEVELOPMENT AND MANAGEMENT IN RURAL JAPAN

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Abstract

Roles and the way of developing and managing infrastructure are changing in Japan. The era of developing massive infrastructure facilities efficiently for mainly economic growth is being over. Effective infrastructure development and management for sustainable society is truly needed. Under such situations, NPO (Non-profit organization) or NGO (Non-Government Organization) are now playing important roles in the fields of environmental conservation, town development, and river management in Japan. The number of certified NPOs exceeds 30,000 at the end of July, 2007. The objectives of this paper are to analyze characteristics and issues in conventional infrastructure development and management and to discuss necessity and functions of NPO for sustainable infrastructure development and management in a rural area in Japan.

Keywords: sustainable infrastructure development and management, NPO, publicness, Japan.

1. Introduction

Roles and the way of developing and managing infrastructure are changing in Japan. The era of developing massive infrastructure facilities efficiently for mainly economic growth is being over. Effective infrastructure development and management for sustainable society is truly needed.

Under such situations, NPO (Non-profit organization) or NGO (Non-Government Organization) are now playing important roles in the fields of environmental conservation, town development, and river management in Japan. The number of certified NPOs exceeds 30,000 at the end of July, 2007. The objectives of this paper are to analyze characteristics and issues in conventional infrastructure development and management and to discuss necessity and functions of NPO for sustainable infrastructure development and management in a rural area in Japan.

Structure of this paper is as follows. In the second section, conventional transactions of infrastructure development and management are characterized. In the third section, their limitations are identified. In the fourth section, expected roles of NPOs to overcome these limitations are described. In the fifth section, functions of NPO are discussed, and in the final section necessity of changing approach from problem solving to value creation with an excellent example of NPO performing the latter approach is briefly introduced.

2. Characteristics of transactions of infrastructure development and management

It is possible to recognize a majority of infrastructure development and management in Japan as business transaction made by administrator(s) and individual(s). The author focuses on the administrator instead of the administration because each administrator's actions will be more important in future than now. In this section, thus, an attempt is made to characterize the conventional transaction between the administrator and the individual. Their future relationship will be discussed later based on results of this analysis.

The conventional business relationship between the two parties is characterized as "public-private dualistic concept (Sasaki and Kim, 2002)." That is, it has been considered for a long time that the administrator always represents public, creates "publicness," and do "right" things. Private has been considered "wrong."

Here, the author uses definition of public and private developed by Kim. Public means things for all, which is the country consisting of the nation, national land, and national interests. A company and an organization use the same concept for its governance as the legitimate reason. "Private" means things other than public and things for oneself including her/his friends and family members (Sasaki and Kim, 2002). "Publicness" is temporarily defined as nature of realizing the public.

It has been considered for a long time that the administrator represents the public and is an unselfish body. The administrator had been fulfilling her/his duties with strong missions of governing the country and each region.

This Japanese perception towards their administrator is clearly different from that among people in the U.S. Behn says, "Yet we Americans have never trusted our government" and raises four reasons for Americans not to trust government. They are that people in the government abuse their authority, are corrupt, exercise policy discretion ineptly, and don't perform (Behn, 2002). The level of Japanese's trust towards the administrator, an important pillar of the government, was considered much higher than that of American.

Each individual is supposed to have various "faces" such as a private person, a citizen, and the nation. Since the public and the private are believed to represent "right" and "wrong," respectively, each individual had been expected to behave as the nation. In order to achieve goals of the country or the organization to which the individual belongs; therefore, she/he had been expected to "sacrifice her/himself for the sake of her/his country or organization."

It should be noted, however, that, this value of sacrificing her/himself for the sake of her/his country does not necessarily contradict conventional outlook on value each individual had possessed. One of the national objectives associated with infrastructure development and management in Japan after the post war period was to promote industrialization and urbanization. For the period with insufficient economic development and low standard of infrastructure development and management, an individual as a private person had strong needs of rapid development of job and residential environment. Within each individual, thus, needs as the nation and as a private person are almost the same, which are along the national goal of infrastructure development and management: promotion of industrialization and urbanization.

It should also be noted that the public-private dualistic concept has been occurring in allocation of space and tasks between the administrator and the individual. That is, common spaces and activities in common spaces have been disappearing, and territories of public and private have been enlarged.

Regarding the space allocation, the author considers that in principle public space has two characteristics though their division may be vague: narrowly defined public space and common space. The former is for achieving public happiness or happiness for all, and the latter is for achieving common happiness. For example, in road, space to smooth traffic corresponds to the public space, and roadside for housewives to chat has an aspect of the common space. In river, space for flood protection facility corresponds to the public space, and riverside where people enjoy fishing and children play with water has an aspect of the common space. It can be interpreted that the nation had been releasing these common spaces to the administrator, and they have been converted to industrial and urban infrastructure to promote industrialization and urbanization. It does not seem to be an overstatement to say that the area of public and private space has been increasing, but that the area of common space has been decreasing.

Regarding the task allocation, the individual has been depending on the administrator to do tasks which she/he used to do before such as road cleaning. Recreational activities in common space such as swimming and fishing have also been disappearing. Again, it seems that the volume of public and private tasks and activities has been increasing, but that the volume of common tasks and activities has been decreasing.

3. Limitations on public-private dualistic concept

3.1 Convergence to conflict between public and private

An inherent limitation on the public-private dualistic concept is that "the relationship between public and private converges to their conflicting discussions since publicness different from the public does not exist (Sasaki and Kim, 2002)." In infrastructure development and management, any claim to pursue other than the public has often been criticized and excluded as an idea of "sacrificing the country for the sake of her/himself" instead of sacrificing her/himself for the sake of her/his country.

For example, the verdict of the first hearing of public noise pollution at Osaka airport in 1974 rejects the plaintiffs' claim of stopping airport operation for between 21:00 and 22:00 which they called "one hour of life". The verdict recognizes the important role the airport plays in domestic and international flight transportation as "publicness" and judges that the operation for the one hour of life is subject to the maximum permissible limit.

Miyamoto criticizes the unreasonableness of "recognizing the plaintiffs' claim as pursuit of private right and the administration's claim as pursuit of public right or publicness and making all national projects "untouchable" deeds beyond rights of the nation and residents (Mitamoto, 2002)." This criticism is made against two debatable points. The first one is to recognize this problem as conflict between public and private, and the second one is to understand public right as "publicness." Miyamoto precisely points out the limitation on public-private dualistic concept.

Kim defines the publicness as "process of thinking things for mutual benefits, discussing, deciding, and implementing by all (Sasaki and Kim, 2002)." It should be noted that this definition is different from its temporary definition made in the previous section. Real issues in this trial should have been "public right of administrative actions and publicness with respect to residential environment. The claim by residents to stop the airport operation for "one hour of life" was rejected just because the concept of publicness with respect to residential environment, which was different from the public, did not exist.

3.2 Regional environment deterioration

Infrastructure development certainly improves quality of life of people through enhancing convenience and amenity. However, it cannot be denied that the quality of life is improved at sacrifice of natural environment. For example, although dam construction has prevented water conflict and solved electricity shortage in the region, discharging water with suspended solid has gradually deteriorated river environment. Rich natural environment for underwater creatures have been lost. After dam construction and operation, children left many rivers for pools to play with water.

Activities in common space cultivate a sense of co-ownership and monitoring ability of environment. Thus, releasing and leaving the common space means decrease in two important items: peoples' sense of co-ownership and monitoring functions of natural environment in the region, which makes people painless about environment deterioration and accept it. Now not a few rivers have a sign saying "Good girls and boys do not play in the river." In the conventional infrastructure development and management in the region, there has been a vicious circle that environment deterioration lowers people's concern and monitoring ability of environment, which leads to its further deterioration.

3.3 Lower benefit cost ratio of infrastructure projects

It seems possible to generalize the discussion of regional environment deterioration to the discussion with broader viewpoints: lower benefit cost ratio of infrastructure projects.

Each individual does not play significant roles in infrastructure development and management except paying tax and providing, that is actually releasing, common spaces. Furthermore, each hardly takes risks, that is, take few preventive or reactive measures for important risks and ask the administrator to do so. It is not surprising to observe that such an attitude lowers benefits and increases costs of each infrastructure project.

If each does not take a significant role in regional infrastructure development and management, it is extremely difficult to incorporate regional characteristics into each project. Such a project would be unattractive and ineffective. Furthermore, if each does not take risks which should be borne by her/him in principle, the administrator has to add contingency fee to deal with transferred risks, which pushes up the project costs. Such a project would be inefficient.

Thus, the conventional attitude of each individual playing few significant roles and taking few risks would possibly make each infrastructure project ineffective and inefficient. Such an attitude is infeasible for the era of regional society but with insufficient budget.

4. Necessity of NPO

Kim considers voluntary intermediary group as another player to take charge of new publicness and summarize the necessity of NPO as follows. "In order to break the deadlock brought by the administrative control and to overcome the limitation and obstruction of efforts towards self-support and self-help life style by individual, clear re-digestion of private resources and activities to change the public-private dualistic structure. It is achieved by only voluntary union of glocal citizens and their activities of acting as go-between "public" and "private" and tying up, connecting, and reactivate the both (Sasaki and Kim, 2002)." Furthermore Kim asserts that "mutual channeling between public and private" by the above-mentioned voluntary intermediate group, that is, the role of voluntary intermediate group of staying in the middle of public and private and channeling the both is important and becomes the core of new publicness (Sasaki and Kim, 2002)."

Mutual channeling between public and private by the NPO is expected to play an important role in infrastructure development and management for the sustainable society. Particularly in the case of cross-sectional and regional environmental problems, which are becoming important topics to restore many Japanese rural areas, NPO should be the key player.

The Japanese administrator has generally been making her/his best efforts in developing and managing infrastructure in each sector. However, its coordination among different sectors and regions is not sufficient yet. For example, to do river basin management, coordination among sectors and areas of forest, agriculture, river, inland water fishery, coastal fishery, water supply, sewage, and even more is needed. Generally an administrative department to coordinate those sectors does not exist in Japan. The NPO is the very first candidate to identify, analyze, and take first initiatives to solve the cross-sectional and regional environmental problems.

5. Functions of NPO

A representative function of NPO is to transform one person's worry into each other's happiness or everyone's happiness. Fig.1 represents this function with pictures of seesaw. This transformation process consists of one person's worry (Fig.1-a), each other's worry (Fig.1-b), everyone's issue (Fig.1-c), and each other's or everyone's happiness (Fig.1-d). Here having worry is represented with being drenched in the rain (Fig.1-a), and happiness is represented with sunshine (Fig.1-d).

Origin of NPO activities often lies in a question of worry raised compulsively from her/his heart such as "No one loves or takes care of this river. Is it all right for us to leave this dirty river as it is?" or "By closing this local bus or railway line, fundamental mobility of not a few people is lost. Is this all right (Fig.1-a)?" When people having the same worry and feeling the same pain get together becomes a starting point of NPO activities (Fig.1-b).

Fig. 1-a　One person's worry

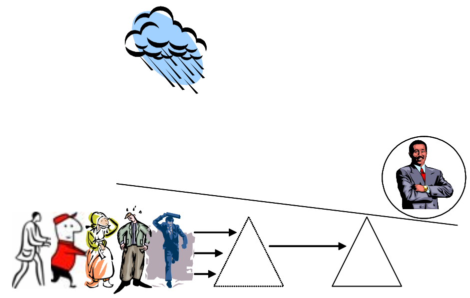

Fig. 1-c　Everyone's issue

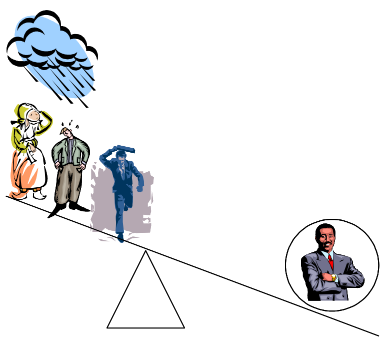

Fig. 1-b　Each other's worry

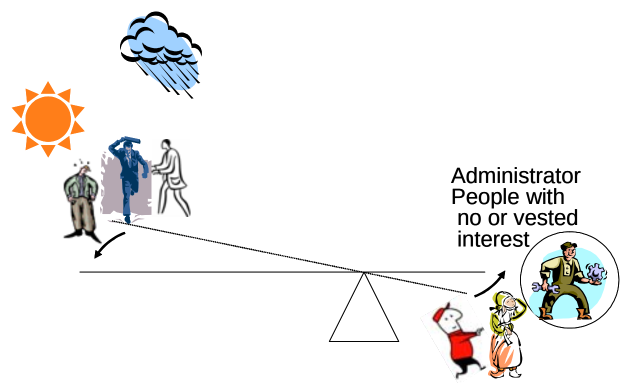

Fig. 1-d　Each other's happiness
or everyone's happiness

Fig. 1 Seesaw Model of NPO Functions

In order to produce activity outputs, NPOs need to share their worry with more people and to transform each other's worry into everyone's issue through making the administrator or people with no or vested interest move. This sub-process is to increase the number of supporters and push the fulcrum towards these people's side (Fig.1-c). The fulcrum means the frontier of public and common issue in the society. By making these people recognize this issue as a new public and common issue, there is a chance that they change their attitudes and way of thinking and take necessary actions, which may have hardly been expected before.

Finally, in order for people drenched in the rain to move the place with sunshine, NPO, people in the region, administrator, and company cooperate to rotate the seesaw in horizontal direction (Fig.1-d).

It should be noted here that NPO and administrator are in the equal platform. NPO often becomes a subcontractor of the administrator. Such a subcontracting business often creates a situation that business fee is not appropriately set or that NPO takes business risks excessively. If such situations continue to occur, the both business opportunities for the NPO and the frontier developed with considerable efforts may be lost.

6. From problem solving approach to value creation approach

One of the biggest hurdles is sub-process represented with Fig.1-c. Some people belonging to an organization may act as components of their organizational system, that is, replaceable. They can only speak "language prescribed by the system." They have difficulty in talking about not only other peoples' feeling but also their own feeling. Many Japanese administrators have this fate (Kato, 1997). It is not easy for an NPO to move "system people." Furthermore, the NPO who points out a regional environmental problem is often isolated because few people are interested in it. If the NPO's claim is against someone's vested interest, pushing the fulcrum of the frontier is a long way to go.

Iijima, the director general of Nonprofit organization Asaza Fund in Ibaragi prefecture, points out limitation on conventional approaches and claims necessity of changing approach: from problem solving approach to value creation approach (Asaza Fund, 2007). Ibaragi prefecture with many rural areas has lake Kasumigaura, the second largest lake in Japan. The lake had first suffered from industrial liquid waste and then domestic wastewater, which caused outbreak of blue-green algae. Many efforts had been made to reduce blue-green algae; however, these efforts had not lasted for a long time. With the goal of only reducing blue-green algae, that is, reducing negative factors, peoples' interest and participation cannot be continuingly maintained.

The Asaza Fund takes a totally different approach. Finding that asaza, floating heart, is a key to protect lake shore through softening waves and to purify water, the fund asks elementary schools to become "foster parents" of floating hearts, that is, growing them in daily lives and planting them in lake Kasumigaura. More than 170 elementary schools in the catchment basin become the foster parents. Floating hearts are perceived as a symbol of restored lake Kasumigaura, and new possibilities of the lake have been searched. Now the fund has developed a hundred-year plan for a sustainable society with several intermediate goals to restore the natural environment such that Japanese crested ibises, which almost becomes extinct during the modernization process of Japan, are returned in 100 years. With this long-term plan, many human networks have been born, and new environmental and economic values have been continuously created (Asaza Fund, 2007).

A key to build sustainable rural area in Japan seems to be something which children, adult, and old people can really be excited about and long for. In the case of Asaza project, they are mystery of growing floating hearts, beauty of the lake filled with floating hearts, and richness of the natural environment where Japanese crested ibises can freely fly. Children also interview old people about sceneries in old days in the region whose results become a foundation of the regional scenery map. These interviews by children also become big enjoyment for old people.

Finding these keys are critical for sustainable rural development in Japan. Sustainable keys are different in each region and may be different for each generation. NPO is expected to play a critical role in finding a sustainable key and implement it in each area.

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PERFORMANCE OF EXTERNALLY BONDED REINFORCED CONCRETE STRUCTURES USING CARBON FIBER REINFORCED POLYMER IN TROPICAL CLIMATE

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Abstract

The emerging field of renewal engineering or sustainable infrastructure may best describe the role of FRP composite in civil engineering application. FRP itself is very durable due to its non-corrodible characteristics as compared to steel. Strengthening of existing concrete structures may be necessary in order to overcome the increase in loading capacity and also environmental effect. The main objective of the current research is to determine the structural behavior of concrete structures by using externally bonded Carbon FRP fabric and plate for flexural strengthening due to tropical climate exposure. Tropical climate countries which experience high average annual temperature, humidity, rainfall and relatively constant ultra violet ray may have detrimental effect on the usage of FRP composite over long period of time. At present, the amount of information on the durability of FRP subjected to environmental condition especially in the tropical climate environment is very limited. It is crucial to study the tropical climate effect of using FRP and its matrix material in structures element in order to gain acceptance in a related country. This is essential because many of the applications of FRP as strengthening or repair materials are for outdoor environment. The study focused on reinforced concrete beams and concrete prisms externally bonded with FRP and expose to numerous environmental conditions. The preliminary results show that the exposure to aggressive environment has an effect on the FRP bonded system.

Keywords: Fiber reinforced polymer, strengthening, repair, sustainable infrastructure, durability, tropical climate.

1. Introduction

Strengthening of existing concrete structures may be necessary in order to overcome the increase in loading capacity and also environmental effect. Durability and ductility are essential to the long-term sustainable service life of FRP material and concrete structural members with FRP reinforcement. Structural reliability and durability implies good performance of material that are able to resist degradation and capable to avoid structural damage. The strengthening of concrete structures through the used of externally bonded FRP composite system raises concern on the durability of the FRP materials at two locations. The first ones is the durability of the FRP material itself and the other one the durability between FRP material and the concrete substrate. The renewal of structural inventory is best summarized into (i) rehabilitation that include the application to repair, strengthening and retrofit structures and (ii) new construction with all FRP or new (Van Den Einde et al., 2003).

Tropical climate of countries which experience high average annual temperature, humidity, rainfall and relatively constant ultra violet ray (UV) may have detrimental effect on the usage of FRP composite either externally or internally retrofitted. The rainy season or the most rainfall is experienced by East Malaysia in the October through February with annual rainfall of 5080 mm compared to 2500 mm of annual rainfall for the Peninsular Malaysia. Even tough, the temperature is quite consistent throughout the year, the temperature records in Malaysia for the last fifty years has shown a warming trend (Zhao et al., 2005).

The amount of information on the durability of FRP subjected to environmental condition especially in the tropical climate environment is still very limited in the literature. Concluded researches show inconsistencies in the results on the degradation effect. It is crucial to study the tropical climate effect of using FRP and its matrix material in structures element in order to gain acceptance in a country which is experiencing tremendous wet and dry cycle through rain, moisture and dry season. This is essential because many of the applications of FRP as strengthening or repair materials are for outdoor environment. However, there is another concern of using FRP as external strengthening materials which is interfacial fracture along the bonded joints that can limit the strengthening performance of FRP materials. It is essential for the long term behavior of the structural bonded joints in civil engineering structures be guaranteed between 50 to 100 years for the acceptance of this bonded system in the construction industry (Täljsten, 2006).

1.1 Interfacial bond

In either flexural or shear strengthening cases, the interface bonding is critical by providing the effective shear stress transfer from the concrete to the externally bonded FRP (Ueda et al., 2005). So, the composite action of structures being externally bonded with FRP material should be preserved during the loading until failure by having a capable and efficient adhesive to transfer stresses between adhesive concrete and adhesive plate bonding (Swamy et al., 1995). The completed research evaluated several interfacial characteristic involving strain development, average and maximum shear bond stress, effective bond length, interfacial energy, and local bond stress-slip relationship.

A study observed three types of failure modes of a GFRP plate bonded to concrete surface subjected to long term aggressive environmental exposure namely (i) cohesive failure in the adhesive layer (ii) adhesion failure and (iii) concrete shearing failure (Mukhopadhyaya et al., 1998). Results of works carried out by two other researchers showed that failure modes by debonding occurred in concrete adjacent to the adhesive concrete interface with noticeable thin layer of concrete attached to the FRP strips after failures (Sharma et al., 2006; Yao et al., 2005). Applied load was observed to be related to strain distribution in which as the load was gradually increased, the strain distribution decreased starting from the loaded end area (Bizindavyi et al., 1999). An investigation showed that the load transfer from plate to concrete at lower loads level is fairly linear and occurred at uniform rate (Mukhopadhyaya et al., 1998). Observation made by a related research indicated that the shear stress is larger at the area of nearest to the loaded end and reach a peak value at normalized load before going for decreasing trend (Sharma et al., 2006). The decreasing trend indicated the initiation of plate debonding and initial cracking at the most stressed region. A very important conclusion made from testing the bonded joints between FRP-adhesive-concrete systems is the existent of effective bond length in which beyond certain bond length the ultimate load experienced no noticeable variation. A larger bond length is only anticipated to cause a longer deformation process as debonding propagates along the interface. Other important conclusion has been made by another study in which the effective bond length is related to FRP stiffness (Nakaba et al., 2001).

Important issues that need deeper consideration in understanding interfacial bond strength in using externally plated FRP reinforcement is concrete surface preparation because of the bonding failure that happen within the concrete layer beneath the adhesive (Ueda et al., 2005). It is necessary to carry out some surface treatment to have a satisfactory bond between the adherents. This is also highlighted as very important because test results in debonding failure modes, and ultimate load are different due to less stringent specimen preparation (Yao et al., 2005). A study carried out earlier also confirmed the important of surface preparation for significant improvement of bonding between FRP and concrete (Toutanji et al., 2001).

1.1 Durability of FRP reinforced Structures in Tropical Climate

Most of the above studies concern with different climate environment which is dominated by severe cold weather condition or extreme temperature of Middle Eastern region and also durability upon exposure to water and solution. Studies on FRP durability on tropical climate environment involved the used of GFRP compare to CFRP with the concern on the improvement of mechanical properties of glass fiber. An experimental research demonstrated that reinforced concrete beam strengthened with CFRP plate under load and exposed to tropical climate for a duration of six months had higher stiffness compared to the strengthened and unexposed beam (Mohd.Sam et al., 2005). This maybe due to better bonding between

CFRP plate and concrete subjected to fully cured adhesive upon outdoor exposure. A durability study to investigate the effect of tropical climate on engineering properties of GFRP laminates bonded to RC beam as a mechanism of external beam strengthening found that tensile and bond strength of GFRP laminates decreased as the results of outdoor exposure (Liew et al., 2003).

A similar test was also carried out to investigate the long-term performance of reinforced concrete structures strengthened with externally bonded fiber reinforced polymer system with combined effect of sustained loading and the impact of weathering (Saha et al., 2005). The experiment results showed that beams subjected to sustained loading exhibited larger deflection and cracks widths when subjected to longer period of weathering exposure. The beams subjected to outdoor weathering showed larger deflection and larger crack width compared to specimen under ambient laboratory condition. Both strength and ductility of beam kept under accelerated weathering decreased with longer weathering period.

2. Experimental Program and Results

This present research is motivated to study the effect tropical climate exposure as well as salt solution on the performance of externally bonded FRP fabric and plate on reinforced concrete structures. Research on durability of FRP material has been initiated at Universiti Teknologi Malaysia, Skudai for couple of years for exposure duration of six months. Study is currently being carried on a longer duration period between 6 to 18 months to further access the performance of CFRP material as strengthening material under tropical climate. Specimen in form of short prism having dimension of 100 x 100 x 300 mm were prepared from concrete of grade 50 N/mm^2. The concrete prisms were bonded with CFRP plate on two sides and subjected to environmental condition of outside weather and salt solution. Eventually, the prism will be subjected to bonding test by double shear test to access the strain and stress distribution. Reinforced concrete beams strengthened with CFRP plate and fabric having dimension of 120 x 180 x 2400 mm are also prepared for tropical climate exposure and tested for flexural investigation under four point load test. The preliminary results of the durability and sustainability studies due to tropical climate and salt solution affected the bond performance. The following sections describe the investigations.

2.1 Interfacial bond study

A research to study the effect of tropical climate on the bonding behavior of external reinforced FRP to concrete was carried out at Unibversiti Teknologi Malaysia, Skudai (AbuHassan, 2006) . Concrete prisms were fabricated for having dimension of 100 x 100 x 300mm and compressive strength of 47 MPa at 28 day test. The dimension of CFRP plate adopted for this study was 1.5 x 50 x 550 mm. The laboratory test on the mechanical properties indicated that tensile strength and tensile modulus was 2400 MPa and 135 GPa respectively. Structural adhesive brand Sikadur 30 was used as the bonding material for FRP and concrete. Electrical strain gauges, LVDTs, and Demec disc were installed on the plate and prism for related measurement during loading. The complete dimension set-up of the testing was shown in Figure 1. The stress is created between the plate and concrete, by applying a tensile force onto the CFRP plate end tabs that resulted for the face of the top concrete surface came into contact with the bearing plate which produced bearing stress and was finally transmitted to the concrete prism. The specimens were subjected to various environmental condition of laboratory air, outside air, and water and salt solution.

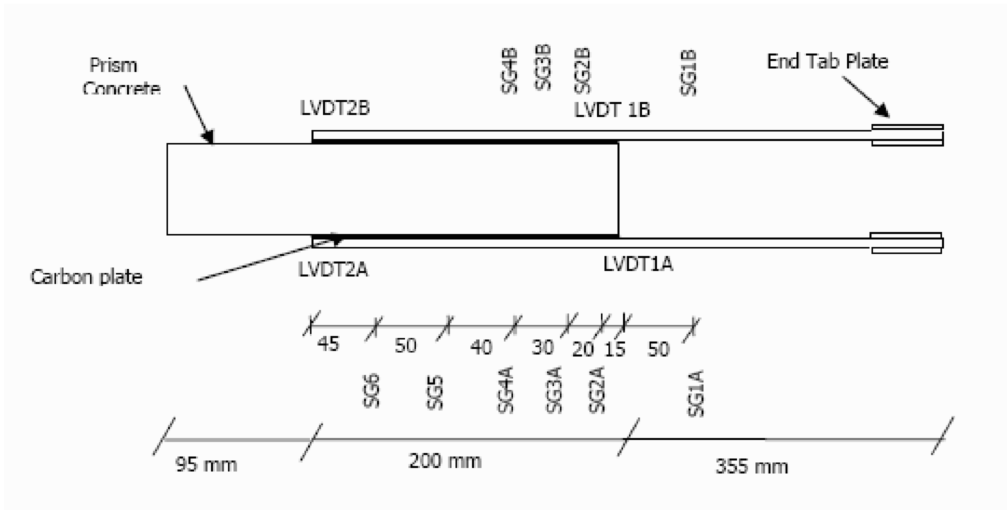

Figure 1 Dimension and instrumentation arrangement (AbuHassan, 2006)

The investigation showed that the bond transfer force from CFRP plate to concrete at low load level was fairly linear, while bond transfer force became non-uniform at higher load. Low level loads also resulted in shorter force transfer length compared to higher load level. Crack can be observed at the loaded end. The full bonded length occurred at 60% of ultimate failure load. The maximum local bond stress occurred in the region of most stress areas near the loaded end. The failure and stress shifted to adjacent and towards the free end region as load was increasing. The results of investigation showed that the exposure regime influenced the bond-slips and time to failure of the samples.

2.2 Flexural Strengthening

An experimental research was carried out to study the performance of reinforced concrete beam strengthened with CFRP plate under load and exposed to tropical climate. The investigation was carried out by focusing on the ultimate load, load deflection behavior, and mode of failure of the beams and compared with the control beam. Four reinforced concrete beams were casted and tested under four-point load to study the flexural behavior of the strengthened beam by externally bonded CFRP plate. The sizes of the beams used were 100 x 150 x 2300 mm for the width, depth, and length with concrete cover of 20 mm. The beams were provided with two 12 mm diameter high tensile reinforcement steel and 6 mm diameter steel for stirrups. Three of the beams were strengthened with CFRP plate and one beam was used as a control beam. Two of the strengthened beams were exposed to the outdoor environment for six months as shown in Figure 2 (Mohd.Sam et al., 2005). The other strengthened beam was not exposed, but tested after 28 days with the control beam. The results of testing after 28 days showed that the strengthened beam was able to carry higher load by about 96% compared with control beam which shows the effectiveness of the plate bonding with CFRP. However, the ultimate load of the exposed beams and the control strengthened beam was about the same at 38.7 kN on the average (Figure 3). This showed that the performance of strengthened beams upon exposure for six months to tropical climate has no significant effect. However, the experimental works showed that the stiffness of the strengthened and exposed beam was higher than the strengthened and unexposed beam.

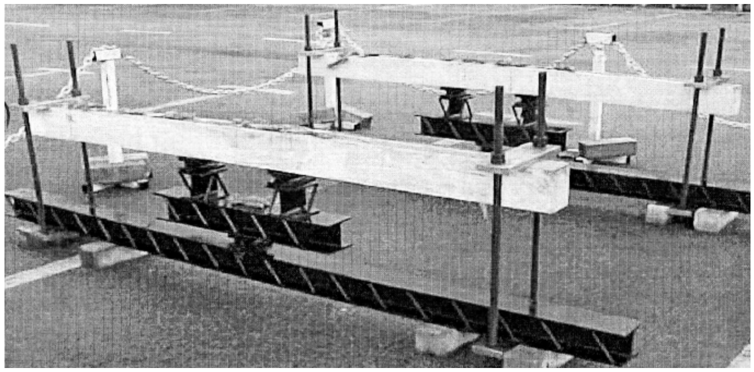

Fig 2. Strengthened beams exposed to tropical weather

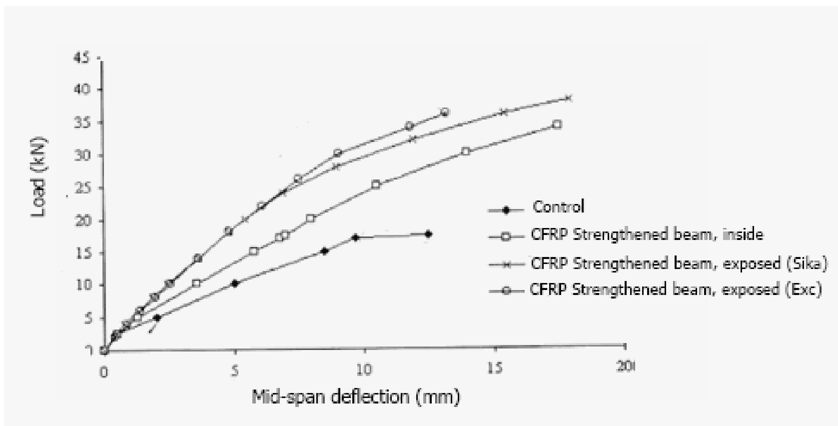

Fig 3. Load deflection of strengthened beam (Mohd.Sam et al., 2005)

3. Discussion

The successful performance of a bonded joint between construction members such as FRP and concrete through the used of adhesion is dependent upon adequate adhesion between the members in the system. Not only should the adhesive used have adequate cohesive strength, but also the extent of adhesion to the bonding surface is required factors to ensure providing strength to the bonded joints. One of the negative aspects of adhesive bonding is that the surfaces need to be clean in order to remove contamination and weak surface layers and to change the substrate surface geometry for eventual satisfactory degree of contact (Täljsten, 2006). The assumption of perfect bonding between the FRP and concrete by using adhesive was adopted in both of the investigations. As such, the bonding failure was found to be on the concrete surface. Important parameters to be considered in measuring the durability of FRP plate bonded system are the bond slip and time to failure. This is significant in studying the critical region of the plate bonded system. The expose beams in flexural strength studies may indicate a fully cured adhesive after the duration of exposure.

4. Conclusion

1. The use of CFRP as strengthening material in concrete structure improves the flexural performance of reinforced concrete beams. However, the exposure to tropical climate seems to produce very minimal impact on the structural performance of the strengthened beam.

2. The interfacial bonding study provided some signs on the failure of bond durability as shown on the stress characteristics behavior. Bond slip characteristics of the strengthened concrete structures can be used to measure the durability of the FRP system.

However, the ongoing research is expected to provide better understanding on interfacial bonding and flexural performance of reinforced concrete structures strengthened with CFRP plate or fabrics. Hence, the use of FRP materials can gain wide acceptance in tropical climate countries for its structural effectiveness for the development of sustainable infrastructures.

Acknowledgements

The authors would like to thanks all relevant department and human resources at UTM, SKudai for their support to complete this research

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