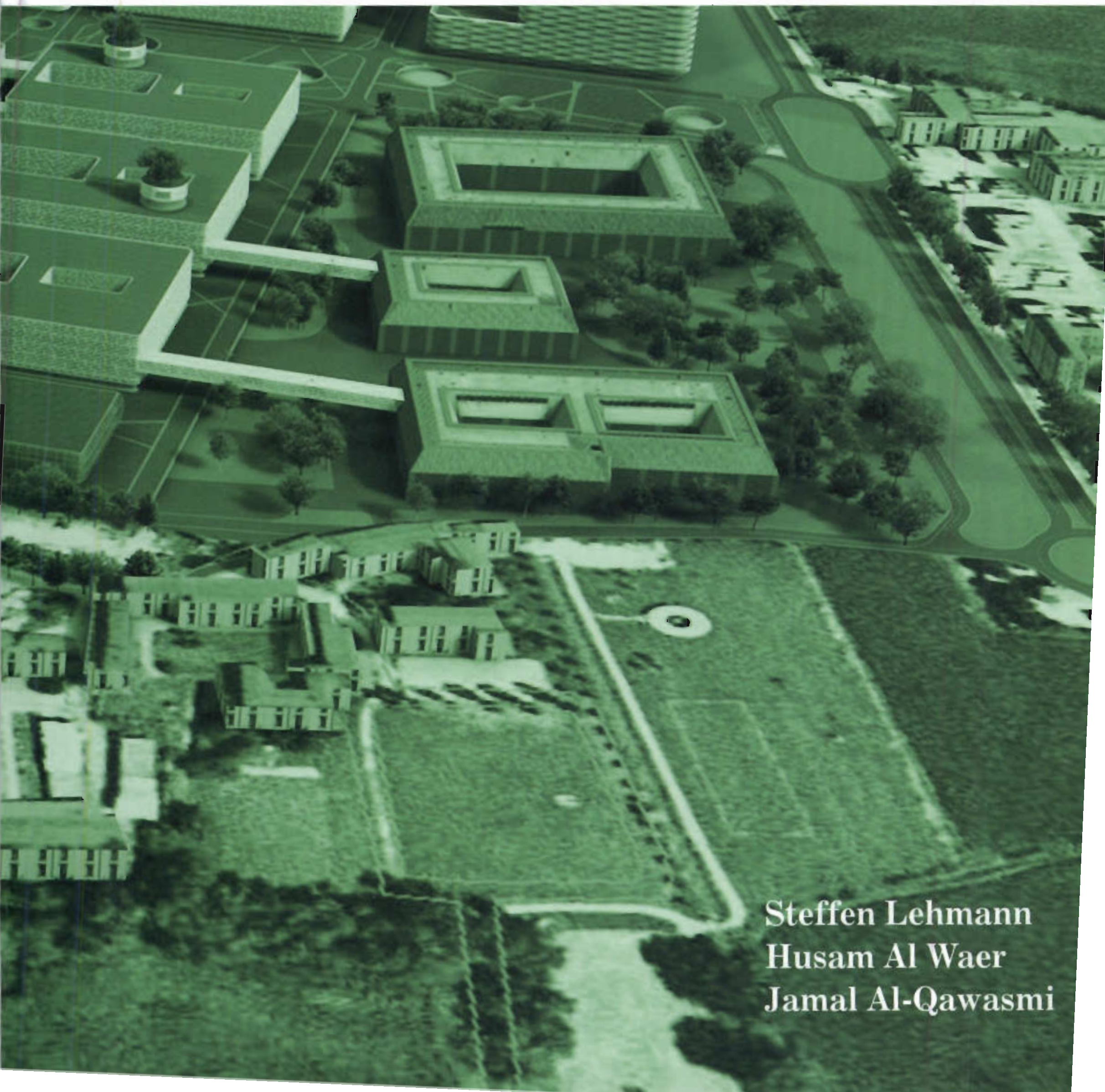
Sustainable Architecture & Urban Development

Vol I



Steffen Lehmann
Husam Al Waer
Jamal Al-Qawasmi

Sustainable Architecture and Urban Development

Volume I

Editors
Steffen Lehmann
Husam Al Waer
Jamal Al-Qawasmi

SAUD 2010
The Seventh International Conference of
The Center for the Study of Architecture in the Arab Region

Proceedings of SAUD 2010 Conference
Held at the University of Jordan, 12-14 July, 2010

ISBN: 978-9957-540-00-5

Published by CSAAR Press,
The Center for the Study of Architecture in the Arab Region

1. Sustainable Architecture
2. Sustainable Urban Development
3. Sustainability

Cover image: Studio Boeri/Hilson Moran

Hilson Moran is a leading multi-disciplinary consultancy for the built and urban environment, with a network of offices in the UK, Ireland, France, Italy and the Middle East.

The Hashemite Kingdome of Jordan
The Deposit Number at the National Library (2010/06/2297)

720

CSAAR (7 : 2010 : Amman)
Sustainable Architecture and Urban Development \ Edited by Steffen Lehmann, Husam Al Waer, Jamal Al-Qawasmi. - Amman: The Center for the Study of Architecture in Arab Region, 2010.

(470)P.

Deposit No.: (2010/06/2297)
Descriptors: \ Urban Planning\\Sustainability\

- أعدت دائرة المكتبة الوطنية بيانات الفهرسة والتصنيف الأولية
- يتحمل المؤلف كامل المسؤولية القانونية عن محتوى مصنفة ولا يعبر هذا المصنف عن دائرة المكتبة الوطنية أو أي جهة حكومية أخرى

Acknowledgments

The Seventh international conference of CSAAR has been an enormous undertaking that would not have been possible without the efforts and cooperation of several people and organizations: conference organizing committee, international review committee, CSAAR advisory Board, Middle Sustainability Group (ESTEDAMA, Geddes Institute for Urban Research at The University of Dundee, and Energy Center at The University of Jordan.

The four-volume proceedings of the SAUD 2010 conference, titled Sustainable Architecture and Urban Development, have been made possible through the contributions of many. First, we want to thank all the authors that responded with their work to our Call for Participation. Without their effort and trust, this conference would not have been possible. We also would like to acknowledge the international review committee for their hard work and dedication at evaluating the numerous papers submitted. A special thank goes to the conference keynote speaker: Prof Dr Raymond J Cole.

We are particularly grateful to the United Nations Sustainable Building and Construction Initiatives (SBCI, UNEP), The International Council for Research and Innovation in Building & Construction (CIB) and The International Initiatives for a Sustainable Built Environment (iiSBE) for all the support they provide for the event. SAUD 2010 is one of the regional conferences taking place around the world in 2010 as a prelude to The World Conference on Sustainable Building, SB11 in Finland, that are all organized under the auspices of CIB, iiSBE and UNEP. Thanks also go to the UNESCO Chair for Sustainable Urban Development in Asia, Middle East and the Pacific; and to all other supporters and sponsors of SAUD 2010 for their generous financial contributions.

Table of Contents

Low Energy Architecture

Vernacular Architecture and Sustainability

Ecological, Social and Cultural Sensitivity

Preface

The increasing urbanization of many parts of the world, coupled with globally critical issues, such as environmental pollution, increasing energy consumption, global warming, water and resources shortage and lack of waste recycling are resulting in major urban crises. In an effort to explore and map the challenges and opportunities of sustainable development, the Center for the Study of Architecture in the Arab Region (CSAAR) has collaborated with The University of Dundee, and the University of Jordan, to organize SAUD 2010, the 2nd International Conference on Sustainable Architecture and Urban Development. This conference was held from July 12 to 14, 2010 in the City of Amman, in Jordan.

The conference aimed to address issues related to best practices of sustainability in urban design, planning and development in the Arab region and elsewhere. Of particular interest for the conference organizers was to identify pathways to achieve urban sustainability in Arab cities. These cities are currently undergoing some of the fastest rates of change and development worldwide, and challenges to harmonize this rapid and sometimes even traumatic experience of change are significant. The rapid, often erratic, growth has not occurred without unwanted consequences in the built environment .

To engage meaningfully in the sustainable development debate, the conference organizers invited architectural practitioners, educators, university scholars and their counterparts in governments, municipalities and environmental design fields, to develop research in a number of thematic streams that encompass not only the spatial and physical aspects of the built environment, but also the social, economic, legislative, and ecological contexts and consequences .

More than six hundred authors from a diverse community of researchers responded with abstracts, and more than three hundred fifty of those submitted papers were submitted for blind peer review. The 128 papers that were selected for presentation at the conference come from a variety of architecture and urban development fields and have the potential for enhancing the interdisciplinary knowledge base by defining best practice of sustainable development. The critical nature of the subject has attracted authors from around the word and therefore the content of the publication provides a global perspective on the subject. This four-volume publication has been organized into twenty two chapters that correspond to the conference sessions: Sustainability Assessment & Buildings Performance; Sustainable Construction Materials & Technologies; Low Energy Architecture; Vernacular Architecture and Sustainability; Ecological, Social and Cultural Sensitivity; Urban sustainability and Low Carbon

Development; Sustainable Construction Materials & Technologies; Design with Nature; Ecological, Social and Cultural Sensitivity; Urban Design and Sustainability; Eco-Mobility: Sustainability in Transport; Cultural Heritage and Eco-Tourism; Sustainability Assessment Methods, Applications and Limitations; Urbanism in the Middle East; Sustainability in Arab Countries; Sustainable Renovation and Restoration; Sustainable Design Issues; Landscape and Ecological Sustainability; Retrofitting the City; Sustainable Housing and Neighborhoods; Sustainability in Developing Countries; and Reflections on Sustainability

The term Sustainability has become ubiquitous to every conference and paper today that it risks being reduced to an empty slogan. Therefore, the editors and co-conveners were keen to seek an intellectual discourse that would help to pin down the exact notion and meaning of the term's use .

The keynote speakers from Canada and Germany considered the diverse and broader context of sustainable urban development, while exploring a pedagogical approach to the integration of sustainability knowledge into teaching and research .

This international conference attracted much attention and recognition among professionals involved in sustainable urban development. Ideas expressed by authors range from empirical investigations to case studies and literature review of various issues related to sustainability of the built environment. In the following pages you will read a range of concepts and learn about researchers' findings. However, the four volumes cannot provide definitive answers and, as a result of the rapid change in the field, some of the claims made may seem quaint and outdated almost immediately after publication. Authors of the session papers responded with a wide and inspiring spectrum of possible positions. The papers suggest that the only constant may be change and the future of the built environment may depend on our ability to keep up with this rapid change and the development of new knowledge.

The Editors and Conference Conveners,
Amman, July 2010

Sustainability Assessment & Buildings Performance

Assessing Sustainability of Cities and Districts for Healthy Communities

A. Oppio[1], S. Capolongo[1], A. Battistella[2], M. Buffoli[1]
[1]Department of Building Environment Science & Technology (B.E.S.T.), Politecnico of Milano, Italy
[2]School of Civil Engineering, University of Pavia, Italy

Abstract

Health, quality of life and sustainable development are strongly interconnected. The quality of living is a complex concept that includes different meanings. The quality of life issue has been studied for a long time, even if its measurement is a more recent matter. According to widely accepted definition of a healthy community given by Hancock & Duhl for WHO in 1986: "A healthy city is one that is continually creating and improving those physical and social environments and expanding those community resources which enable people to mutually support each other in performing all the functions of life and in developing to their maximum potential", this paper suggests an approach focused on the effects that urban planning and designing can have on the health of citizens.

The experience explained shows as local authorities can support professionals in designing process by a multicriteria assessment tool, that covers a wide range of healthy and sustainable development issues, such as 1) environmental quality and wellbeing, 2) waste, 3) energy and renewable resources, 4) mobility and accessibility, 5) use of land and functional mix, 6) quality of urban landscape. Although the current version of the evaluation tool has been defined in order to carry out design-stage assessments, the system has the capacity to carry out assessments also at later stages. This evaluation procedure can be considered as a common platform from which different stakeholders can agree goals and work together contributing to increase the benefits of a well-designed built environment.

***Keywords**: health, multicriteria evaluation, sustainable communities*

1 Introduction

With reference to the holistic approach to achieving goals of sustainability in European cities delivered in the European Union Health Strategy adopted in 2007, health, quality of life and sustainable development are strongly interconnected.

The quality of living is a complex concept that includes different meanings. The quality of life issue has been studied for a long time, even if its measurement is a more recent matter (Iezzi, 2006). It's possible to distinguish two main approaches: the first one, depending on which the quality of life corresponds to the social wellbeing and it can be measured objectively (Bauer,1996; Oecd, 2001; Osberg, 2004); the second one, that emphasizes the perceptive dimension of quality of life, such as needs, feelings and aspirations (Andrews, Whitney, 1976; Campbell et al., 1976). According to its multidimensional meaning, the sustainable development concept includes both the former and the second approach.

Furthermore, actions to promote good health conditions can support the fulfilment of the recommendations related to health stated in Local Agenda 21, the United Nations program of action on sustainable development adopted during the 1992 Earth Summit in Rio de Janeiro, and in the 2002 World Summit on Sustainable Development held in Johannesburg built on the implementation of Agenda 21. As the first principle of the Rio Declaration for Environment and Development affirms that human beings are at the centre of concerns for sustainable development, ensuring good health conditions for all is one of the main requirements of development. The Rio Conference first highlighted the role of urban communities in shaping healthy and sustainable development: health is considered as an outcome of all the factors (environmental, economic and social) that affect both human beings and sustainable development.

This view, focused on the relationship between environment and lives of individuals, families and communities, depends on a social model of health contrasting with the medical model that considers health the polar opposite of illness. These relationships can be described in terms of layers of influence (Whitehead & Dahlgren, 1991): in the centre there are individuals with a set of fixed characters. Then there are determinants of health that can be modified: individual ways of living, patterns and norms of their community, structural and more general factors such as housing, working conditions, access to services and provision of essential facilities.

In this perspective and according to widely accepted definition of a healthy community given by Hancock & Duhl for WHO in 1986: "A healthy city is one that is continually creating and improving those physical and social environments and expanding those community resources which enable people to mutually support each other in performing all the functions of life and in developing to their maximum potential", it is meaningful focusing on the effects that urban planning and designing can have on the health of citizens.

Although how different factors affect health and how these information can be used by policymaking still must be investigated, because these relationships are complex and vary, it is widely acknowledged that the quality of environment is one of the principal causes of differences in people's health (Ottawa Charter for Health Promotion 1986 and The European Urban Charter II, 2008).

Actually many of the problems of the cities like pollution, inequity, lack of services and accessibility depends on decisions about the development of land and buildings. To have more attractive cities in the future it is important that professionals involved in planning and local authorities integrate health considerations into city urban planning processes, programme and projects, focusing on the major determinants of health: the physical and social environment in which people live and the nature of their lifestyles.

As the urban plans and initiatives can have both positive and negative influences on the conditions in which people live and work, their access to facilities and services, their lifestyles and their capability to build strong and long-term social networks, the paper will show how it is possible to orient planning and designing practice, both at urban and neighbourhood level, to sustainable development's principles using a bottom-up approach based on multicriteria evaluation.

More in deep the paper is divided in four parts: the first one focuses on the premises of the study and on the methodological approach; the second provides a overall description of the set of the performance indicators; in the third part will be explained the assessment framework and in the last one will be discussed the actual state of the study and his future developments.

2 Methodology

In these last years the city of Milano is involved in a deep urban development process in which most of the areas that were brownfields will be mainly turn into residential, tertiary and service use.

With reference to this scenario, the role of the Prevention Department of the Local Health Agency is to support urban development process by analyzing the potential risks and threats for public health due to built environment in urban plans proposals, both at a large and at the district scale. Furthermore this assessment task will be enforced by the EXPO 2015, that will promote new urban transformations.

Because of the multidimensional character of the heath promotion strategies, has been created a inter-institutional workgroup between Lombardy Region, Municipality of Milano, Local Health Agency and other agencies and offices concerned with the development of sustainable communities in order to move health issues from health care services where they are traditionally considered.

In order to analyze thoroughly the relationship between built environment, health and quality of life, the Local Health Agency of the city of Milano has commissioned to the B.E.S.T. Department of Politecnico of Milano the research work described in this paper. The study has been carried out by an interdisciplinary group of researchers, involving also technicians of the Prevention Department of the same authority. Despite the study started in 2008, it represents a innovatory answer to instances emerged in the field of public health over the years, that have increasingly shifted the action to prevention more than on treatments, focusing on the influences of environment over lifestyle. The concept of the study has been promoted and discussed during several times of interaction among researchers and technicians of the Local Health Agency in order to achieve a wide agreement on targets by all relevant stakeholders with the purpose of developing awareness of the process and capability to apply and implement the assessment tool.

More in deep, the requirements emerging from this first discussions and shared between all participants were the followings: to give an overall picture of health and quality of life topics at the local level; to promote healthy community strategies with the aim of setting local priorities and goals according to WHO and EU vision; to support the assessment task of technicians of the Local Health Agency; to monitor progresses by evaluating changes over time; to increase the public awareness of the relationship between built environment and health creating the circumstances for a more effective intersectorial field work and training between urban planners and public health professionals. In order to meet all of these requirements, a set of performance indicators was developed supported by a deep survey of best practices regarding the issues covered by the indicators, with the aim of creating a clear base of common knowledge, an interchange platform supporting actors involved in urban planning and management in taking actions with the purpose of improving living conditions and health for all the categories of citizens.

3 Definition of the set of indicators

Target setting is extremely important in the searching for sustainability process because it aims at a desired quality of life. Targets are generally a compromise or trade off between what is envisioned and what is feasible (Oppio, Caputo, 2008).

The evaluation of sustainability and quality of life at the local level represents a supporting tool for long-term policy-making because it establishes a basis for monitoring the progress of actions. There are a lot of initiatives in Europe that try to measure and monitor the level of sustainability and quality of life of local communities by different set of indicators with reference to environmental, social and economic issues. Among these, the WHO Healthy city project starts the challenges related to the links between health gains and quality of life to local governments, health authorities and urban planners. Since much of the planning and design profession concerns the design and creation of liveable places for people, planning and public health professionals are intrinsically linked. In this perspective, urban planning can be considered as a form of primary prevention and contributor to health outcomes (Duhl L.J.,. Sanchez A.K 1999 WHO).

According to the most relevant goal of this program, that is understanding which are the issue of a healthy urban planning, many efforts were made in order to define an effective set of indicators for assessing buildings and urban space proposals, but also for improving the living conditions in the future. This preliminary research aimed to identifying targets and criteria has been carried out with reference to the importance given urban planning by the Healthy Cities' strategy, that strongly recognize its influence over the factors health's main social and environmental factors (Barton, Tsourou, 2000).

The set has been established by specifying a number of selected issues identified according to different experiences of Healthy city project (i.e. Healthy City Project -City of Milan 2002; WHO - Active city 2008; WHO - Healthy cities 1994) and existing sets of sustainability indicators (i.e. European Common Indicators 2003; Urban Audit 1998-2000; Local Quality of Life Indicators 2005; Ecosistema metropolitano 2008; GBTool 2002-2008; Protocollo Itaca 2005, S.I.S.Te.R. Project 2002).

This first wide set of indicators was seized on the specific needs of the Local Health Agency of the city of Milan. After various brainstorming with the technicians of the Local Health Agency directly involved in this research, a deep analysis has been carried out, elaborating a set of 23 indicators, that cover all the issues emerging from previous analysis. Indicators investigate six different systems: environmental quality and wellbeing, waste, energy and renewable resources, mobility and accessibility, use of land and functional mix, quality of urban landscape (see Figure 1). More specifically the indicators selected according to these previous systems, are: 1. Air, 2. Noise, 3. Water, 4. Ionizing radiations (Environmental quality and wellbeing); 5. Solid waste management, 6. Liquid waste management (Waste); 7. Energy consumption and monitoring, 8. Passive technical systems for sustainability, 9. Active technical systems for sustainability (Energy and renewable resources); 10. Distances to parks and local services, 11. Public transport system, 12. Availability of pedestrian and bicycle paths, 13. Links between existent mobility system and new settlements (Mobility and accessibility); 14. Functional and social mix, 15. Urban density, 16. Filtering areas, 17. Protection of sensitive users, 18. Hazardous and nuisance activities (Use of land and functional mix); 19. System of exterior areas; 20. Urban equipment, 21. Visual comfort, 22. System of urban green areas, 23. Parkings for inhabitants (Quality of urban landscape).

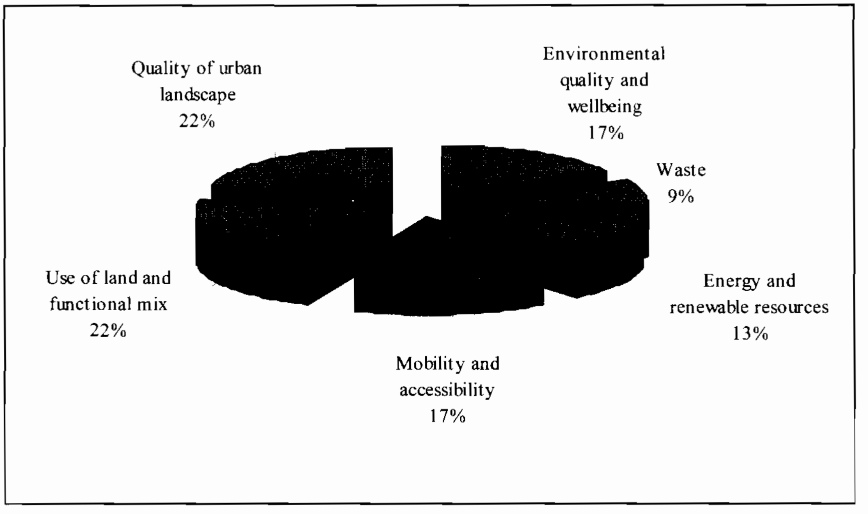


Figure 1. Repartition of the 23 indicators in the 6 systems.

A brief description of targets and contents of each indicators' system will be afterwards provided.

The first two systems focus on the main determinants of the environmental quality. The goals of the indicators included in these two groups has been defined with strong reference to regional and local policies, laws and codes. A specific attention has been paid to the sensitive users.

The system "Mobility and accessibility" refers to the quality of life of people directly involved and to the level of environmental pressure exerted by this kind of activity. It is also recognized the importance of promoting alternative and light modes of transport (such cycling), if only safe and attractive for all. In the same group of indicators is considered the accessibility to public open areas and basic services that is essential in a sustainable community for the quality of life and the viability of the local economy (ECI, 2003). This issue is strictly linked to the first one because having the most important services close to home reduces the need to travel.

The System "Use of land and functional mix" considers the man-made capital, that is the urban development pattern and the uses. The requirements covered by these indicators has been established with the aim of creating a well-built urban structure able to promote a lifestyle that encourages people of different social and economic conditions to meet each other. Under this perspective has been conceived the "Urban density" indicator, whose meaning is very close to spatial efficiency (well-planned integration of transport infrastructure with housing and other uses).

The system "Energy and renewable resources" aims to define the macro areas which are essential for a sustainable design. Particular attention has been paid to those aspects whose result is the optimisation of the energy management from single buildings to the whole city. At this purpose, the "Energy consumption and monitoring" indicator establishes a hierarchy of values assignable to new buildings following the parameters of the National System of Energy Certification. It also suggests the use of advanced monitoring systems able to explain what kind of changes are necessaries to optimize the waste of energy consumption.

At the end the system exploring the "Quality of urban landscape" acts on the factors linked also to the formal quality of those places developed by the architectonic and urban design. Within this family of indicators it is important to define how the coordination of all elements of a new intervention can influence the inhabitants' psycho-physical well-being. For example, the "System of exterior areas" indicator considers on one side the public space, for which every new construction intervention must include areas usable by every housing unit, on the other side the design of the nearby open spaces, that have to be part of an organic project that considers them from the very beginning, thus not allowing any casual, unplanned public space. Moreover, The "Visual comfort" indicator measures the well-being of a community where anything that can visually pollute the place is taken into account, particularly big publicity boards, advertisement signs, street signs and the public lighting system.

Each indicator is supplemented by an assessment sheet that specifies the meaning and the overall goal, the impacts on health, the performance evaluation scale both at neighbourhood level and at urban one, best practices supported by pictures and notes and references. These sheets are useful not only to support the assessment of plans and projects with reference to the effects on health, but also to orient the planning and design process to the principles of a sustainable built environment.

More in deep the performance values are expressed by the following qualitative scores: negative performance, critical performance and good practice. Despite this kind of assessment means losing the quantitative information, it can contribute to promote understanding and communication between different stakeholders involved in the assessment process. Each of the scores is described by a reference judgement, that points out the requirements that is relevant to meet in order to achieve the best score. Such a performance evaluation scale can be considered at the same time the basis of the evaluation report delivered by the Local Health Agency and a companion guide for designers and planners, that could raise their awareness about the determinants that affect public health and enlarge their professional skills.

4 Assessment process

The set of the performance indicators described before represents the multidimensional assessment framework. The general score of each plan/project is given by the score achieved at the level of the 6 thematic issues, that is once more given by the score achieved at the lower level of each indicator.

More in deep, the qualitative scores of the assessment sheet has been tied to numerical value: negative performance=0; critical performance=1; good practice=3. As the score achieved by each thematic issue is given by the average mean of the scores gained by each indicator, the performance values of plans/projects are defined according to the three different ranges as described in table 1.

Table 1. The numerical ranges linked to the performance values

Ranges	Performance values
$0 \leq x \leq 1,5$	negative
$1,5 < x \leq 2,25$	critical
$1,5 < x \leq 2,25$	good

The final result of the assessments made, via numerical scores and performance values, is shown by two different types of chart: a spider diagram, that shows the score achieved by each thematic issue and three kind of histograms, one that focus on the distribution of the scores for each of them, the second that show the general score of the plan/project and the last one that explains the absolute score of each indicators.

This way of communicate the results of the assessment process is very useful because it highlights in a clear and smart way which are the weakness and the strengths of the proposal evaluated, in order to point out corrective actions and to effectively address intervention to a higher level of sustainability. Concerning this, it's important to specify that the proposed assessment tool must be applied entirely, not restricting the evaluation to the final numerical value, but carefully considering all the requirements used to build the three level of the performance scale.

5 Developments and Conclusions

The study can be considered as a promising, interdisciplinary and experimental start for developing actions for the sustainable development of healthy communities. In the next steps of the research, it is expected that the assessment tool will be implemented with reference to the first results of its application to urban plans and projects. This stage will be very meaningful in order to understand if the evaluation protocol is effective for improving future urban plans and projects and for transferring the lesson learnt. Thus, great importance will be given to measure the extent to which plans and projects achieve health and quality of life principles at city level.

The results of this step of the evaluation process can be considered useful information for the monitoring of future interventions. Since stages and contents of the evaluation are planned under the perspective of a cyclic process, the evidences emerging from each phase can be used as input for the following steps.

According to this conceptual framework, will be established a "Regional Permanent Observatory on urban development plans and projects" including technicians of Local Health Agencies, researchers of Politecnico of Milano and representatives of different departments of regional authority in order to optimize the use of resources, attaining maximum synergy and efficiency from intersectorial cooperation. More in deep, Local Health Agencies will have the task i) to assess the proposals, ii) to monitor the interventions during a long horizon time and iii) to transfer the outcomes of the evaluation to the regional observatory. These outcomes will be validate and used by the research group of Politecnico of Milano with the purpose of strengthening the assessment tool and informing the political level.

Nevertheless the assessment tool, as actually defined, can be considered definitely useful for all the stakeholders involved by producing results based on performance scores that could promote a kind of benchmarking process. This can only be achieved successfully when done strategically in the policies, programs and initiatives of different sectors across the city. Partnerships among authorities with different tasks are encouraged and also the creation of networks of cooperation and knowledge transfer on health and quality of life which can go beyond this experience.

Acknowledgements

All the people that have contributed to the study. Workgroup of the Local Health Agency of the City of Milan.

References

Ambiente Italia (2003). *European Common Indicators*, Milan.

Ambiente Italia (2008). *Ecosistema Metropolitano*, Milan.

Andrews, F.M., & Whithey, S.B. (1976). *Social Indicators of Well-Being: Americans' Perceptions of Quality of Life*, New York: Plenum Press.

Bauer, R.A. (1966). *Social Indicators*, Cambridge: Mit Press.

Barton, H., Grant, M., & Guise, R. (2003). *Shaping neighbourhoods: a guide for health, sustainability and vitality*, London: Spon press.

Barton, H., & Tsourou, C. (2000). *Healthy urban planning: a WHO guide to planning for people*, London: Spon press.

Campbell, A., Converse, P.E., & Rodgers, W.L. (1976), *The Quality of American Life: Perceptions, Evaluations and Satisfactions,* New York: Russel Sage Foundation.

Comune di Reggio Emilia. (2002). *Valutazione della qualità ambientale dello spazio residenziale.*

Duhl, L.J., & Sanchez, A.K (1999). *Healthy cities and the city planning process*, Copenaghen: WHO Regional Office for Europe.

Edwards, P., & Tsouros, A. (2006). *Promoting physical activity and active living in urban environments: the role of local governments*, Copenhagen: World health organization Europe.

European Commission. (2000). *The Urban Audit. Toward the benchmarking of quality of life in 58 European Cities*, Luxembourg: Office for Official Publications of the European Communities.

European Environment Agency. (2005). *Core set indicators. Guide* (Technical Report 1-2005). Luxembourg: Office for Official Publications of the European Communities.

Faludi, A., & Voogdt, H. (1995). *Evaluation of complex policy problems*, Delft: Delftsche Uitgevers Maatschappij.

Frank, L.D., Engelke, P.O., & Schmid, T.L. (2003), *Health and community design: the impact of the built environment on physical activity*, Washington: Island Press.

Friedmann, J. (1987). *Planning in the public domain: from knowledge to action*, New Jersey: Priceton University Press.

Friend, J.K., & Jessop, W.N. (1969). *Local government and strategic choice. An operational research approach to the processes of public planning*, London: Tavistock Publications.

Hancock, T., & Duhl, L. (1986). *Healthy cities: Promoting health in the urban context*, Copenhagen: WHO Regional Office Europe.

Lafferty, W. (2002). *Sustainable Communities in Europe*, London: Earthscan.

Moldan, B., & Billharz, S. (1997). *Sustainability indicators: a report on the project on indicators of sustainable development*, New York: Wiley.

Newton, P. (2001). Urban indicators for managing cities. In V. De Villa & M. Westfall (Eds.), *Urban indicators for managing cities: Cities data book.* Manila: Asian Development Bank.

Office of The Deputy Prime Minister,& Audit Commission. (2005). Local quality of life indicators, London: Audit Commission for local authorities, National Health Service in England.

Organisation for Economic Co-Operation and Development. (1993), *Core set of indicators for environmental performance reviews* (Environment Monographs n° 83), Paris.

Organisation for Economic Co-Operation and Development. (2001). *The Well-being of Nations: The Role of Human and Social Capital* (OECD Publication No. 81073 2001), Paris.

Oppio, A., Caputo, P. (2008). The quality of life of local communities: an assessment tool. A case study in Lombardy region – Italy, in Foliente G.

et al. (Eds.) *Proceedings of the 2008 World Sustainable Building Conference*, Balnarring, Vic.: ASN Events Pty: Melbourne, Australia.

Oppio, A. (2007), Costruzione e valutazione di scelte progettuali sostenibili, in S. Mattia (Ed.) *Costruzione e valutazione della sostenibilità dei progetti* (vol.II), Milano: FrancoAngeli.

Osberg, L. (2004), The Relevance of Objective Indicators of Well-Being for Public Policy, *Annual meeting of the Canadian Economic Association*, Toronto: Ryerson University.

Nations Department of Public Information. (1993). *United Nations, Earth Summit Agenda 21*, New York.

WHO Regional Office for Europe, (1991). *Health for all targets – the health policy for Europe* (European Health for All Series, No. 4). Copenhagen.

Whitehead, M., & Dahlgren, G. (1991), What can be done about inequalities in health? *The lancet*, 338: 1059–1063.

A Holistic Approach for Evaluating Sustainable Development: Exploring Indigenous Approaches in China

Wenli Dong, Steffen Lehmann, Jamie Mackee
The University of Newcastle, Australia.

Abstract

Traditional reductionist methods of analysis, which breakdown and isolate the component parts will bring the risk of fragmented decision making with potential unforeseen consequences. Systemic, holistic and hierarchical assessment of sustainability is therefore needed. This paper shows that there are two kinds of sustainability evaluation frameworks which are identified: one is in nominal loops. The other is in linear, ordinal categories, without loop. Each category has its strength and weakness because of their intrinsic characteristics. There is also systemic approach in eastern way of thinking that could combine the strength of both sides: Chinese indigenous knowledge to view the environment is keeping the balance of waxing and waning between sub-systems in the cycle of the universe. Discussion on the overlapping worldviews could provide better understanding on systems theory to be applied on sustainability evaluation methods based on the indigenous approaches of China. The framework developed in this research will inherit the character of "ordinal loops" of Chinese traditional diagrams. The conceptual process utilizes the eastern thinking model into the organisation of sustainable development evaluation framework, which can be adopted by policy-makers, designers, and stakeholders in Asia-Pacific.

Keywords: *Sustainable development evaluation; typology; holistic framework; indigenous knowledge*

1 Introduction

Sustainable development can be described as a journey toward the goal of sustainability. Agenda 21, the milestone of sustainability recognised the integrated concerns in decision making of environment and development. A complex system to manage ourselves, individually and collectively is required. Traditional reductionist methods of analysis which breakdown and isolate the component parts will bring the risk of fragmented decision making with potential unforeseen consequences. Systemic, holistic and hierarchical assessment of sustainability is needed. This could be found in both the modern integral environment system and Chinese indigenous knowledge. Despite the similar psychological and social roots, the two diagrams of each human-nature interface are inherently different, where the western one is simplified, linear and bipolar in terms of space and time, the eastern approach represents a circular movement with periodical recurrence in a tri-polar frame.

Entering the 21st century and distancing itself from its early planned economy there are now new economic and social imperatives in China. However, in the last twenty years Chinese cities have confronted serious problems of balancing fast, intensive economic and urban development while attempting to achieve sustainability (Xiong 2005). Meanwhile, many of the urban theories and sustainability evaluation methods applied to Chinese cities have been appropriated from western models of urban development. Since the concept of sustainability is value-based, and values can vary over time and between cultures (PCE 2002). The sustainable development evaluation needs to be tailored-to-fit the environmental, social and economic conditions in an individual region(Roberts, 2006b).

There has recently been a movement toward indigenous approaches to sustainability supported by local knowledge (George and Dei 1995; Phillips O. and TiTilola O. 1995; Bank 1997; Berkes 1999; Appleton, Fenandez et al. 2005).This has provided motivation for this research to find best practices in sustainable urban development and evaluation methodologies that are based on indigenous philosophies and thinking and the urban practice in Chinese cities.

2 Aim and methodology

This paper aims to explore the sustainable development evaluation trends and types and provides insights into the theories which could underpin the sustainability evaluation framework for Chinese cities and Asia-pacific regions. The approach of this paper has been to review international sustainability evaluation frameworks that are widely adopted and Chinese indigenous knowledge to conceptualize theory by logical argumentation. They are integrated into the framework for the organisation of city data, indicator system, theories and guidelines for sustainable urban developments.

3 Structure based categories of sustainable development evaluation framework

In order to compare the western and eastern sustainable development framework, Markovie (2006) refers to the integral environment system in the western one which represents a simplification of linear and bipolar structure in terms of space and time(Markovie, 2006). This drives the research to look into the differences between the eastern and western thinking models.

In the review of the sustainable development evaluation framework based on the philosophical structure, the following categories are identified: Circular and spectra categories, holorchy which is often associated with the integral theories, and other novice forms, such as PRISM and pyramid (Figure 1). Table1 Summarize the aims and limits of the theories.

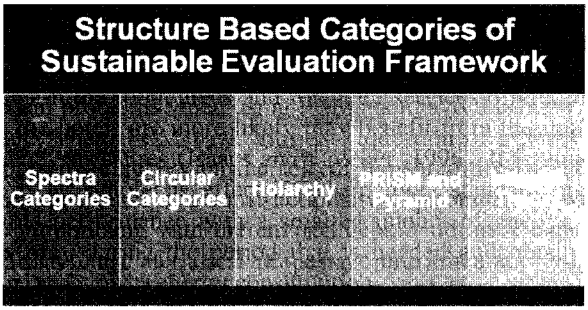


Figure 1: Identified categories of sustainable development evaluation framework

Circular categories include the complementary relationships and feedback loop. The later models, take Pressure -State-Response model (PSR) for instance, allow for a better inclusion of non-environmental variables. But there are problems of compatibility when the model components are simple, and actual situations are more complex. The former models assume that parts could be substituted for each other, and that improvement in one area would compensate for degradation in another (PCE, 2002), such as Weak Sustainability' Model and the Philips' Physical – Functional – Institutional – Cultural model. The limits of the complementary relationships include the failure for acknowledging the ecological constraints that humans, other species, markets, policies and developments must operate within, and the inclination to put the main priority at the health of the economy (Humphrey et al, 2002). It has been pointed out that sustainable development based on the pursuit of economic efficiency and ecological pragmatism only slows down ecological and social degradation rather than reverses it (Knight 2000). Philips (2003) discovers the potential of the four constituent parts to be a holistic model by describing them as integrated and interconnected, holding and pulling each other into a state of balance. However the difficulty to identify the rules under the management of indicators and their quantifiability constrains its full potential.

Table1: Summary of the aims and limits of the theories

Type	**Tri-modalities of Circular Categories**		**Quadra-modalities of Circular Categories**		**multi-modalities of Circular Categories**	
Name	Weak Sustainability' Model(PCE, 2002)	The PSR Model (OECD indicator model)	PICABUE (I Cooper, 1997)	Physical – Functional – Institutional – Cultural	Pentagonal Model (Nijkamp, 1998)	Quantifiable City Model (May 1997)
Aim	This model shows that economy, society and the environment are competing interests, but environmental and social problems can always be solved if the economy is sound (Lowe, 1998). This means this model assumes that parts could be substituted for each other, and that improvement in one area would compensate for degradation in another (PCE, 2002).	The Pressure (or Driving force, as in the UN Commission for Sustainable Development (UNCSD)) -State-Response model (PSR) model allows for a better inclusion of non-environmental variables. The PSR model is sufficient for practical purposes at most cases.	Equity: concern for today's poor and disadvantaged. Futurity: concern for future generations Public participation: concerns that individuals should have an opportunity to participate in decisions which affect them. Environment: concern to protect the integrity of eco-systems.	Philips defines sustainable place as a place which, through natural or man-made attributes, is able to foster conditions physically, functionally, culturally and institutionally that prolong and nurture life-generating forces for man. The four constituent parts are integrated and interconnected, holding and pulling each other into a state of balance that is part of the holistic nature of sustainable development.	It aims to identify critical success factors influencing the introduction of renewable energy technologies; It also aims at socio-economic vitality and revitalizing the historical parts of the city in sustainable way.	It is to aid policy development and test for research ideas in the city of Leeds (UK).
Limits	The weak sustainability model fails to acknowledge the ecological constraints that humans, other species, markets, policies and developments must operate within (Humphrey et al. 2002). Besides, the main priority in this model is the health of the economy, which is been pointed out that sustainable development based on the pursuit of economic efficiency and ecological pragmatism only slows down ecological and social degradation rather than reverses it (Knight 2000).	There are problems of compatibility when situations are more complex; the underlying economic trends need better description. Because of above limit, the indicator community has formulated the Driving force – Pressure – State – Impact - Response model, which includes P-S-R as special cases.	As the early stage of BEQUEST	It is difficult to identify the rules under the management of indicators and the quantifiability.	It's limited on the assessment of urban policy interventions	The "urban metabolism" and "quality of life" are all popular terms in sustainability with complex components and processes themselves.
Type	**Holarchical Relationship**		**PRISM and Pyramid**		**Integral Theory**	
Name	Strong Sustainability Model (PCE, 2002)	3-Q Model	The Prism of Sustainability	Sustainable Community Indicators (Hart, M. 1999, p.16)	Lovelock's Gaia theory	Wilber's integral map of reality (Wilber 2000c)
Aim	Strong sustainability requires ecological thinking to be integrated into all social and economic planning (Lowe, 1998). It recognizes that economy is a subset of human society, and they are constrained within the capacity of the natural system (PCE, 2002) (Lilley, 2006).	The 3-Q Model: Quality Integration for Urban Sustainability. The 3-Q Model appeared in the BEQUEST workshop info sheet. In this model, all aspects are nested into each other.	An ethical framework to rationalise social actions and act as a filter for appropriate sustainability indicators. The four corners and six edges are all one single or combinational modality.	Maureen Hart suggest that Built and financial capital, Human and social capital to be diagrammatically organised as a pyramid.	Physiosphere-Biosphere-Physiosphere (Wilber 2000b). Human cultures must obey the rules of both the physiosphere and the biosphere. the noosphere transcends and includes the biosphere	It recognises four different categories of methods for understanding or constructing reality: objective (or behavioural), interobjective (or systemic), subjective (or psychological) and intersubjective (or cultural) methods in the giving the four(Riedy, 2005) .
Limits	Without the relationships and dependencies the 'Strong Sustainability' model represents, it can be misinterpreted as showing the economy at the centre of decision making, with ecological considerations being less important and peripheral.	Quality of life is dependent on the other qualities. It should be noticed that, each modality in this model require a complex of indicators to evaluate.	The PRISM is not fully developed of its potentials. The four extremes are basically still western's perception of the world. The four faces need to be explored, especially on their gradual meanings.	The term 'capital' which is commonly refers to money and material goods.	As the Wilber's integral map of reality, this theory perceives human mental world to beyond everything including the environment. A typical ideology of mentalism	Wilber's integral theory is only interested in the human mental world. There are still problems not solved for its adaptation to the sustainable development.

There has been a trend to enrich the components of the circular models from eastern knowledge. The PRISM includes an institutional dimension with the moral imperative of sustainability emphasised (PRISM and Knight, 2000). UN Habitat II (1996) also accepts a hex-modalities structure to include ethical and spiritual dimension, which is much treasured by the eastern philosophies, especially in the Confucianism which stresses the humanity's relationship and moral. In the absense of the moral dimension, which is one of the principles of confucianism, will make the sustainable development incomplete.

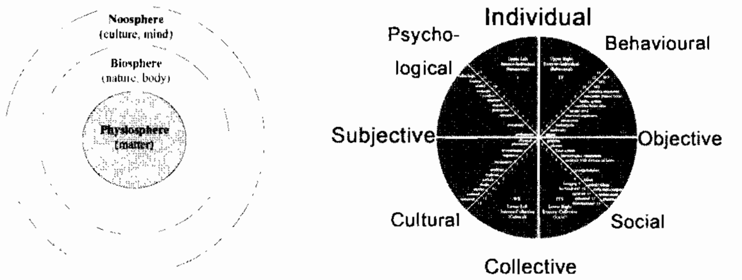


Figure 2: The holarchic relationship and Integral Theory (Wilber, 2001)

A 'holarchy' is a hierarchy of holons in which each 'higher' level in the hierarchy transcends and includes the previous levels(Riedy, 2003). Holarchical models like strong sustainability requires ecological thinking to be integrated into all social and economic plan (Lowe, 1998). It recognizes that economy is a subset of human society, and they are constrained within the capacity of the natural system (PCE, 2002) (Lilley, 2006). But without the relationships and dependencies the 'Strong Sustainability' model represents, it can be misinterpreted as showing the economy at the centre of decision making, with ecological considerations being less important and peripheral. According to the diagram of Dooyeweerd's framework, each modality affects and informs those above. The second, the greater the distance between the ordered modalities the less influence they have on each other. And the third feature is that the modalities are nested within each other thus providing continuity. This theory is contributing for revealing the complexity of an urban environment as a system and its multi-dimensional meaning (Lombardi, 2001).

Holarchical Relationship is especially preferred by the integral theorists. Wilber's map of reality integrates the different ways of knowing that humans have discovered or developed over the course of human history (Wilber 2000a, 2000b, 2000c, 2001). He seeks to include objective and subjective knowledge, individual and collective knowledge, scientific and spiritual knowledge and Eastern and Western knowledge within a coherent framework that finds room for all (Figure 2). Integral theory recognises four different categories of methods for understanding or constructing reality: objective, inter-objective, subjective and inter-subjective methods in the giving the four(Riedy, 2005). As the Wilber's integral map of reality, this theory perceives human mental world to beyond everything including the environment. As a typical ideology of mentalist, Wilber's integral theory is only interested in the human mental world. There are still problems not solved for its adaptation to the sustainable development.

4 The spectrum of sustainability

Spectra categories represent the linear, ordinal categories, no loop. As to the two extremes of the linear sustainability, there are various opposing views available (Table2).

Table2: The spectrum of views on sustainability (Brandon & Lombardi, 2005) (Knight-Lenihan, 2007)

Weak sustainability	Strong sustainability
Conserve at all cost	Seek technical fix
Anthropocentric view	Anthropocentric view

The commonly 'weak and 'strong' sustainability actually correspond to two sustainability models. The weak sustainability model, as discussed before, goes to the left side of the shallow-deep ecology spectrum, and the strong sustainability model, goes to the other side.

In Brandon & Lombardi's illustration, the spectrum of views on sustainability is ended with 'Conserve at all cost' and 'Seek technical fix'. The former are those who suggest that we should conserve at all costs, change the way we live and seek a reduction in economic growth as a means of reducing consumption. The latter are those who believe that necessity is the mother of invention and a technical fix will be found which will remove the need fir such drastic measures to be taken. They believe the market will drive up the price of non-renewable resources and this in turn will encourage innovators to provide sensible alternatives(Brandon & Lombardi, 2005). This spectrum also displays a matter of weak or strong, as in the following O' Riordan's spectrum. 'Seek technical fix' corresponds to the somewhere between 'accommodators' and 'soft technologies'. 'Conserve at all cost' is the 'deep environmentalist' view which is also what we called 'Deep green'.

Anthropocentric-Ecocentric view is another way to generally depict the degree of emphasis put on ecological sustainability in terms of achieving sustainable development. It should be noticed that the above two-extreme spectrums don't imply a greater level of sustainability.

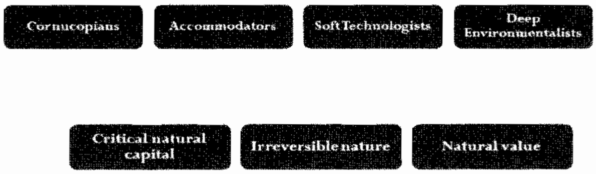


Figure 3: O' Riordan's spectrum (above) and Dobson's Typologies (below) (Dobson 1998), after the naming by Knight-Lenihan (2007)

O' Riordan's spectrum (1981), describes the individual beliefs that tend to be held by those supporting either a weak or strong position. Dobson's Typologies summarises the shift from an emphasis on assessing natural 'capital' for human benefit through to appreciating nature for itself. The typologies are listed under three 'conceptions' of what Dobson calls views on 'environmental sustainability'. Critical natural capital is what is required for the production and reproduction of human life(Dobson, 1998). And irreversible nature captures the idea of a shift away from seeing nature as providing capital, to the idea that what should be sustained are elements of non-human nature whose loss would be irreversible (Dobson 1998)(Figure 3). However, Dobson's Typologies don't include renewal, which in Knight-Lenihan's view, renewal is encompassed because ecological systems constantly change and replenish.

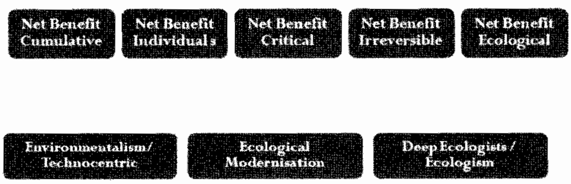


Figure 4: SD Assessment Framework (Knight-Lenihan , 2007)

The SD Framework is developed by Knight-Lenihan(2007) after the above typologies. It is used to assess how ecological issues are likely to be balanced against economic or social needs. The key aspects relating to different approaches taken to sustainable development emphasis differing views of nature and how it should be traded off where the left extreme assumes all natural capital can be traded off (Figure 4). The framework could help to make it clear that what approach will be taken towards ecological sustainability when compared with economic and social needs.

The summary of the above categories are listed in the table 3.

Table 3: Summary

[illegible]	**Circular Categories**	**Spectra Categories**	**Holarchy**	**Integral Theory**
	Physical-Social Environment (Enyedi 1996)	Anthropocentric-Eco-centric		
		Weak-Strong Sustainability		
	Economy-Society-environment	Dobson's Typologies	Economy-Society-environment	Sustainable community indicators(Pyramid)
	The PSR model		The 3-Q Model	
	Society-economy-environment		Physio-Bio-Noosphere holarchy	
	Environment Explorer	O' Riordan's spectrum(1981)		Integral Theory by Wilber
	Physical-Functional-Institutional-Cultural			
	PICABUE			
	Enyedi 1996			
	DPSIR model	SD Framework by Knight-Lenihan, S. (2007)		
	Techware- Socioware-Ecoware- Financeware-Orgware			
	Environment Explorer			
	WSUD		Dooyoweered' s theory	PRISM

The Spectra Categories are actually not measuring frameworks for sustainability. They are only a reflection on the attitudes that the individual or a framework holds. However, it represents a liner, reductionist thinking in the western philosophies. It is also lacked in most of the circular categories.

The circular categories are most common in current evaluation frameworks with different modalities. As the weak sustainability model represents, this category inclines to the views that all of the categorical modalities could compensate to each other's losses. While the holarchy, which is represented by strong sustainability model, mostly stresses the irreplaceable position of natural environment.

The integral theory, including the PRISM model has valuable attempts on the integration of the eastern and western thinking, circular and spectra structures. But Wilber's integral theory is only interested in the human mental world. There are still problems not solved for its adaptation to the sustainable development. The PRISM is not fully developed of its potentials. It still needs to explore the eastern way of thinking the universe, especially traditional Chinese understanding of the human-environment interface.

5 Searching for an indigenous approach in China

The Chinese worldview derived from Chinese philosophical traditions of Confucianism, Taoism, Buddhism, neo-Confucianism which are based on ideals of harmony, human perfectibility and systemic theory within natural systems and processes. In imperial times, institutional religions are various organic mixtures of Buddhism and Taoism within a Confucian framework (Jenkins, 2002).

Chinese traditions offer conceptual resources for ecological thinking by placing economics within a wider socio-ecological fabric, emphasising soft technologies, challenging meta-economic assumptions, and encouraging systemic wisdom(Goossaert & Keith, 2006).

5.1 Dominating philosophies in traditional China

Confucianism is a humanistic philosophy and socio-political doctrine with religious qualities (Yang, 1961). It involves a deep-rooted combination of political, moralistic and cosmological ideas which establish a philosophical basis for the inter-connectedness of all things in a unitary, holistic, dynamic and morally charged universe(Jenkins, 2002).

However, Confucianism is confined to human social questions rather than extending to an analysis of nature. The social ecology Confucianism promotes is 'anthropo-cosmic' view which reflects a view that human moral virtues have their natural counterpart in cosmic processes (Tucker and Berthrong, 1998).

The world consists of human activity and natural phenomenon in mutual interactions changing overtime. This is represented in both the Yin-Yang diagram of Taoism and also the integral environment system(Markovie, 2006). Taoism believes that there are 'natural laws' which are summarized as opposition, interdependence, inter-transformation, and dynamic between Yin and Yang (Figure 5).

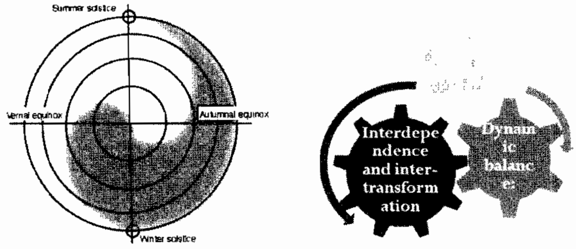


Figure 5: Taiji (Supreme Ultimate) and its 'natural law'

Yin and Yang consist of two stages of a cyclical, wavelike, and continually changing relationship. This is the law of opposition; Yin and yang are not inherently paradoxical since they can change into each other. This is the other law of Interdependence and inter-transformation. The last law is that the qualities of yin and yang counter and complement in oscillating flux. Taiji (Supreme Ultimate) is the expression of their unity, opposition and energy. So the dynamic balance explains the gradients on a scale of complete yin and yang (Bramble, 2003). Luo-Pan as the integrated tool for Taoist to assess the world could be divided into holarchic four modalities: central pool of heaven, earth, human and heaven. This is the traditional framework for ancient Chinese to evaluate sustainability. The indicators within the holons represent the circular movement and periodical recurrence.

Buddhism is the only non-indigenous member of the three chiao in ancient China. It is found that there are close links between Buddhist philosophy and systems theory. They are summarised as the synergies based on the nature of holism and the cyclical nature of communication and feedback loops. The key relational qualities are interconnectedness, interdependence and mutual conditioning (MacKee, 2008).

The three philosophies of Confucianism, Taoism, and Buddhism were formally synthesised in the philosophically eclectic neo- Confucianism. It avoids reductionism views which explain the whole only in terms of parts, focuses on organisational principle and understanding of systems, dynamics and tensions, and produces a supple conception of law with moral content.

5.2 Deep ecology and indigenous philosophy

Chinese indigenous philosophy and contemporary ecological perspectives share theoretical and practical approaches to the human-nature dialogue. Its notions mirror the aims of disciplines such as deep ecology, eco-feminism, and eco-psychology.

Deep ecology is an important turn and leading power in the course of contemporary environmental movement. It doesn't believe the science and technology could adjust the serious problems of the environment (Girardot, Miller, & Liu, 2001). Its thoughts reflect the development of modern ecology and change of the philosophic paradigms in recognizing the relations of man and nature.

Various narratives link Taoist texts and concepts to one another, and potentially inform Western religious and scientific perspectives (Birdwhistell, 2001). An examination of the Taoist and ecological notions of 'order' discusses how the notion of 'otherness' relates to a potential dialogue between Taoist mystical thought and ecological inquiry(Lafargue, 2001) (Kleeman, 2001). The nature and evolution of the Taoist notion of 'Central Harmony' is viewed as its self-evident relation to the interdependence of humans and nature (Lai, 2001; Zhang & Li, 2001).

Campany (Campany, 2001) discusses how westerners perceive ecological messages in Taoist texts, and how the folk religion component of Taoist traditions can be unscrambled in environmental language. Richard Sylvan and David Bennett address that Daoism could enrich the Deep Ecology theory from various aspects. Although deep ecology also acknowledges the organic unity of diversities, it lacks the cosmology behind it (Bennett, 1988).

It is suggested in the context of Chinese culture, the impacts of Confucianism and Taoism should be integrated. The Confucian social model will be a crucial biosphere to the ecological system. Therefore, there is tremendous potential for an indigenous Chinese environmental ethic based on ancient Chinese thought. The religions form people's attitudes towards nature (Tucker 1994). In regarding to the environment issues and social justice, Chinese Taoism and Confucianism separately contribute to the natural ecology and social ecology with emphasis on the harmony with nature (Callicott, 1994).

5.3 Sustainability evaluation framework

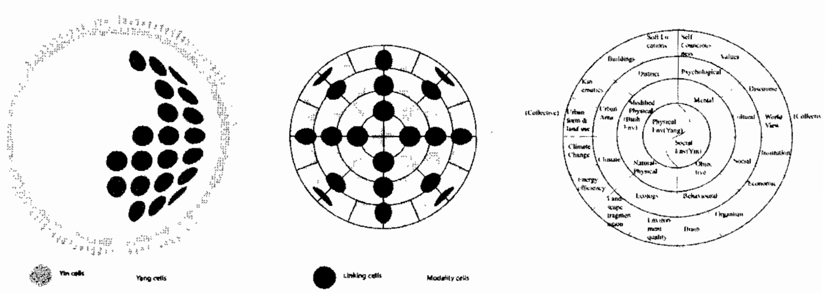


Figure 6: Holistic Sustainability Evaluation Framework for Asia-Pacific Regions

The framework above is embedded with the character of "ordinal loops" of traditional diagram 'Yin-Yang" that is suitable for sustainability evaluation framework for Chinese cities. In this framework the "ordinal" is represented in "individual-collective axis". "Loop" is represented in cyclical structure (Figure 6). The left diagram shows the hierarchical modalities. The middle one illustrates the dynamic changes between the human and environment interfaces. The right diagram displays the distinction between basic modalities and linking modalities.

The linking modalities which are on the rims of the cells include axis modalities and quadrant modalities. They are shown in the following table.

Table 4: Holistic Sustainability Evaluation Framework for Asia-Pacific Regions

Human Environment							-
Subjective Human Env				Objective Human Env			
Psychology	- --+	Culture	- -++	Society	- --+	Behaviour	-- --

Physical Environment							+
Natural Physical Env				Modified Physical Env			
Climate	+ +++	Ecology	+ +++	Land-use	+ +++	Kinematics	+ +++

The last diagram (Fig 7) shows the hierarchical contents of the basic modalities. The framework above is embedded with the character of "ordinal loops" of traditional diagram that is suitable for sustainability evaluation framework for Chinese cities. In this framework the "ordinal" is represented in "individual-collective axis". "Loop" is represented in cyclical structure.

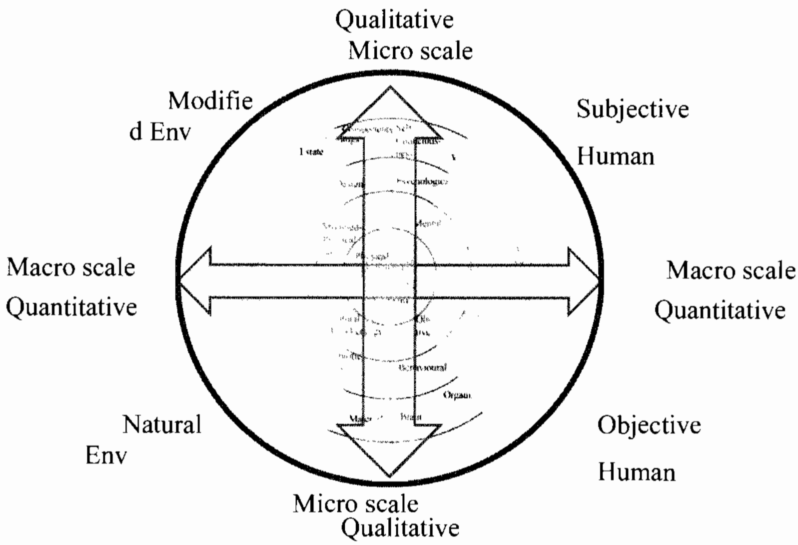


Fig 7: Holistic Sustainability Evaluation Framework for Asia-Pacific Regions

6 Discussion

The development of integrated theories shows that the western culture needs other's help from those who cherish nature, like the introduction of Eastern religious thought. In Asia, western science and technology are introduced to the east in the past century along with the danger of the unbalanced nature. Thus indigenous traditions are urgently recalled in respect for the nature. The construction of a theoretical framework towards an indigenous environmental philosophy can be applied viably to practical ecological issues that concern us today. There are western scholars and Chinese influenced by Western culture that have tried to derive theories from the Chinese classical works. However, whether an adulterated version of Taoism could be antithetical to resolving western forms of anthropocentric thinking and environmental issues is still questioning (Paper, 2001). Whether indigenous Chinese approaches could really work in the west is also not approved.

It is noted that there is insurmountable distance between the ancient Eastern philosophy and contemporary environmental issues from the history and culture. An overview of current Chinese environmental activities and the impact of the Taoist tradition in China provide reminders regarding the Taoism and contemporary environmental awareness (Miller, 2001a, 2001b; Zhang, 2001). John C. Cobb suggests that traditional Chinese view of nature did not stop the environmental destruction of ancient China, so the feasible approach is to amend the Western tradition, rather than transplant foreign ideas (Tucker, 1993). John Passmore rejects the learning from Eastern philosophy and religion, assuming that the eastern wisdom and value do not prevent environmental degradation in the East (Passmore, 1974).

Environmental problems are pressing so much. It is rather doubtable that any philosophy could heal the world. Deep Ecology could be more effective in the Western tradition; In China, the indigenous ecology should also be viewed holistically. Chinese environmental destruction and degradation has already indicated that the contemporary environmental problems are getting severe in China. It will be difficult to understand how the Chinese traditional ideal environment can be praised by their attitudes.

Scholars are cautious about the possible contribution of Chinese philosophy in case of the cultural transplantation, the effect of the eastern impacts, and the current environmental problems of China. They are more willing to rediscover their tradition by the inspiration of Taoism. Indeed, Taoist represents the perspective of only a small number of hermits, ordinary Chinese has been changing the in the environment in the long history(Tuan, 1968). What should also not be ignored is that all cultures have their own soil to grow so the world view and its tradition are hard to be separated. The model worked in the east may not be well adapted in the west. Cultural transplantation does not necessarily work for this sake.

So the indigenous Chinese model needs to be renovated to be utilized as tools for Asia-Pacific Regions, not for the whole world. But it could searched as inspirations for a reinterpretation of the traditional western approaches to reverse environmental degradation (Ames, 1990). The framework introduced in this paper provides one possibility. It still needs to be verified by the local urban practices in future research.

7 Conclusion

From the review on modern evaluation frameworks, different kinds of sustainability evaluation frameworks have been identified: one is in nominal loops, such as triangle (OECD, 1994), rectangle (Cooper, 1997; Phillips, 2003), pentagon (May et al., 1997; Nijkamp, 1998), hexagon (Engelen, White, & Nijs, 2003; UN, 1996), representative holarchy s is Dooyeweerd's theory for revealing the complexity of an urban environment as a system and its multi-dimensional meaning (Lombardi, 2001).

The other is in linear, ordinal categories, no loop (such as Weak sustainability- Strong sustainability (PRISM & Knight, 2000), an anthropocentric view- An eco-centric view, Dobson' s Typologies with a sequence of Critical Natural Capital—Irreversible Nature—Nature Value (Dobson, 1998), O'Riordan's spectrum "Comucopians---Accommodators—Soft Technologies—Deep Environmentalists" (O'Riordan, 1981), SD Assessment Framework "Net Benefit Cumulative—Net Benefit Individual—Net Benefit Critical—Net Benefit Irreversible—Net Benefit Ecological" (Knight-Lenihan, 2007). Each category has its strength and weakness because of their intrinsic characteristics.

The framework developed in this research will inherit the character of "ordinal loops" of Chinese traditional diagram 'Yin-Yang' that is suitable for sustainability evaluation framework. The result of this research will have significant implications, including: Providing internationally applicable approach for best practice in urban development and sustainable evaluation method which is based on the eastern way of thinking and the practice in Chinese cities; The conceptual process utilize the eastern thinking model into the organisation of sustainable development evaluation framework; Generating systemic recommendations by the systemic framework and combinational analysis method.

This paper also noted that the construction of a theoretical framework toward an indigenous environmental philosophy can be applied to current sustainable urban development issues in China and Asia-Pacific. However, its applicability in different cultural regions and local practice still needs to be tested. The future work is to further establish the qualitative criteria and quantitative indicators for evaluation and validate this framework by case studies on urban developments at different spatial scales of selected Chinese cities. The paper forms part of the first author's higher research degree literature review and conceptual process.

References

Ames, R. T. (1990). Putting the Te back into Taoism. In J. B. Callicott & R. T. Ames (Eds.), Nature in Asian Traditions of thought: Essays in Environmental Philosophy: Association for Asian Studies

Bennett, R. S. a. D. (1988). Taoism and Deep Ecology. Ecologist, 18.

Birdwhistell, J. (2001). Ecological Questions for Daoist Thought: Contemporary Issues and Ancient Texts. In N. J. Girardot, J. Miller & X. Liu (Eds.), Daoism and ecology : ways within a cosmic landscape (pp. lxxiii, 478 p.). Cambridge, Mass.: Center for the Study of World Religions Distributed by Harvard University Press.

Bramble, C. (2003). The architect's guide to Feng Shui : exploding the myth. Oxford: Architectural Press.

Brandon, P. S., & Lombardi, P. L. (2005). Evaluating sustainable development in the built environment. Oxford, UK ; Malden, MA: Blackwell Science.

Callicott, J. B. (1994). Earth's Insights: A Survey of Ecological Ethics from the Mediterranean Basin to the Australian Outback: Berkeley and Los Angeles: University of California Press.

Campany, R. (2001). Ingesting the Marvelous: The Practitioner' s Relationship to Nature According to Ge Hong. In D. L. Barnhill & R. S. Gottlieb (Eds.), Deep Ecology and World Religions: New Essays on Sacred Ground (pp. 308). Albany: State University of New York Press.

Cooper, I. (1997). Environmental assessment methods for use at the building and city scales: constructing bridges or identifying common ground? . In P. S. Brandon, P. L. Lombardi & V. Bentivegna (Eds.), Evaluation of the built environment for sustainability (1st ed., pp. xxiii, 568 p.). London ; New York: E. & F.N. Spon.

Dobson, A. (1998). Justice and the Environment: Conceptions of Environmental Sustainability and Dimensions of Social Justice. New York, USA: Oxford University Press.

Engelen, G., White, R., & Nijs, T. (2003). Environment Explorer: Spatial Support System for the Integrated Assessment of Socio-Economic and Environmental Policies in the Netherlands. Integrated Assessment, 4(2), 97-105.

Girardot, N. J., Miller, J., & Liu, X. (2001). Daoism and ecology : ways within a cosmic landscape. Cambridge, Mass.: Center for the Study of World Religions Distributed by Harvard University Press.

Goossaert, V., & Keith, B. (2006). China: Religions. In Encyclopedia of Language & Linguistics (pp. 324-328). Oxford: Elsevier.

Jenkins, T. N. (2002). Chinese traditional thought and practice: lessons for an ecological economics worldview. Ecological Economics, 40(1), 39-52.

Kleeman, T. (2001). Daoism and the Quest for Order In D. L. Barnhill & R. S. Gottlieb (Eds.), Deep Ecology and World Religions: New Essays on Sacred Ground (pp. 308). Albany: State University of New York Press.

Knight-Lenihan, S. (2007). A Critique of the Influence of Sustainable Development on Ecological Sustainability:A New Zealand Application. The University of Auckland

Auckland, New Zealand.

Lafargue, M. (2001). Nature as Part of Human Culture in Daoism. In D. L. Barnhill & R. S. Gottlieb (Eds.), Deep Ecology and World Religions: New Essays on Sacred Ground (pp. 308). Albany: State University of New York Press.

Lai, C.-T. (2001). The Daoist Concept of Central Harmony in the Scripture of Great Peace: Human Responsibility for the Maladies of Nature. In D. L. Barnhill & R. S. Gottlieb (Eds.), Deep Ecology and World Religions: New Essays on Sacred Ground (pp. 308). Albany: State University of New York Press.

Lombardi, P. L. (2001). Responsibilities toward the coming generation forming a new creed. Urban Design Studies, 7, 89-102.

MacKee, J. (2008). Sustaining Cultural Heritage in South and Southeast Asia: integrating Buddhist philosophy systems theory and resilience thinking to sustainable conservation approaches. Paper presented at the BEAR 2008 Building Resilience Conference.

Markovie, A. (2006). Feng Shui as a Tool For Spatial and Social Development Planning. Paper presented at the 2nd International Conference on Scientific Feng Shui and Built Environment 2006.

May, A. D., Mitchell, G., & Kupiszewska, D. (1997). The development of the Leeds Quantifiable City Model In P. S. Brandon, P. L. Lombardi & V. Bentivegna (Eds.), Evaluation of the built environment for sustainability (1st ed., pp. xxiii, 568 p.). London ; New York: E. & F.N. Spon.

Miller, J. (2001a). Daoism—A Vital Tradition for the Contemporary Ecological Consciousness. In D. L. Barnhill & R. S. Gottlieb (Eds.), Deep Ecology and World Religions: New Essays on Sacred Ground (pp. 308). Albany: State University of New York Press.

Miller, J. (2001b). Respecting the Environment, or Visualizing Highest Clarity. In D. L. Barnhill & R. S. Gottlieb (Eds.), Deep Ecology and World Religions: New Essays on Sacred Ground (pp. 308). Albany: State University of New York Press.

Nijkamp, P. (1998). Macro-Econmic Perspective (on SUD). Paper presented at the BEQUEST Workshop.

O'Riordan, T. (1981). Environmentalism. London: Pion Press.

OECD. (1994). Environmental Indicators. Paper presented at the Organization for Economic Cooperation and Development, Paris.

Paper, J. (2001). Daoism and Deep Ecology: Fantasy and Potentiality. In D. L. Barnhill & R. S. Gottlieb (Eds.), Deep Ecology and World Religions: New Essays on Sacred Ground (pp. 308). Albany: State University of New York Press.

Passmore, J. (1974). Man's responsibility for nature : ecological problems and Western traditions London Duckworth.

PCE. (2002). Creating Our Future: Sustainable Development for New Zealand. Wellington, New Zealand.

Phillips, C. (2003). Sustainable place : a place of sustainable development. Chichester: Wiley.

PRISM, & Knight, S. (2000). Sustainable Development in New Zealand: Here Today, Where Tomorrow? A discussion paper prepared by the Pacific Rim Institute of Sustainable Management and Stephen Knight for Sustainable New Zealand. . Wellington, New Zealand: Parliamentary Commissioner for the Environment.

Riedy, C. (2003). A deeper and wider understanding of sustainable development. Paper presented at the Ecopolitics XIV Conference: Greening Sustainability.

Riedy, C. (2005). The Eye of the Storm-An Integral Perspective on Sustainable Development and Climate Change Response. University of Technology, Sydney, Sydney.

Roberts, P. (2006a). Evaluating regional sustainable development: Approaches, methods and the politics of analysis. Journal of Environmental Planning and Management, 49(4), 515-532.

Roberts, P. (2006b). Evaluating regional sustainable development: Approaches, methods and the politics of analysis. Journal of Environmental Planning and Management, 49(4), 515 - 532.

Singh, R. K., Murty, H. R., Gupta, S. K., & Dikshit, A. K. (2009). An overview of sustainability assessment methodologies. Ecological Indicators, 9(2), 189-212.

Tuan, Y.-F. (1968). Discrepancies Between Environmental Attitude and Behavior: Examples from Europe and China. Canadian Geographer, 12(3).

Tucker, M. E. (1993). Religious Values Derived From Other Traditions: The Ecological Dimensions of Taoism and Confucianism. Dialogue and Alliance, 7(2c).

UN. (1996). Habitat II. Paper presented at the United Nations Conference for Human Settlement Istanbul.

Zhang, J. (2001). A Declaration of the Chinese Daoist Association on Global Ecology. In D. L. Barnhill & R. S. Gottlieb (Eds.), Deep Ecology and World Religions: New Essays on Sacred Ground (pp. 308). Albany: State University of New York Press.

Zhang, J., & Li, Y. (2001). Mutual Stealing among the Three Powers in the Scripture of Unconscious Unification. In D. L. Barnhill & R. S. Gottlieb (Eds.), Deep Ecology and World Religions: New Essays on Sacred Ground (pp. 308). Albany: State University of New York Press.

A Multidimensional and Participatory Approach to the Building Performance Assessment: Addressing the SBTool Model to Social Multi-Criteria Decision Analysis

Sergio Mattia[1], Alessandra Oppio[2], Alessandra Pandolfi[1], Matteo Ghellere[3]

[1] *Politecnico di Milano - D.I.A.P. (Architecture and Planning) Department, Italy*

[2] *Politecnico di Milano - B.E.S.T. (Building Environment Science & Technology) Department, Italy*

[3] *CNR-ITC, Italy*

Abstract

The development of complex decision making processes has encouraged the involvement of different stakeholders in the evaluation procedures and tools. Multicriteria evaluations are increasingly used in the assessment of the deliberative process, addressing research experiences and applications towards a new challenge: giving broader meaning and stronger consistency to the outcomes of the decision making process. It means to open the decisional arena to different groups with different points of view and to involve multiple weights systems in the multicriteria evaluation framework.

According to these general assumptions, the paper gives a critical review of the evaluation methods and tools developed in the field of the performance assessment of the buildings sustainability, starting from the procedures set by the Green Building Challenge (Gbc), with the purpose of *1)* pointing out strengths and weaknesses of the Gbc evaluation models and *2)* understanding the opportunities to adapt their evaluation framework to the principles of the deliberative multicriteria appraisal.

Keywords: *deliberation, multicriteria evaluation, building performance*

1 Introducing the framework of multicriteria evaluations in the decision making process

The Multicriteria decision aid (Mcda) methods have been significantly developed in the last thirty years, because of the increase of complexity and conflicts in decision making process (Bobbio, 2004). These techniques could be considered as tools that support stakeholders and shareholders involved in Decision Making (DM) to organize the available information and to analyze the effects of every single choice, exploring people expectations and minimizing the probability of failure of the final decision (Mattia, 2007). Moreover, recent delays of DM processes (first of all, concerning great interventions, as continental infrastructure networks and corridors) have pointed out the need of involving all the possible stakeholders and shareholders in the appraisal procedures (Bobbio, 2004); for that reason, the multidimensional assessment methods are increasingly applied as part of deliberative processes, launching research experiences towards the new challenge of giving broader meaning and stronger consistency to the outcomes of the decision making process.

Looking at the multicriteria decision aid systems developed for the multiple criteria decision making, it is possible to identify some common features (Mattia, 2007): *1)* the definition of different options to be analysed, starting from alternative criteria, *2)* the involvement of a wide range of stakeholders and shareholders and *3)* the concern for the uncertainty that forces the decision makers to assume a certain relativity about the process outcomes. For this reason, as it is widely acknowledged that the need for evaluation tools aiding complex decisions comes from the consciousness about uncertainty (Funtowicz & Ravetz, 1994), their most important requirement is the attention paid to the process, which should be as democratic and transparent as possible, to be able to face the problems of the legitimacy of multiple points of view (Proctor & Drechsler, 2006).

According to these general assumptions, in the last years the interest of the local administrations into the active involvement of citizens, stakeholders and shareholders in the decision making process, has also been experienced in several contexts, where the different initiatives impacted directly on the local communities (Bobbio, 2004; Proctor & Drechsler, 2006; Mattia, 2007). This trend points out the growing demand of advanced methodologies of public involvement in the different stages of the decision making process because of the lack of participatory infrastructures that would be able to promote an effective contribution of those social groups that are generally excluded from the decisions (Bobbio, 2004; Mattia, 2007) and because of the increasing mistrust in the capability of the actual economical development model to ensure a sustainable and fair future to the contemporary society as a whole (Mattia, 2007).

In this framework, the paper gives a critical review of assessment methods and tools developed in the field of the performance assessment of buildings' sustainability by the Green Building Challenge (Gbc) process – launched by

Natural Resources Canada in 1996 and managed by the International Initiative for a Sustainable Built Environment (iiSBE) in 2002 – in order to point out: 1) their strenghts and weaknesses and 2) to understand the opportunities to adapt their evaluation framework to the principles of deliberative multicriteria evaluation (Proctor & Drechsler, 2006). This analysis is followed by the proposal of updating the evaluation model proposed by the Gbc, starting from a critical interpretation of its more recent version (SBTool), referring to four fundamental issues: *1)* the evaluation process, *2)* the spreadsheets structure, *3)* the assessment criteria and *4)* the weights allocation. Finally, are included some notes about the relevance of the evaluation as support for decision-making processes.

2 The SBTool Model

Starting from the 90s, many different evaluation systems and tools of environmental performance assessment for buildings have been developed, as BREEAM in the United Kingdom, LEED in the United States (promoted by the US Green Building Council), ENERGY RATING in Denmark, ECOPROFILE in Norway, ECOEFFECT in Sweden, ESCALE in France, TOTAL QUALITY in Austria and the DGNB procedures in Germany. These tools are applied with the aim of facing the sustainability issues in the constructions sector with multiple different purposes, as *a)* combining the energy problems with economical and social concerns, *b)* enhancing relationships with urban plans, *c)* applying the appraisal procedures in the different stages of the building life-cycle, *d)* including the urban context and the site features in the evaluation, *e)* involving different stakeholders and shareholders (as designers, evaluators, users, investors and researchers) in the deliberative and evaluative phases and *f)* promoting the performance approach instead of mandatory ones (Oppio, 2002; Bianchi, 2007). It is important to remark that most of these earlier examples of assessment systems did not pursue all of the objectives previously mentioned at the same time. Furthermore, the environmental evaluation and certification systems could be divided into two principal categories: *a)* the eco-balances, applied to assess the environmental effects of the building process, and *b)* the multicriteria systems, based on the attribution of scores, that measure the extent to which the requirements used by tools to appraise the sustainability of building are met. These last ones generally include not only the environmental dimension of sustainability, but also the social and the economic issues.

In this context, the most significant tool is the *Sustainable Building Tool* (SBTool), that is the most recent development of the *Green Building Tool* (GBTOOL, 2KV1.81). The importance of this tool is given from its capability of considering crosswise the sustainability issues previously listed according to a broad multidimensional perspective. Anyhow, SBTool and GBTool are not the only tools that systematically faces the sustainability matters; other examples of sustainable assessment tool that try to deal adequately with the complexity of this issue are the previously mentioned LEED (Leadership in Energy and Environmental Design) and its neighbourhood assessment version or the ITACA protocol in Italy in its different regional specifications and uses.

Unlike the most widespread evaluation methods for the environmental sustainability, SBTool, as its previous version (GBTool), pays significant attention to the opportunity of seizing the assessment framework to the features of the local context. As a matter of fact, the requirements system could be considered as a general framework that allows the local organizations involved in the *GB process* to develop one or more rating structures that suit the characters of their own regions and areas.

The most recent version of the software configures the building performance assessment in a hierarchical system, using three progressive detail levels: *1.* Evaluation issues; *2.* Performance categories; *3.* Criteria. The criterion is the single performance parameter and, therefore, it is the lowest evaluation level in the hierarchy; the category is the intermediate appraisal stage, whereas the evaluation issues are the most general assessment ranks. This last level includes seven thematic areas, each one divided into performance categories and criteria, both quantitative and qualitative: *A)* Site Selection, Project Planning and Development; *B)* Energy and Resource Consumption; *C)* Environmental Loadings; *D)* Indoor Environmental Quality; *E)* Service Quality; *F)* Social and economic aspects; *G)* Cultural and Perceptual aspects.

Referring to the assessment stages, as in the previous version of this tool, the evaluation process is based on the importance assigned to different parameters; moreover, the performance analysis could be applied to four fundamental phases: Pre-design, Design, Construction or Operations. According to the long-term perspective for the sustainable development, the tool provides a group of specific requirements for the operating period. Furthermore, SBTool can be applied mainly to three different building types (out of a total amount of 18) separately or in a mixed-use project and both to new or existing constructions. More in depth, the appraisal process consists of the following stages: *1)* selection of the assessment criteria with reference to different building types and to life cycle phases (*assessment checklist*); *2)* weighting the three levels of analysis, evaluation issues, performance categories and criteria (*weighting*); *3)* definition of the benchmark parameters (*benchmarking*); *4)* final assessment, referred to the previously defined benchmarks (*assessment*); *5)* report of the final relative and absolute performance results, respectively represented by a spider web diagram (describing the sustainability level achieved in each of the 7 issues) and by twelve sustainability indicators, called Environmental Sustainability Indexes (*results*).

Weighting and benchmarking are two fundamental stages of the evaluation process. There are two weighting systems according to the different tool levels: *1)* the evaluation issues or the performance categories and *2)* the criteria. At the first level, weights go from 1 (that represents the lowest importance) to 5, except for issues and categories considered as *Mandatory*: in these cases, it must be assigned a weight that is higher than 3. The default weighting system gives the main importance to the environmental issues, assigning to it an higher weight for the Energy and Resources consumption, for the Environmental Loadings and for the Indoor Environmental Quality. At the second level, it is possible to select the criteria to be included in the evaluation. In order to make the weighting process as impartial as possible, a score from 1 to 3 should be assigned to each criterion, referring to the extent (global or regional; urban or neighbourhood; building or site), the intensity (strong or direct; moderate or indirect; weak) and the duration (more than 50 years; more than 10 years; less than 10 years) of potential effects and impacts on the environment.

Concerning the benchmarking, the tool provides for a worksheet for each evaluation issue. Benchmarks could be expressed as numerical values or in text form and, although these standards could be both qualitative or quantitative, the performance values are fixed on a scale that ranges from -2 to 5, where -2 represents an extremely negative performance, 3 relates to a good construction practice and 5 is the best building procedure. The 0 value represents the lowest acceptable performance level, generally (but not always) defined by regional regulations and constructions standards. As this performance scale could vary according to the different features of the context in which the tool is applied, it is required that a third party subject sets the performance levels.

In order to give transparency to the evaluation process, for each criterion the tool provides for a sheet that specifies the step of the building life cycle in which it could be applied, the intent, the indicator, the assessment method and the performance values scale. As it is possible to apply the evaluation procedure to different steps of the building life-cycle, SBTool can be considered contemporarily as an *ex-ante*, an *in itinere* and an *ex-post* evaluation tool, that allows the evaluators to verify the consistency of different project options for the intervention purpose, defined with reference to the benchmarks and to the features of the local context, in order to manage the entire construction process, from the options selection (Pre-design; Design) to the control of the energetic and environmental performance in the operating step. The comparison between initial requirements and operating results is undoubtedly meaningful for the improvement of the phases of programming, designing, constructing and managing buildings during a long-term period, but it is not enough to ensure the quality of the construction process and products. As a matter of fact, the initial requirements could not be achieved all together in the best way and at the same time: the absolute best solution is an illusion that a real Multicriteria decision making (Mcdm) process should avoid, searching for the most acceptable and efficient compromise (Mattia, 2007), that is the only possible solution for problems with many different, multiple and sometimes conflicting objectives. The choice of the most satisfactory option could be done with reference to the performance acceptability limits, defined by technical regulations, or to the range between the minimum and maximum value of the performance itself, or to the concept of the marginal utility of economic goods (Bentivegna, 1987).

In this perspective, it is clear that one of the most relevant characters of SBTool is its transparency: the involved actors are numerous and heterogeneous (stakeholders or not) and, first of all, the worksheets compilation should be independent, so that they will not influence the one each other. For that purpose the file *PROJECT ASSESS* enables the control of all the inputs entered from designers by the side of an evaluator, that does not have any role in the project and, then, no potential interests in addressing the outcomes of the appraisal procedure. The general character of the evaluation framework and its adaptability are other meaningful features. Authorized evaluators can replace the general weights and benchmarks provided by the tool with their own system, ensuring that the appraisal will be relevant for their specific local conditions. Consistently to the key principles of the sustainable development – promoting specific actions for the local dimension, considering at the same time their broader impacts – this attention for the tool suitability to the regional context of the building represents the strength, that makes SBTool preferable to the previous assessment methods.

3 Critical analysis of the Evaluation Model

After the description of the relevance of Mcda and Mcdm techniques in the decision making process and the description of the SBTool's features, the paper examines the current version of the evaluation system, whose improvement could increase the importance of using it as a tool that could support the decision making process for designing sustainable project options. The paper does not run upon the several and significant positive features of the tool, as they are considered as known. Instead, the critical review of the evaluation model is provided to underline the usefulness of this tool and to identify the limitations that could be solved to obtain a more effective and efficient tool from the point of view of the social and economic matters.

The first criticism of the software is the lack of analysis of social and economical issues, that represents, with the environmental matters, the three principal pillars of sustainability.

Moreover, the SBTool evaluation process allows the evaluators to seize the weights system to the specific conditions of the project (through the file *PROJECT SETTING*), even if exclusively considering the environmental issues (that are described in details through regional and local context criteria). Therefore, the adjustment of the weighting system is considerably significant, when it is applied to environmental issues (energy consumption, polluting emissions and so on), whereas it is not meaningful for social and economic criteria, like, from one side, perceptual matters and cultural topics, or, to the other side, costs and revenues. Although SBTool evaluates the economical and social sustainability variables (in the thematic areas concerning the Social and Economical aspects, the Cultural and Perceptual aspects – and partially – the Service Quality), socio-economic data about the context are not required, on the contrary of the environmental information. As a matter of fact, sustainability evaluations should consider even the regional governance system, the relationships that exist between the different actors involved in the project and which are the deliberating subjects and how they could decide about alternatives of public interest: all this information is not currently available in SBTool and the model's update has taken it into account.

Another critical point of the assessment structure is that it is strictly linked to environmental and energy issues. The lack of a special attention to the social dimension concerns essentially to the following issues: exclusion of the project stakeholders contribution in the weighting and in the criteria selection phases and the lack of transparency in the choice of weights of issues and performance categories. In order to guarantee a decision-making process open at least to the most important stakeholders, it is necessary that the evaluation system and, then, even the weighting phase would be developed in the wider involvement of the actors that could be directly or indirectly interested in the project. At this level, the actors contribution could be active (providing resources, knowledge and similar inputs about the economical, environmental and social issues) or passive (considering only effects and impacts on the subject). The evaluation system should convert in objective terms (e.g. in numeric values) all the previous issues, in order to give a proactive and effective contribution, even from the social point of view, to the weighting of each SBTool parameter. For the purpose of identifying the key actors in the decision making process, it is possible to use the stakeholder and shareholders analysis, a process that allows the evaluators to involve different interested groups, enabling the identification of institutions and relations which, if ignored, can have negative influence on projects and policies or, if considered, can be built upon to strengthen them. At this end, it is to be pointed out that the actual version of the evaluation system prevents even non institutional actors from expressing preferences and opinions related to the project appraisal. The third party subject, that should select the parameters' weights, as well as being neutral, should have technical capabilities, cultural knowledge and decisional independence, in order to be able to select parameters' values in a way that is as fair and impartial as possible. For these reasons, citizens are not involved in the evaluation stages. That is why the PROJECT SETTING file can be considered a weakness point of the tool, because weights are not selected by non institutional subjects.

The lack of transparency in the weighting phase is a significant critical element even for the evaluation structure. As a matter of fact, the SBTool worksheets are filled separately from three different subjects. Only one has the duty of choosing the weights of all the parameters used in the assessment structure. As well as the criteria are defined exclusively by a single actor, the percentage of weights are identified on the basis of reasons that are not openly described. As it is applied at the criteria level, the quantitative evaluation of effects on the context ensures a minimum degree of transparency and objectivity, therefore even weights of the evaluation issues and of the performance categories should be assigned according to more general matters, as urban development policies, strategies and plans.

Between the weaknesses, it is pointed out the length of the whole evaluation procedure, that depends on the project complexity and on the number of criteria to be assessed. The collection of data about the emissions of single combustibles used to define the Primary energy factor, for example, requires quite long time, that could be minimized only by the quantity and the quality of available documents and reports.

Finally, SBTool is affected by some methodological problems, as the arbitrariness in the mandatory criteria selection and the strictness of the distribution of the weights of criteria into multifunctional projects. As afterwards described, in order to guarantee a minimum sustainability level of buildings' performance it's necessary to identify minimum thresholds to be respected according to different uses. Moreover, SBTool does not allow to differentiate the contribution of every use in the total score achieved by a project. The problem is increased when the intervention to be assessed includes more than one use, different buildings and open spaces.

4 Addressing the SBTool Model to a Social Multi-Criteria Decision Analysis (Smcda)

From the previous analysis it is outlined that it is necessary to modify the current version of SBTool's evaluation framework. The most obvious criticism comes from the weighting phase that, as previously described, has a central role in the evaluation process. More in depth, the research has tried to solve the followings weaknesses: the limited development of the weights' assignment by comparison with the other steps of the assessment process and the stakeholders, shareholders and users exclusion from the decision-making process. It is meaningful, therefore, to open the weights selection stage, according to specific participation rules, in order to make the weighting determination process as shared and transparent as possible. At the same time, the parameters selection stage should be modified to promote the involvement of stakeholders and shareholders (even not institutional).

In this context, a different evaluation process is proposed, in order to solve the principal weakness points of the current software version. In the evaluation procedure shown afterwards, the weights of parameters are defined according to objective and subjective preferences. At this purpose, has been used these evaluation techniques: the stakeholders analysis (Jacobs, 1996; Schmeer, 1999; Bryson, 2004; UE-Cespi, 2007), the stakeholders consensus analysis (Elgizouli et al., 2005) and the impacts evaluation (Leeuw & Vaessen, 2009). In this sense, the context analysis has also been developed, including new social and economical indicators:

1) *energy intensity* (Mwh/€): connection between energy consumptions and Gross domestic product; this indicator represents a productivity factor of the energy resources use and it is associated to five SBTool classes (Enea, 2005): A (Site selection, Project and Urban development) – Project category; B (Energy consumption and resources) – Renewable energy consumption and Non-renewable energy consumption categories; C (Environmental loadings) – Greenhouse effect gases emission and other atmospheric emissions categories; E (Service quality) – Verifiability, flexibility and adaptability and Operational

performance maintenance categories; F (Social and economical issues) – Economical matters category;

2) *Number of renewable energy system* (number): number of systems using renewable energy resources in the reference context; this index is related to the classes named A – Project category, and B – Renewable energy class;

3) *Crime rate* (number): number of violent crimes (slaughter felonies, fraudulent homicides, infanticides, manslaughters, attempted homicides, fraudulent lesions, sexual assaults, kidnappings, bombings and incendiary attempts, more or less serious robberies) for 10.000 inhabitants, relating to SBTool classes (cf. Istat data) named E – Operational phases safety category, and F – Social matters class;

4) *Poverty range* (%): the incidence of relative poverty calculated as the connection between families (and the number of people in families) with the family equivalent consumptions lower than the poverty line and the total number of inhabitant families (and people); it is referred (cf. Ires and Sisreg data) to the F thematic area in all its categories;

5) *Family per capita Gross domestic product* (Euros): the Gross domestic product referred to market prices is the final result of the productive activities of the resident units and it is the sum of the values added to activities market prices, decreased from the credit services and increased of Vat and indirect export taxes; this indicator is associated to the SBTool class (cf. Ires and Sisreg data) named F – Economical matters category;

6) *Families that state to have at least a problem* (scarce luminosity, seepages, crumbling frames or floors) *in their house for 100 families* (%): calculated in percentage of families that encounter troubles concerning the lighting, water resistance and construction components quality (frames, shutters, floors and so on). This parameter could be used only for the appraisal of residential interventions and it is associated to the classes (cf. Istat data): B – Non-renewable energy consumptions in the life-cycle and Potable water categories; E – Verifiability, flexibility and adaptability and Operational performance maintenance categories; F – Economical matters category

7) *Families average monthly expenses for furniture, household electrical appliances and house services* (Euros): the monthly operating average expenses of a family for facilities and services; this parameter could be used only for the appraisal of residential interventions and it is connected to the classes (cf. Istat data): E – Verifiability, flexibility and adaptability category; F – Economical matters category;

8) *Housing space* (square meters): the available space expressed in square meters per occupier in houses; this parameter could be used only for the appraisal of residential interventions and it is referred to the classes (cf. Ires and Sisreg data): E – Efficiency category; F – Social matters category.

Still referring to the context analysis, in order to outline a detailed framework of the possible connections between context indexes and evaluation criteria, an objective tree for every specific thematic area has been created: in this case the hierarchical structure of SBTool in thematic areas, categories and criteria has made it easier, because the "branches" of the objective tree were previously organized. For each criterion up to 3 context indicators have been identified. The relevance of each indicator is given by the percentage of criteria that it influences on the total number of criteria for any evaluation issue. Therefore, the context analysis process has been developed through the following stages: *1)* benchmarking, *2)* context performance indicators calculation, *3)* scores assigning. Once all indicators have been calculated, the sustainability level of the context, with reference to the SBTool thematic areas, is obtained. About the scores assigning step, it is important to consider that the context analysis contributes for the 50% to the weight of each evaluation issue: 50 scores are automatically distributed among them, proportionally to their non-sustainability level. More in depth, the mathematical formula describing this distribution rule of the scores is:

$$P_i = \frac{S_r - S}{\sum_i^6 (S_r - S)} \cdot 50$$

where P_i are the scores assigned to the i-th evaluation issue, S_r the reference sustainability level for the i-th evaluation issue and S_i the context sustainability level of the i-th evaluation issue.

The criteria impacts analysis is applied in order to evaluate the effects of evaluation factors on the context. This kind of analysis is already available in SBTool, but the inclusion of a subjective component in the decision making process – the stakeholders – introduces significant changes to this appraisal stage. The modifications involve the measurement scale of the impact factors: whereas in the current SBTool version the impacts are assessed by numerical values (e.g. the range in km, the duration in years) that some times could be misleading, in the implementation proposal of the tool they are assessed by a qualitative scale. Referring to the impact duration, for example, coherently to the sustainability concept and with the Life-cycle approach, the Life-cycle stages (design, construction, operation and dismission) have been considered instead of the number of years. Thus, the main phases of the impact analysis are: *1)* single components evaluation for the impacts of criteria (range, intensity, duration), *2)* analysis of the contribution of each criterion, *3)* score assigning.

The weighting construction for each single parameter is then developed in this sequence: *1)* Decisional stakeholders opinions: weights in the SBTool system are distributed between thematic areas, categories and criteria; *2)* Non decisional stakeholders opinions, involving thematic areas and categories; *3)* Context, that refers to thematic areas; *4)* Criteria impacts.

After these analyses, the weight of each single parameter has been developed as described. It is essential to consider separately the different evaluation levels, because in every stage 100 scores are distributed proportionally to preferences resulting from the previous analysis. At the evaluation issue level, the final weights are given by the sum of the scores assigned according to the comparison between the stakeholders opinions (50 scores) and the context analysis outcomes (50 scores). The performance categories weights, instead, are obtained by the scores got through the comparison between the stakeholders preferences (100 scores). Finally, the weights of every single criterion have been defined by the sum of the scores achieved by the Decisional stakeholders preferences (50 scores) and by the impacts analysis (50 scores).

It emerges thereby that the weights at different levels are given, except for the performance categories, from the crossing evaluation of subjective (stakeholders) and objective (context and criteria impacts) preferences. This system guarantees an equilibrium between the stated judgements.

Conclusions and future developments

Despite is not possible to points out relevant insights given the few application of this version of the evaluation tool restricted into an academic context, the process suggested to solve the current criticisms of SBTool in a social Mcdm, is coherent with the purposes highlighted in the critical analysis of the evaluation model. Integration between multicriteria analysis and participation methods has been particularly taken into consideration, in order to strengthen the iterative and interactive character of the appraisal process. Actors involved in the decision making process are able to assume final decisions consciously because of the opportunity of verifying the impacts of their choices according to the available information and their expectations into a transparent evaluation framework. In this perspective, the implemented tool, as previously described, could be considered as a sort of decisional multicriteria analysis, depending on its own relevance in the improvement of decision making capabilities improvement, since it makes explicit, rational and efficient the selection between multiple and/or conflicting goals. In this context, assessment is considered as an explorative and constructive activity, based on the use of specific procedures and techniques, in order to verify the level of needs satisfaction in a local context, to activate knowledge and reflection on the process and on the project outcomes, contributing to improve the transparency and to strengthen the legitimacy of the taken decisions (Munda, 2004).

References

Aa.Vv. (2004). *Libro Bianco, Energia, Ambiente*, Edificio, Milano: Il Sole 24Ore.

Bentivegna, V. (1987). *Insediamento residenziale. Criteri, norme e indirizzi per la pianificazione e la progettazione*, Firenze: Alinea.

Bobbio, L. (2004). *A più voci,* Napoli: Edizioni Scientifiche Italiane.

Batteau, P., Jacquet-Lagréze, & E., Monjardet, B. (1981). *Analyse et Agrégation des Préferences dans les Sciences Sociales*, Paris: Economica.

Beinat, E., & Nijkamp, P. (1998). *Multicriteria Analysis for Land-Use Management*, Dordrecht: Kluwer Academic Publisher.

Bresso, M., Gamba, G., & Zeppetella, A. (1992). *Valutazione ambientale e processi di decisione: metodi e tecniche di valutazione di impatto ambientale*, Roma: NIS.

Bryson, J. M. (2004). *What to do when Stakeholders matter*, Public Management Review, 6,1, (21 – 53).

Elgizouli, I., Nagmedlin, G., Fernandes, M., & Dougherty, B. (2005). *NAPAssess: A Decision Support Tool for Use in the Sudan NAPA Process*. Presented at the United Nations Climate Change Conference (COP 11), Montreal, Canada. November 28-December 9, 2005.

Ente per le Nuove tecnologie l'Energia e l'Ambiente (ENEA) (2005). *Rapporto energia-ambiente 2005*, Roma: Enea.

Funtowicz, S.O., & Ravetz, J.R. (1994). The worth of a songbird: Ecological economics as a post-normal science, *Ecological Economics*, 10, 197–207.

Jacobs, S. (1996). *Stakeholder Analysis: methods and concepts. Slide Presentation and Notes for Workshop Series on Participatory Tools*, Washington, D.C.: World Bank.

Leeuw, F., & Vaessen, J. (2009, December). *Impact Evaluations and Development: NONIE guidance on impact evaluation*, Network of Networks on Impact Evaluation (NONIE), Retrieved December 2009, from http://www.worldbank.org/ieg/nonie/guidance.html

Lichfield, N., Darin-Drabkin, H. (1975). *Land Policy in Planning*, London: Allen and Unwin.

Malczewski, J. (2000). *GIS and Multicriteria Decision Analysis*, London: Jonn Wiley & Sons.

Mattia, S. (1993). *Progetto, qualità, decisione*, Bergamo: Over.

Mattia, S. (2004). *L'ambiente, la città, i valori*, Milano: Spirali.

Mattia, S. (2007). *Costruzione e valutazione della sostenibilità dei progetti*, Milano: FrancoAngeli.

Moro A. (2006). *Architettura, urgenza, sostenibilità*, Milano: Empirica.

Munda, G. (2004). Social multi-criteria evaluation: Methodological foundations and operational consequences, *European Journal of Operational Research*, 158, 662–677

Nijkamp, P. (1977). *Theory and Application of Environmental Economics*, Amsterdam: North Holland.

Nijkamp, P. (1979). *Multidimensional Spatial Data and Decision Analysis*, London: Jonn Wiley & Sons.

Nijkamp, P., Rietveld, P., & Voogd, H. (1990). *Multicriteria Evaluation in Physical Planning*, Amsterdam: Elsevier.

Nijkamp, P. (1989). Multicriteria Analysis: A Decision Support System For Sustainable Environmental Management, in F. Archibugi & P. Nijkamp (Eds.), *Economy and Ecology: Towards Sustainable Development*, Dordrecht: Kluwer Academic Publishers.

Oppio, A. (2002). La sostenibilità ambientale nel settore delle costruzioni, *Quaderni di Diritto ed Economia del territorio*,1-2.

Proctor, W, & Drechsler, M (2006). Deliberative multicriteria evaluation, *Environment and Planning C: Government and Policy*, 24, 169-190.

Rietveld, P.(1980). *Multiple Objective Decision Methods and Regional Planning*, Amsterdam: North Holland.

Roy, B. (1985). *Méthodologie multicritère d'aide à la décision*, Paris: Economica.

Schmeer, K, (1999). Stakeholder Analysis Guidelines, in *Policy Toolkit for Strengthening Health Sector Reform*, Bethesda: Abt Associates.

Stanghellini, S. (1996). *Valutazione e processo di piano*, Firenze: Alinea.

Overseas Development Administration (1995). *Guidance Note on How to Do Stakeholder Analysis of Aid Projects and Programmes*. Social Development Department, London: ODA.

UE, Centro Studi di Politica Internazionale (CeSPI), (2007, October). Interact Programme Compart Project, *Questionnaire for stakeholders analysis*, Retrieved October 2007 from http://www.cespi.it.

UK Department of Transport, Local government and Region (DTLR) (2009, November). *Multicriteria analysis manual,* Retrieved November 2009, from http://iatools.jrc.ec.europa.eu /public/IQTool/MCA/DTLR_MCA_manual.pdf.

Vincke, P. (1989). *Multicriteria Decision-aid*, London: Wiley & Sons.

Voogd, H. (1983). *Multicriteria Evaluation for Urban and Regional Planning*, London: Pion.

Evaluation of Thermo-energetic Performance of a Hotel in Lisbon with Methodological Basis in the New Portuguese Legislation

Jorge Tavares Ribeiro[1], Ingride Beltrão Coelho[2]
[1]*Technical University of Lisbon, Portugal*
[2]*Bioetiqueta – Sustainability and Energy Certification, Portugal*

Abstract

The buildings of the XXI century must contribute and compete for the common design of modern societies that seek to develop in a sustainable manner. In this context, architecture and engineering are frequently confronted with high degree of complexity paradoxes that require sustainable solutions that allow match some aspects that may contain itself a contradiction. Indeed, if one hand is recommended to reduce energy consumption of buildings, on the other hand, it is desirable to have an increase of thermal comfort inside buildings. Unequivocally, the reduction of energy consumption of buildings, not neglecting the patterns of comfort to users is one of the challenges faced today by architects and engineers.

Based on the assumptions of the new Portuguese legislation (MOPTC-RSECE, 2006 and MOPTC-RCCTE, 2006), evaluates the thermo-energetic performance of a building constructed, carrying also the simulation of alternatives which may be applied in the building and have beneficial effects on the thermo-energetic performance of building. The simulations carried out, through the use of specific software, allows to identify alternatives (including constructive aspects) that could be adopted in buildings built and future buildings, as well as their limitations. Tenders are therefore a review, in relative terms, of the façade components, according to the benchmarks, and identifies where they can intervene to improve the thermo-energetic performance of the building.

Both methodologies, RCCTE and RSECE, are applied to a real case study – a hotel of Lisbon – to the periods of heating (winter) and cooling (summer).

Keywords: *thermo-energy performance, building envelope, hotel*

1 Introduction

Reducing energy dependence is one of the most serious problems that face today's economies. To at least reduce the size of the problem are often highlighted two ways – the rational use of energy and harnessing the potential of indigenous energy resources (*i.e.*, the use of renewable energy). The first is reflected in the way energy is consumed or used, and contribute to it, for example, through the use of more efficient equipment, construction of buildings lower energy consumers, engineering projects and more streamlined architecture, etc. The second may be, without doubt, an important contribution to reducing energy dependence and excessive consumption of fossil energy. Although these two pathways were not independent and should act in coordination for the common goal, this paper focuses on the second way mentioned.

Simultaneously, much of the energy consumed worldwide is due to tourism, particularly in the hotel business. At hotels, beyond the function of shelter like any other building, it requires security, trust, and especially to guarantee a degree of comfort (including thermal comfort), according to their classification. In many cases, the hotels (especially the urban hotels), rather than benefiting the local climate, have been creating artificial environments within, obtain at the cost of equipment and infrastructure high consumers of water and energy.

Moreover, the architects – whose work significantly influences the thermal performance of buildings – are not always sufficiently aware and informed about the procedures to reconcile these demands with the remaining constraints (functional, aesthetic, etc.) of the project (Coelho, 2007). According Coelho (2007) often there is a “divorce” between the measures of buildings energy conservation and their architectural form, because these issues are treated separately. Coelho (2007) adds that many times the resolution of energy issues is made at a later draft of the definition of the shape of the building in short-party intervention in this area to adopt the measures needed to meet the legal requirements established.

In this context, it is presented a study of thermal-energetic behaviour of a hotel, as well as their simulated behaviour of feasible constructive alternatives that can be implemented in the building, which point towards better utilization of renewable energy.

2 Objective

The objective of this study is the thermo-energetic evaluation of several alternatives for constructive intervention in a hotel, in full operation, with high energy consumption. This assessment is to identify, characterize and simulate the different constructive alternatives that have influence on energy consumption, ensuring standards of comfort. Thus it is intended to contribute to increased knowledge on the real possibilities of improving the energy performance, enhancing the thermal comfort in hotels.

3 State of the Art

About twenty years ago the European Commission published a draft document for the energy certification of buildings, based on data concern that buildings were responsible for 40% of energy consumption in Europe. Today, the outlook remains, despite the relevance of the proposals set out then to reduce that percentage of energy consumption by 50% (EURIMA, 2005). In 2004 the European Commission launched a new initiative on energy efficiency in buildings, the Green Building Program (EU, 2004), which aims to improve the efficiency and promote the integration of renewable energy in non-residential buildings. Furthermore, it was intended to actively support the dissemination of the European Directive on the Energy Performance of Buildings and encourage their implementation.

3.1 Energy consumption in hotels

Normally, the hotels are buildings of considerable size, and therefore large energy consumers in the room areas and for other services offered by the hotel. For this reason, the hotels are more likely may benefit from the implementation of energy efficiency measures (Isaacs and Crocker, 1996). It is understood that the use of energy in a hotel is effective when, for a standard pre-defined, it achieves the same performance with a smaller amount of energy, *i.e.* when a system operates only during the period that is needed and obtain the desired thermal behavior, with lower energy consumption.

In the hotel sector, although some hotels (*e.g.* Copthorne Hotel and The Swallow Royal Hotel) have already implemented Buildings Energy Management Systems (BEMS) since the 1980s, only in 2005, some of the largest groups and chains of hotels promoted the World's First Sustainable Hotel Sitting, Design and Construction Guiding Principles Released in order to understand and adopt the principles for the design of Sustainable Hotels and published a valuable manual (CI and IBLF, 2006), with guidelines and principles applicable to this industry.

The Thermie Programme (EC, w.d.) were established energy consumption in a hotel (see extract in Table 1), which are mainly associated with cooling and heating systems, ventilation, HVAC, preparation of hot water, lighting, restoration, elevators, etc.

Table 1: Parameters regarding energy consumption in hotels (EC, w.d.)

Efficiency rating	Good	Fair	Poor	V.Poor
B) Medium-sized hotels (50-150 rooms) without laundry, with heating & air conditioning in some areas				
Electricity (kWh/m^2 year)	< 70	70-90	90-120	> 120
Fuel (kWh/m^2 year)	< 190	190-230	230-260	> 260
Total (kWh/m^2 year)	< 260	260-320	320-380	> 380
Water (kWh/m^2 year)	< 160	160-185	185-220	> 220

While some hotels (especially those of lower rating) use natural ventilation as a source of fresh air and cooling, the hotels of the highest rating invest in

HVAC technologies, whose minimum requirements (see Table 2) are regulated by the World Tourism Organization (as cited in Lawson, 2001 and Bohdanowicz; Martinac, 2002).

Table 2: Minimum HVAC system requirements for hotels (as cited in Lawson, 2001 and Bohdanowicz; Martinac, 2002)

Hotel rating	Service provided
★	Heating or fan cooling when necessary.
★★	Heating or fan cooling when necessary. Central heating and comfort cooling seasonally available.
★★★	Central heating and comfort cooling seasonally available. Individual heat control in bedrooms. Temperature maintained within the range of 18 – 25 °C.
★★★★ and ★★★★★	Central heating and comfort cooling available in entire premise. Individual heat and air conditioning control in all rooms. High quality equipment with very low noise emission level.

In Portugal, after the review and started to apply the new Portuguese legislation – Characteristics of Thermal Behavior of Buildings Rule (MOPTC-RCCTE, 2006) and Energy Systems to Air Conditioning in Buildings Rule (MOPTC-RSECE, 2006) as a part of National Certification System for Energy and Air Quality in Buildings (MEI-SCE, 2006) – protocols were signed between state agencies and professional organizations, conduct to the training of qualified trainers experts for the energy certification.

3.2 Thermal comfort

In general, the studies on thermal comfort theory analyze and establish the necessary conditions for the evaluation and design a thermal environment suitable for human occupation and activities, in addition to establishing methods and principles for a detailed thermal analysis of an environment.

The technological advances and cultural patterns seem to have done to be forgotten that the occupation of space by human people, as well as the necessary adaptation and understanding of ways to interact with the space, is strongly linked to the site and climate. The thermal comfort in addition to physical factors, is defined by a range of personal factors that make this task very subjective, but can be viewed and analyzed from two perspectives: personal and environmental. From the personal point of view, thermal comfort is defined as a condition of mind which expresses satisfaction with the thermal environment of the area attended. On physical terms, comfortable environment is the conditions which enable the maintenance of internal temperature, without activating the thermoregulation mechanisms, *i.e.*, it is necessary that the human body is at zero heat balance with the environment, as is mentioned in one of the most widespread thermal comfort theories (Fanger, 1970). The ISO 7730 (1994) considers that an area provides thermal comfort when 10% or less of its occupants feel uncomfortable. This is a standard that closely follows the research developed by Fanger (1970) and the general principles have been adapted by the ASHRAE (1981) and ASHRAE (1992).

For the thermal comfort and building relationships with the internal buildings environment, the brothers Olgyay (Olgyay, 1963, 1998) were the first to deepen knowledge in this field. Based on previous studies on the level of comfort, Givoni (1992) defined a method for determining the "comfort zone" by means of a psychometric chart. Many other studies have been conducted without the use of climate chambers, but through real situations of everyday, more specifically by Humphreys and Nicol (1998), among others, which took into account the expectations and the psychological component of individuals, has led to the Adaptive theory, much more flexible and adaptable to the particularity of every climate and every culture.

The patterns of thermal comfort for the hotels are normalized by ASHRAE (1997), ISO 8996 (1990), ISO 9920 (1995) and ISO 7726 (1998).

3.3 Energy efficiency

To define the concept of energy efficiency it is necessary to compare the energy performance in a building (equipment, heating, cooling, etc.) with reference values for energy requirements for each site in order to achieve accurate results and tailored to each situation. However, in general terms the criteria are:

Energy efficiency and power of installed equipment, to be accounted for internal gains;

Building materials for the needs of thermal behavior for the local climate;

Occupation, including the number of individuals and residence timetable;

The heating and cooling systems installed and the preparation of hot water system.

4 Methodology

The general methodology (see Figure 1) designed to achieve the objective proposed, begins with the energy calculation consumed for an existing building, by the software RCCTE-STE, versão1/2006 (INETI, 2006), in order to identify the benchmarks levels and needs of heating and cooling. The calculations are delivered through the two methods proposed in the Portuguese legislation (MOPTC-RCCTE, 2006 and MOPTC-RSECE, 2006). It is important to clarify that it is not to apply the existing regulations, but only to incorporate the assumptions that underlie it. The software mentioned can perform calculations, according to the application of RCCTE and RSECE methods.

After a critical analysis of the outputs, the procedure is to identify the parameters involved in order to recognize the importance or weight of the results. Thus became a set of feasible intervention parameters in the existing building, thus enhancing the thermal comfort and reducing energy consumption (translated by the room requirements of heating and cooling). It should be noted that are considered feasible interventions those that do not involve excessive costs and do not interfere with the entire functioning of the hotel and can be performed with the closure of parts of the hotel by short time periods.

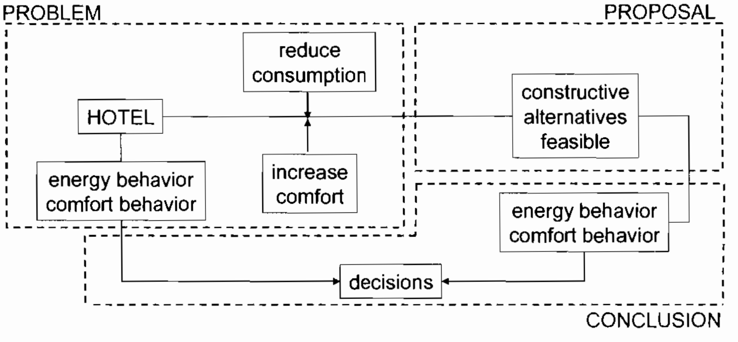


Figure 1: General methodology.

The results obtained for the proposed interventions, according to the methodologies RCCTE and RSECE were then compared, as well with the simulation results of the existing building.

4.1 RCCTE method

The heating or cooling needs of an autonomous fraction of the building is the useful energy that is necessary to keep permanently 20 ºC or 25 ºC on the inside (MOTPC-RCCTE, 2006) during the conventional heating or cooling season, respectively. The nominal needs calculated for reference conditions, is an objective way to compare buildings from the stage of licensing, in terms of thermal behavior: the greatest needs mean that it is necessary to heat or cool the building.

With this method, it is clear that the calculation of heating N_{ic}, or cooling, N_{vc}, needs depends on the morphology and the thermal quality of the envelope, taking into account solar and internal heat gains, that can not exceed the maximum allowable nominal annual needs useful energy for heating N_i, or cooling, N_v, *i.e.* $N_{ic}<N_i$ or $N_{vc}<N_v$, respectively. The N_{ic} is obtained by:

$$N_{ic} = \frac{(Q_t + Q_v - Q_{gu})}{A_p} \text{ (kWh/m}^2\text{.year)},$$

where:

Q_t – Heat loss by conduction through the building envelope;

Q_v – Heat loss by air exchange;

Q_{gu} – Useful heat gain from lighting, equipment, occupants and solar gains through the windows;

A_p – Useful floor area

and

$$N_i = \begin{cases} 4.5 + 0.0395 \times GD \text{ if } FF \leq 0.5 \\ 4.5 + (0.021 + 0.037 \times FF) \times GD \text{ if } 0.5 < FF \leq 1 \\ [4.5 + (0.021 + 0.037 \times FF) \times GD] \times (1.2 - 0.2 \times FF) \text{ if } 1 < FF \leq 1.5 \\ 4.5 + 0.06885 \times GD \text{ if } FF > 1.5 \end{cases}$$

where:

FF – Shape factor of a autonomous fraction;

GD – Degree days of the local climate.

Using a simplified methodology, already validated in Europe (natural ventilation), the calculation of N_{vc} is obtained by the expression:

$$N_{vc} = \frac{Q_q \cdot (1 - \eta)}{A_p} \text{ (kWh/m}^2\text{.year)},$$

where:

Q_q – Total gains of the building;

η – Load factor of these gains;

A_p – Useful floor area.

and, for climatic south zone $N_v = 32$ kWh/m^2.year.

4.2 RSECE simplified method

The calculation method implemented by RSECE is based on the model developed by the CSTB (CEN TC89). The model considers convective and radiant parts of lighting and other internal gains and distinguishes the inside air temperature from the radiant temperature of interior surfaces. The hourly meteorological data (weather and solar gains) in the national municipalities are given by the software, as well as profiles of use of rooms (internal gains). The method of calculation allow to determine the thermal loads (heating or cooling), on an hourly basis, for the indoor temperature set. The RSECE simplified method accepts as valid the superposition principle (applicable to linear systems), in which the behavior of a system is composed by the sum of the behaviors of the each parts. Thus, according to the RSECE simplified method, the thermal load (energy) in a building with different thermal zones is equal to the sum of heat loads in each zone.

5 Case Study

5.1 Geographical and functional characterization

The methodology has been applied to a hotel in Lisbon - Açores-Lisboa Hotel– situated in a privileged area of the city (see Figure 2). This is a medium-sized hotel (50 to 150 rooms - see Table 1) 4-star opened in March 2005, which makes it appealing for the timeless of construction techniques and concerns among the designers in terms of thermal comfort and environment. Is a hotel considered as a major consumer of energy within the RGCE (Management of Energy Consumption Regulation), which requires inspections and continuous monitoring of energy consumption, enabling the preparation of plans for rationalization of energy consumption

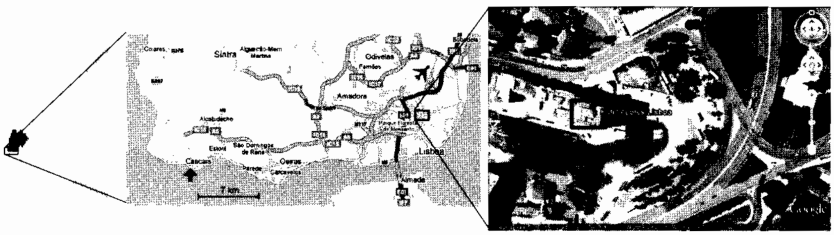


Figure 2: Açores Lisboa Hotel site.

The choice of this case study has to do with the fact that those responsible for the hotel have shown great concern and interest in this subject, particularly as regards the possible involvement of some hotel chain in the process of environmental certification and registration in the Eco-Management and Audit Scheme (EMAS).

The building has 14 floors above ground and 3 basement levels for parking and technical services (see figure 3).

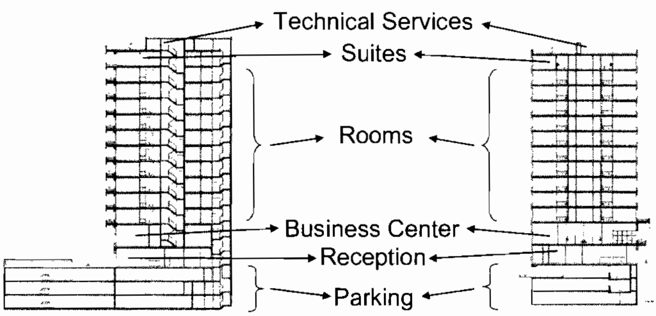


Figure 3: Section East-West and section South-North of Açores Lisboa Hotel.

The hotel has 128 rooms: 105 double rooms, 15 executive board twins, 5 suites and 3 double rooms for disabled people. All rooms have areas equal or greater than 15 m^2, the livings of the suites have areas above 10 m^2, all sanitary facilities of the rooms and suites consist of a bathroom upwards of 4.5 m^2 (see Figure 4). Double rooms and suites are furnished with bed, bedside tables with lighting fixtures, closet with mirror, chair or sofa, curtains, telephone, radio, cable TV, minibar, hair dryer, internet connection, at least two power points, safety system in the access doors to the rooms, writing desk and the trunk.

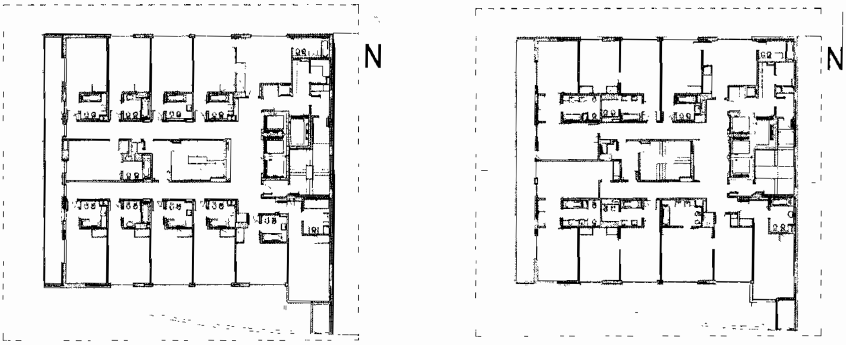


Figure 4: Plant of 2 to 11 floors (left) and plant of 12 floor (right).

In terms of infrastructure, this hotel has HVAC systems in rooms and suites and in some areas of common use. The requirements with regard to access in a hotel with 4-star rating should include, in addition to the service entrance separate from the input of users, commonly used ladders and stairs or emergency service and lifts, at least a freight elevator if the establishment has more than 3 floors including ground floor. The Açores Lisboa Hotel also offers all others the services, *i.e.* has a reception/concierge permanent, breakfast in the dining room and room service, dining and bar service, custody in a private safe services, housekeeping, laundry and ironing. In addition the hotel also offers a lounge with TV, terrace, business center, meeting rooms, WI-FI in public areas, indoor parking (underground) and rent a car. Regarding the areas of services, all floors are equipped with kitchen pantry.

5.2 Climate characterization

"Lisbon (…) is a type of Mediterranean climate, with hot dry season, and its altitude is not above 160 m. The weather in Lisbon depends to a large extent on the combined influences of the Atlantic Ocean and the Tagus estuary, on the banks of which the city has developed" (Alcoforado, 1987).

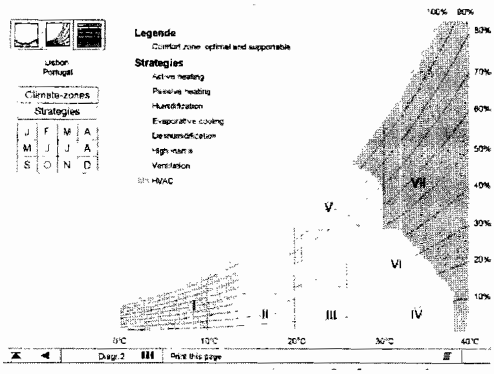


Figure 5: Psychometric chart of Lisbon (Redin, 2006).

For the winter season (heating), the most appropriate strategies are located in zones I and II (see Figure 5) concerning the promotion of active and passive heating, by maximizing solar gains, the restriction losses by conduction, the application of insulation in exterior walls, roofs and floors, as well as the reduction of losses by the glazing. For summer season, the cooling strategies most appropriate are located in zone V on the promotion of effective ventilation and, in the zone VI on the implementation of walls with a strong inertia.

5.3 Constructive characterization

The building has a traditional structure of reinforced concrete, filling walls of masonry brick, two panels with insulation in the air box between cloth, coat the outside of aluminium type "alucobond", and insulation on the slab.

Since a hotel is a building with additional concerns regarding the accommodation, the area of greatest interest to this study is the area of rooms, which occupy 66% of the total. Thus, given that the floors 2 through 11 are intermediate floors, have no losses or gains to be recorded in the direction of heat exchange between them, resulting in a pattern of energy consumption and thermal comfort similar in its characteristics. Only the height location of the floors could give them some differences in the calculations for glazing, but once the building is located on a corner, with no obstructions constructed, the floors were considered similar. For the simulation of thermo-energy behavior of the building it was divide the area of the rooms in two types of units, one for intermediate floors (P_int – floors 2 to 11 – see Figure 6 - left) and the other on rooftop (P_12 – 12 floor – see Figure 6 - right). In the latter, it was considered the outer covering that gives gains and losses by heat exchange between the interior and exterior resulting in a different thermal behavior. In each type of unit, were also considered an unheated space or not helpful (Lna), which included all areas of vertical and horizontal circulation as well as the pantry of each floor – see Figure 6.

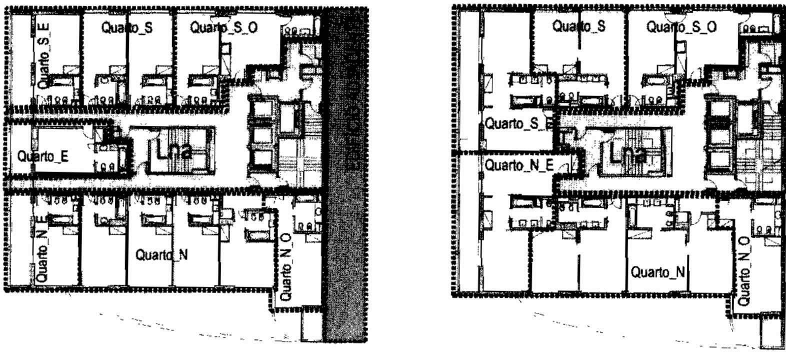


Figure 6: Fraction P_int (left) and Fraction P_12 (right).

Bearing in mind that the thermal inertia of an autonomous fraction depends on the capacity of heat storage sites, on the superficial mass surface of each of the elements, which in turn depends on its location in the building, and in accordance with the regulations, was considered the following 5 generic items:

Elements of the external envelope – elements of the fraction "skin" that contacts with the outside (4 types of external walls, PE1 to PE4, and outside coverage), with another fraction (floor and coverage) and, with unheated spaces (3 types of walls and coverage);

Interior elements of autonomous fraction – considers the total mass of interior elements (3 types of interior walls);

Thermal flat bridges – considered the thermal bridges flat heel of the pillars, PTP_P, beams, PTP_V, and heterogeneities, whose heat transfer coefficient is calculated on a one-dimensional in the normal direction to the envelope;

Linear thermal bridges – occur in singular points of the envelope are recorded individually by coefficients of linear thermal transmittance, ψ (Maldonado *et. al.*, 2006);

Glazing – the requirements are presented in terms of "the ratio of solar energy transmitted through the glass, with its sun protection device (100% active), and solar energy incident on it" (Maldonado *et. al.* 2006), translated by the solar factor. The glazing characterized by fraction and by typology, in geometric terms, quantity, orientation and location in height to the ground. All window openings frames are made of metal with double glass (thickness: blade pool with 8 mm – SKN 154 Cool-lite, blade of air with 12 mm and interior blade – Stadip Silence 44.2) without thermal cutting, *i.e.* with thermal performance worsened by the absence of the interconnection (usually plastic) of metal parts (frame), with more insulating features than the frames material.

5.4 Energy characterization

In this study, which is based on an approach based on bioclimatic concerns enhance the thermal comfort by reducing energy consumption, it was considered the existing HVAC systems with installed power greater than 25 kW, ventilation (natural ventilation), equipment (lighting (156 W), hairdryer (800 W), TV (120 W), power loading of the mobile phone or laptop (90 W) and mini-bar (25 W)) and an occupation of two people by typology. However, these equipment and the occupants result in heat gains associated with internal heat sources.

It is also worth mentioning that was implemented a centralized energy management system, that controls the hours of operation of some equipment outside the peak hours, namely the temperature of all areas of the hotel as well as lighting. So the energy consumption are monitored and some parameters are optimized, ensuring more efficient use of facilities and equipment, reducing operating costs including energy costs.

5.5 Simulation of feasible intervention alternatives

Despite high energy costs are options to reduce consumption such as design strategies for passive solar systems or just the use of insulation to reduce heat loss significantly. The solar gains and losses control are the alternatives with greater potential for intervention.

Thus, in winter it is proposed to reduce losses in the envelope by reducing the thermal coefficient of elements in exterior walls, and thermal flat bridges and boost the useful solar gains by increasing the solar factor of the glazing. In summer, the decrease in solar gains through exterior obstructions such as outside shutters (with high air permeability), would not materially affect the results and has not, therefore, been considered. The installation of exterior shutters or flaps in the south-facing openings would make substantial reductions in the expected solar gains. However, these options would have aesthetic implications on the façade and interior visual comfort implications, and therefore they were not considered.

The choice fell on interventions in the exterior envelope, where the total losses and solar gains are more significant, leaving the interior envelope without any intervention, even though it also recognizes that it would have great interest in terms of feasible alternatives. Were taken the following options:

Propose feasible interventions that seek to reduce the energy requirements of heating, N_{ic}, without compromising the results more satisfying the cooling needs, N_{vc}, on both floors. It should be noted that were not taken into account the cost of works necessary for the implementation of these solutions, but only the degree of intervention;

Propose constructive amendments in order to respect the outside image of the hotel. Thus, considered as feasible alternatives (summarized on Table 3), the intervention in glazing and insulation in the air box of the outer coat.

Table 3 – Feasible proposals

A1	$g_{glass} = 0.38$	SGG Parsol gris 8 mm + SGG Planilux 8 mm
A2	$g_{glass} = 0.55$	SGG Antelio argent 8 mm + SGG Planilux 8 mm
A3	$g_{glass} = 0.75$	Double Glass colorless 8mm + 5 mm
B	$U = 2.7$	Thermal cut in frames
C1	$U = 0.26$	PE1b = alucobond+air box 2+wallmate 4+plaster 2+brick 11+air box 2+wallmate 4+brick 11+plaster 2
C2	$U = 0.21$	PE1c = alucobond+air box 2+wallmate 4+plaster 2+brick 11+air box 2+wallmate 4+brick 11+plaster 2+rockwool 2.5+pladur 1.3
	$U = 0.33$	PE2a = alucobond+plaster 2+brick 11+air box 2+wallmate 4+brick 11+plaster 2+rockwool 2.5+pladur 1.3
	$U = 0.33$	PE3a = alucobond+plaster 2+brick 11+air box 2.5+wallmate 4+brick 11+plaster 2+rockwool 2.5+pladur 1.3
	$U = 0.33$	PE4a = plaster 2+brick 11+air box 2+wallmate 4+brick 11+plaster 2+rockwool 2.5+pladur 1.3
	$U = 0.41$	PTP_Pa = alucobond+plaster 2+concrete+plaster 2+rockwool 7+pladur 1.3
	$U = 0.35$	PTP_Va = alucobond+plaster 2+concrete+air box 2+wallmate 4+brick 11+plaster 2+rockwool 2.5+pladur 1.3
C3	$U = 0.32$	PE1a = alucobond+air box 6+plaster 2+brick 11+air box 2+wallmate 4+brick 11+plaster 2+rockwool 2.5+pladur 1.3
	$U = 0.33$	PE2a = alucobond+plaster 2+brick 11+air box 2+wallmate 4+brick 11+plaster 2+rockwool 2.5+pladur 1.3
	$U = 0.33$	PE3a = alucobond+plaster 2+brick 11+air box 2.5+wallmate 4+brick 11+plaster 2+rockwool 2.5+pladur 1.3
	$U = 0.33$	PE4a = plaster 2+brick 11+air box 2+wallmate 4+brick 11+plaster 2+rockwool 2.5+pladur 1.3
	$U = 0.41$	PTP_Pa = alucobond+plaster 2+concrete+plaster 2+rockwool 7+pladur 1.3
	$U = 0.35$	PTP_Va = alucobond+plaster 2+concrete+air box 2+wallmate 4+brick 11+plaster 2+rockwool 2.5+pladur 1.3
D	$U_{winter} = 0.34$ $U_{sumer} = 0.33$	Coverage of floor thermal paving Grisol
E	$U_{PTP\_P} = 0.78$ $U_{PTP\_V} = 0.35$	Correction of flat thermal bridges

In addition to these 9 proposals were also considered combinations of these, a total of 55 feasible alternative interventions.

6 Results

The results obtained by RCCTE method are summarized in Figure 7. For the winter, the feasible alternative that produces better results is to maximize profits by solar glazing and minimize losses through the envelope (proposal A3+B+C2+D). Comparing with the original N_{ic} (76.29 kWh/m^2.year and 59.95 kWh/m^2.year, respectively for floor 12 and intermediate floors), the N_{ic} reductions are more pronounced in the floor 12 (43.83 kWh/m^2.year – 43 %) than in the intermediate floors (35.63 kWh/m^2.year – 37 %), highlighting the importance of intervention in coverage. In summer, adding insulation decreases the N_{vc}, and this reduction is always more effective when the intervention occurs in coverage. Moreover, the solar factor of the glass is always accompanied by a significant increase in solar gain glazing, which makes the N_{vc} increase proportionally, *i.e.* the increase in the solar factor of the glass, *g*, should always be complemented by a system of exterior shading overhangs and horizontal blinds, among others.

The feasible intervention alternative with better thermo-energy performance, in the sum of the heating and cooling requirements, is the proposal A3+B+C2+D on both floors (63.67 kWh/m^2.year and 50.89 kWh/m^2.year, against 90.23 kWh/m^2.year and 68.60 kWh/m^2.year, on the floor 12 and on the intermediate floors, respectively).

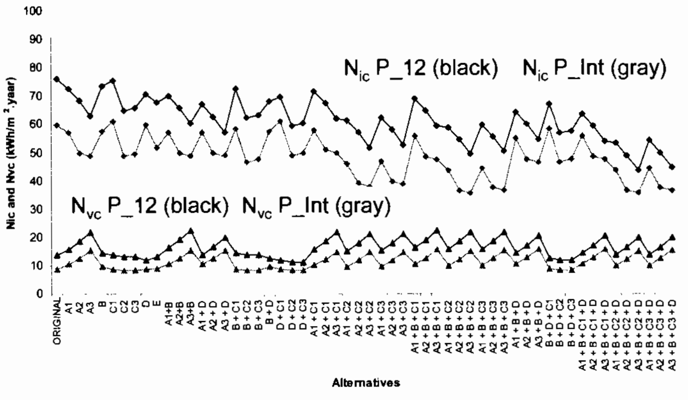


Figure 7: Heating and cooling needs (RCCTE method).

The results of RCCTE are unrealistic, since the internal gains considered in this methodology are much lower than usual service buildings, specifically in this case study – a hotel. According to the RCCTE method the value of internal heat gains for hotels is 4 W/m^2. In the modeling performed by applying the RSECE method, the internal heat gains of 22.6 W/m^2 (9 W/m^2 (equipment) + 8 W/m^2 (lighting) + 5.6 W/m^2 (users)) are more suitable for a building of this nature.

The results obtained through the RSECE method was also summarized in graphic form (see Figure 8). For the winter the alternatives that produce better results are the proposals A2+C3 and A2+B+C3 on the floor 12 and A2+C2, A2+B+C2 and A2+B+C2+D on the intermediate floors. In the summer (see Figure 8) the alternatives that produce better results are the proposals A1+B+C2+D on the floor 12 and A1+B+D on the intermediate floors.

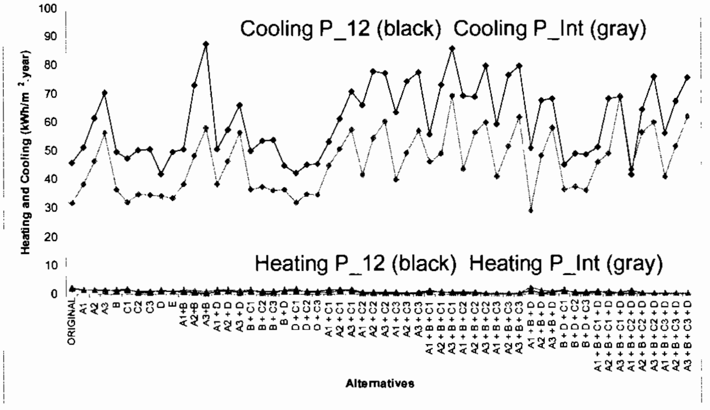


Figure 8 – Heating and cooling needs (RSECE method).

The alternative, using the RSECE method, that presents the best performance for the sum of needs for heating and cooling, is the proposal D+C1 (38.82 kWh/m^2.year, about 6% lower than the original).

Comparing the results obtained by applying both methods, the proposals with better thermo-energetic performance do not match. Moreover, for the reasons mentioned above, the RCCTE method should not be used to assess the energy evaluation of service buildings. Indeed, the proposal A3+B+C2+D (with the best overall performance by the RCCTE method) provides an increase of 66 % of global consumption when using the RSECE method. The proposal recommended (D+C1) by RSECE method corresponds to an uninteresting result in the RCCTE method (10% higher than the original).

7 Conclusions

The characterization and analysis of energy consumption and thermal comfort conducted, either in the existing or proposed, to draw conclusions about the relative importance of different parameters in determining consumption (see Coelho, 2007). On the other hand, will also estimate future consumption based on knowledge of the variables that determine them, which may serve to support the development of projects for future hotels or even the development of maintenance plans that include interventions, both in the external or interior envelope.

Note also the importance of the simulations in decision-making during the conception and design, without compromising the thermal comfort inside the building and reducing energy consumption. Although it was possible to identify some common features, that could be standardized, it is not considered that there are generic models applicable to hotels, since each building must be assessed individually, given their particular characteristics.

Acknowledgements

The authors thank the Açores Lisboa Hotel willingness to provide the data needed to the study, and the interest and commitment to achieving results.

References

Alcoforado, M. J. (1987). Brisas Estivais do Tejo e do Oceano, na Região de Lisboa, *Finisterra*, XXII, 43, Lisboa.

ASHRAE (1981). *Thermal Environmental Conditions for Human Occupancy, Standards 51-1981*. The American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc, USA.

ASHRAE (1992). *Thermal Environmental Conditions for Human Occupancy, Standards 55-1992*. The American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc, USA.

ASHRAE (1997). *Fundamentals Handbook*, The American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc, USA.

Bohdanowicz, P.; Martinac, I. M. (2002). Thermal Comfort and Energy Saving in the Hotel Industry. *16th International Congress on Biometeorology*. Royal Institute of Technology, Stockholm, Sweden. (retrieved ams.confex.com/ams/pdfpapers/50090.pdf)

CI ; IBLF, (2006). Sustainable Hotel Sitting, Design and Construction. (retrieved http://www.internationaltourismpartnership.org/sustainable.htm)

Coelho, I.B. (2007). Avaliação do Desempenho Térmico de um Hotel em Lisboa, com Base Metodológica nos Novos Regulamentos – RCCTE e RSECE. MSc Thesis on Bioclimatic Architecture. FAUTL, Lisboa.

EC (w.d) European Commission, Directorate-General for Energy (DG XVII), Rational Use of Energy in the Hotel Sector. Thermie Programme Action B-103. (retrieved ftp://ftp.cordis.europa.eu/pub/opet/docs/hotelv6.doc)

EU (2004) GreenBuilding Program – Improved Energy Efficiency for Non-Residential Buildings. (retrieved http://www.eu-greenbuilding.org/index.php?id=162)

EURIMA (2005). *Time to act*!, response to the Commission´s Green Paper on energy efficiency, Brussels.

Fanger, O. (1970). *Thermal Comfort*, McGraw-Hill Book Co, New York, 1970.

Givoni, Baruch (1992). Comfort, climate analysis and building design guidelines. *Energy and Buildings*. Vol. 18, no. 1, 1992.

Humphreys, M.; Nicol, F. (1998). Understanding the Adaptive Approach to Thermal Comfort. *ASHRAE Transactions*: Symposia: 991-1004.

INETI (2006). *Software RCCTE-STE – versão 1/2006*, ADENE, INETI, Lisboa.

Isaacs, N.; Crocker, N. (1996). *Commercial Buildings Energy Survey: Hotels,* Center for Building Performance Research, Victoria Univ. of Wellington.

ISO 8996 (1990). Ergonomics: Determination of metabolic heat production, ISO, Geneva.

ISO 7730 (1994). Moderate Thermal Environments: Determination of the PMV and PPD Indices and Specification of the Conditions for Thermal Comfort, 2nd ed. ISO, Geneva.

ISO 9920 (1995). Ergonomics of the thermal environment: Estimation of the thermal insulation and evaporative resistance of a clothing ensemble. ISO, Geneva.

ISO 7726 (1998). Ergonomics of the thermal environment: Instruments for measuring physical quantities, ISO, Geneva.

Lawson F.R., (2001). Hotels and Resorts – Planning, Design and Refurbishment. Architectural Press, UK.

Maldonado, E.; Camelo, S.; Santos, C. P.; Ramalho, A.; Horta, C.; Gonçalves, H. (2006). *Manual de apoio à aplicação do RCCTE*, INETI, Lisboa.

MEI-SCE (2006). Min. Econ. Inovação – Sistema Nacional de Certificação Energética e da Qualidade do Ar Interior nos Edifícios. DL nº 78/2006. *Diário da República* nº 67, Iª Série-A de 4 de Abril. 2411-2415

MOPTC-RCCTE (2006). Min. Obras Públicas, Transp. Com. – Regulamento das Características de Comportamento Térmico dos Edifícios. DL nº 80/2006. *Diário da República* nº 67, Iª Série-A de 4 de Abril. p. 2468-2513

MOPTC-RSECE (2006). Min. Obras Públicas, Transp. Com. – Regulamento dos Sistemas Energéticos de Climatização em Edifícios. DL nº 79/2006. *Diário da República* nº 67, Iª Série-A de 4 de Abril. p. 2416-2468.

Olgyay, Victor (1963, 1998). *Arquitectura y clima. Manual de diseño bioclimático para arquitectos e urbanistas*, Princeton University Press, Editorial GG, S.A., Barcelona.

Redin (2006). Software P.E.M. - Pascool Electronic Metahandbook, versão 1.2.

Daylighting Strategy for Sustainable Schools: Case Study of Prototype Classrooms in Libya

Belal Abdelatia[1], Catherine Semidor[2], Christian Marenne[2]
[1] *University of Bordeaux 1, France.*
[2] *GRECAU Laboratory at the ENSAP of Bordeaux, France.*

Abstract

Over the last several years, topics related to sustainable development and energy saving in Western countries led to several research projects aiming to promote the amount of natural daylight used school buildings. Most of these projects concern the amount of light required to perform specific tasks in school buildings. Very little of the research done, however addresses the other numerous qualitative aspects of using natural daylight in educational buildings. These same questions are now arising in Libya, especially those pertaining to the use of natural daylight. The promotion of natural daylight in the classrooms saves electrical energy and improves the working conditions for both teachers and students. The extreme solar heat in Libya has always been an imperative factor in relation to building heat. Especially in the months June through August great care is required to avoid overheating while still preserving the natural daylight. Current school buildings found in Libya sacrifice the use of natural daylight in order to obtain safe heating conditions.

The present research aims to propose and to test several architectural devices that can be integrated into educational building designs, allowing the penetration of natural daylight while respecting the traditional aestheticism and creating a comfortable environment for the school's various needs. In addition, this research presents a design process in which the final sustainable architecture enhances school and student performance and also stands up to external conditions, meeting the targets of durability in its daylight strategies.

***Keywords**: Classrooms, Natural daylight, Visual comfort, Sustainable visual environments, Sustainability.*

1 Introduction

A student's learning capacity , such as the ability to concentrate during a class, does not only depend on personal factors, such as motivation, psychological conditions, intelligence, etc. but also depends on several other, external factors that affect not only the student, but the overall environment of the school.

Visual comfort is one of the main features that contribute to the creation of a suitable educational environment. This comfort is defined as "a subjective feeling of satisfaction with the visual system mainly due to the absence of any discomfort induced by the overall visual environment" (AFE, 1995).

Therefore, a person should feel comfortable in an environment where the lighting is not too bright and illuminates properly the worktables and spaces necessary for the daily activities.

Because visual activities such as reading and writing are very important during the educational phase, it is essential to create comfortable visual conditions in school buildings that will contribute to these activities.

Furthermore, the use of natural daylight in buildings significantly reduces the electric energy consumption, especially in the secondary and tertiary sectors (Page, J et al, 1994). For instance, it has been shown that artificial lighting of non-domestic buildings represents 50% of the energy consumption in Europe (Scartezzini, 1991). It also has been shown that it is possible to reduce this consumption with 30 to 70 percent by combining the use of artificial and natural lighting (Mc. Nicholl, A. and Owen L. J, 1994).

Internationally, these studies aroused a growing interest in natural daylight as an efficient way to save and rationalize the energy consumption in buildings. Indeed, today the use of natural daylight is considered as one of the main strategies for all bioclimatic, passive solar and/or high quality environmental design.

As remarked by Veitch (2004), a Canadian researcher specializing in the interaction between the quality and usage of light, there is no real consensus on what good quality lighting means. On the contrary, concerning artificial lighting, it is generally accepted that the lighting, luminance, luminance repartition (contrast between the surfaces), uniformity, glare control, flickering of fluorescent light tubes and the spectral power distribution, are all important aspects of a luminous environment.

Veitch proposes to deepen the concept of quality by the study of the interaction between the inhabitants and the environment. She observes that the evaluation of the quality of a natural lighted space involves the consideration of a multitude of factors (Veitch, 2004). She also proposes an integrated model of the light quality as illustrated in figure 1. Thus, this quality model acknowledges that the response of the occupier to his/her light environment is contextual. That it depends of his or her personal characteristics, the layout of his or her environment, and the culture. Moreover, according to this model, the well-being of the inhabitant (see upper part of the diagram) does not only depend on the notion of visibility, but also on different factors specific to the photobiology.

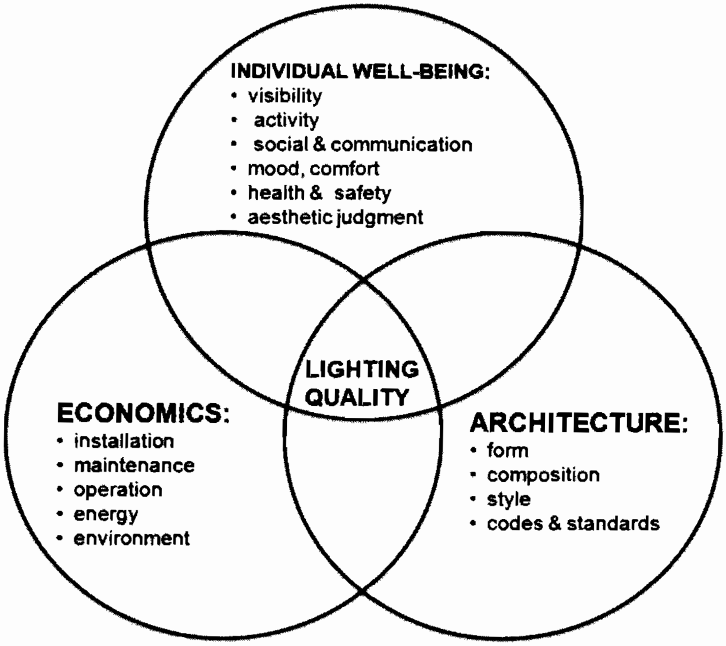


Figure 1: Integrated model of the light quality (source: Veitch, 2004).

Research also confirmed that the visual comfort related to the quantitative and qualitative aspects of the natural daylight significantly contributes to the well-being of pupils and thus leads to better school performances. A research under more than 20,000 elementary students and 100 schools in the USA confirmed this statement. It has been proved that students with the most natural lighting in their classroom progressed 26% faster in reading and 20% faster in mathematics in classrooms with high levels of daylight (Heschong Mahone Group, 1999). The present research has been motivated by this specific link between an improvement of the light quality and school performance increase.

Although the natural light in Libya, due to an always clear sky, is potentially sufficient to supply the necessary lighting of its buildings, and the resort to permanent artificial light limited, a protection against the hot solar radiation is in return necessary. It is this issue which the author wishes to address in this study of strategies for natural classroom lighting in hot and dry climates.

2 Sustainable Visual Environments

The idea of sustainability is an important part of contemporary architecture. Concerns related to the creation of sustainable architecture, sometimes wrongly narrowed down to "low energy building" concepts, in fact go far beyond the energy related issues. While they are focused on environmental targets, they must also take into account factors such as the building's aesthetics, functions, internal microclimate and other aspects which affect the human's psychophysical state.

Two elements of sustainable building design which have direct effects on student performance are natural daylighting and indoor air quality. Studies now show that better indoor air quality in schools results in healthier students and faculty, which in turn results in fewer student absences and further improves student achievement (Karanikoloudis G. 2005). Recent studies on the effect of natural daylight in schools reveal that students perform better in daylit classrooms, as well as various other health benefits. Sustainable design, by definition, uses daylighting principles and helps improve indoor air quality, thus helping to eliminate health conditions related to closed indoor spaces and other building-related illnesses.

The presence of daylight in buildings maximizes architectural potential while increasing human comfort and visual perception. Architecture literally depends on light, be it natural or artificial. As light reveals the forms and the spaces created within a building, it simultaneously reveals the design and intention for which it was originally designed and extends its value beyond mere functional use (Guzowsky, 2000).

To guarantee a comfortable and 'healthy' luminous environment, and control the amount and distribution of natural light that enters a space, a good daylighting strategy is essential. This is generally composed of more than a simple opening in the façade (window) or on the roof (skylight). Depending on the local climate, and the building's orientation, functions and requirements, customized solutions or devices may need to be implemented.

Daylighting systems can range from simple static features (louvers, light-shelves, fixed overhangs, laser-cut panels, prismatic elements, anidolic systems, etc.) to adaptable dynamic elements (blinds, movable lamellae, advanced glazing, holographic optical elements, etc.) and/or a combination of these elements (Tuaycharoen et al., 2007). The palette of devices available is very broad. Numerous cutting-edge techniques are constantly being implemented in the field of design to increase daylight penetration within indoor spaces, improve distribution and uniformity, control direct sunlight and/or reduce glare (Wienold et al., 2006). It should be noted, however, that although numerous methods have been developed for the assessment and prevention of glare from natural light, no method is currently available to assess the simultaneous impact of both daylight and artificial lighting sources on the perception of glare (Boyce et al., 2003).

Any given visual activity has different relationships with the spaces surrounding it. The architectural spaces must meet very complex requirements, including the various human needs for a specific orientation in space and time and also needs related to the society and culture. Indeed, light, both natural and artificial, plays a key-role in creating a mood and an atmosphere that should meet an occupants' expectations (functions, aesthetics, ergonomics, etc.) and demands (privacy, concentration, etc.), while facilitating perception and expressing a design message of its own (Kramer, 2001).

Thus daylight, in the context of design, should not be considered as an afterthought, taken into account after the spatial characters of the building have already taken shape. Rather, daylight should be valued as a necessity that literally drives and directs the design of a built environment. From its early stages of conception and development, daylight should dictate the quality of the internal spaces, ultimately leading to buildings which are economically cheaper to run, less harmful for the environment, and, above all, healthy, inspiring and stimulating for their occupants.

3 Methodology

Because of its very high sunshine levels, Libya's architecture is particular attentive to the protection of school buildings and the window openings against solar radiation. This helps reducing the excess heat caused by the sun, as well as the glare caused by direct sun radiation and the extreme luminous differentiation in indoor spaces. With respect to the classroom's orientation, the solar protection is usually obtained through wall ledges or semi transparent curtains.

The consideration of natural lighting in the research phases is a main objective. Few studies consider the impact of solar protections on the natural lighting. In certain cases, artificial lighting is even used because the solar protections are too efficient. This thus leads to an over consumption of energy while the solar protection is meant to reduce the energy costs. Thus, it is important to find a compromise between efficient solar protection and suitable natural lighting inside the buildings.

In sub-tropical climates, Such as Libya, the main sources of energy consumption inside school buildings are the lighting and air conditioning. Between these two sources, lighting represents 80% of the total energy consumption. Moreover, the fact to use the air conditioning to compensate the heat of the light represents a significant part of the total cooling costs of a building during the summer months. This is why many researchers actively explore the possibilities to incorporate daylight in the architectural lighting design, in order to reduce the energy costs of the buildings (M. Bodart, A. De Herde, 1987).

In order to do this, the research team studied the traditional orientations of school buildings. For example, school buildings with openings on the South and

East façades are more protected from the uncomfortable dominant winds. The team elaborated natural light strategies according to their uses and temporality.

Initially, a simulation method will be validated, which will be used to evaluate the proposals which will be presented in the continuation of this thesis, and which will be the result of the inventory of the methods which are found in the traditional way of building in Libya. The classroom which was studied here to develop the work method is a standard, recently built class rooms, with openings missing sun protection on one side.

4 Natural lighting strategies

Natural lighting strategies aim to capture and spread a maximum of natural daylight to avoid visual discomfort. A clever use of natural daylight will thus help reducing the energy consumption spent on lighting while still providing adequate illumination.

These natural lighting strategies must be designed to simultaneously meet the needs of the users and the requirements of the building, thus finding a balance between the conflicting needs of transmission and protection. Specifying daylighting solutions for energy efficiency, comfort and well-being can, however, be a very complex task. They are often highly dependent on climate, latitude, orientation and function, in which many factors and variables can diverge from each other thus making the selection and optimization of different daylighting systems extremely difficult.

This study focused on the following strategies for daylight usage:

- Spreading out of natural daylight in such a way that it creates a good distribution of the light inside the building and facilitates its penetration in a given space.
- Protection against solar radiation or glaring light which have negative consequences on the spatial activities, such as reflected sunshine glaring on the desks, chalkboards and walls.
- Control of the natural daylight in order to manage the quantity and distribution of light in a given space according to the needs of its occupants.

5 Combined Lighting

A class room cannot be adequately lit by natural light all year long. It has to be combined with artificial light for night-time use and as an additional source of light during days when natural daylight is insufficient. Artificial and natural lighting must therefore be considered from a complementary point of view and not separately. Figures 2 and 3 explain the mechanisms of energy saving strategies through the use of natural daylight. It also illustrates the variations of natural and artificial lighting for a classroom whose dimensions are 6m long and 3 m high.

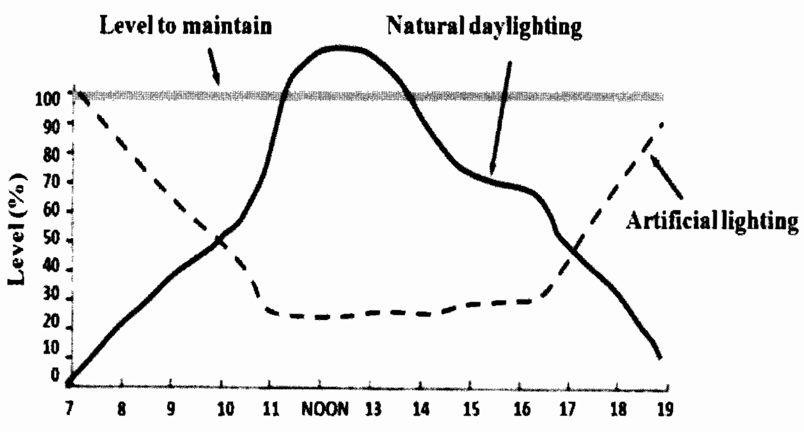


Figure 2: Principles of the combined lighting strategy: to increase the illumination level by using artificial lighting in places where the natural daylight is not enough.

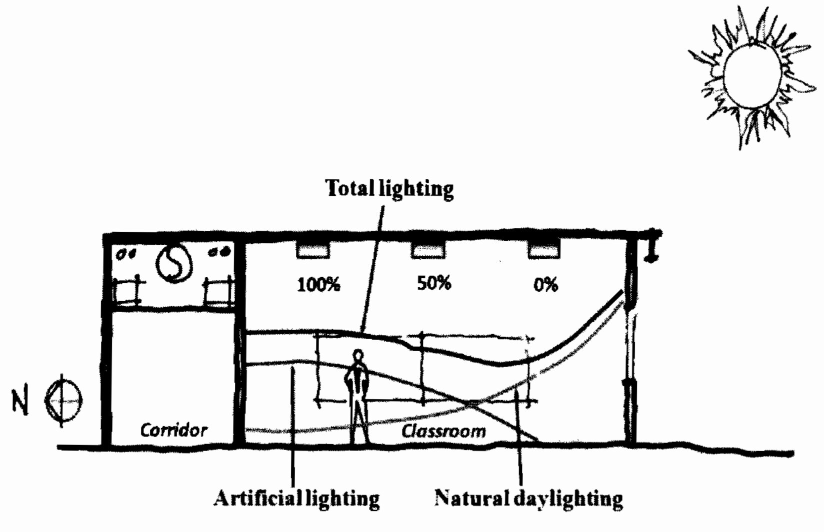


Figure 3: The combined lighting strategy (source: Drawing made by author).

This combination of artificial and natural lighting results in a significant saving of electrical energy, while providing a good level of visual comfort in indoor spaces. For that purpose, it is necessary to know how much artificial daylight is required. This will automatically send us back to the availability of natural daylight, its daily and seasonal variations, and its penetration in indoor spaces.

6 Classroom's Specifications

The classrooms selected for this study are selected from the Primary School Prototype Projects (see Figure. 4), and have little controlled natural lighting. The classroom is usually occupied from 7:00 a.m to 3:00 p.m , and is side-lit with unilateral windows that account for 20% of the floor area.

The school is located in Ghadames, latitude 30.1°N, longitude 9.5°E, with a desert climate. The classroom is on the ground floor of a building facing east and south. The dimensions of the classroom are 6m wide x 8m long x 3.18m high. The working plane is situated at a height of 0.85m above floor level.

The finishing materials of the classroom were selected among the materials that are generally used in primary school contruction:

- Floor : stone coverings, reflection coefficient 25 to 45%
- Walls : cream paint reflection coefficient 60 to 70%
- Ceiling : white paint, reflection coefficient 70 to 80%
- Ground coverings: concrete, reflection coefficient 20 to 30%

It is assumed that there is no building in the vicinity that could obstruct direct light from entering the windows. This information will be used for the computer simulation.

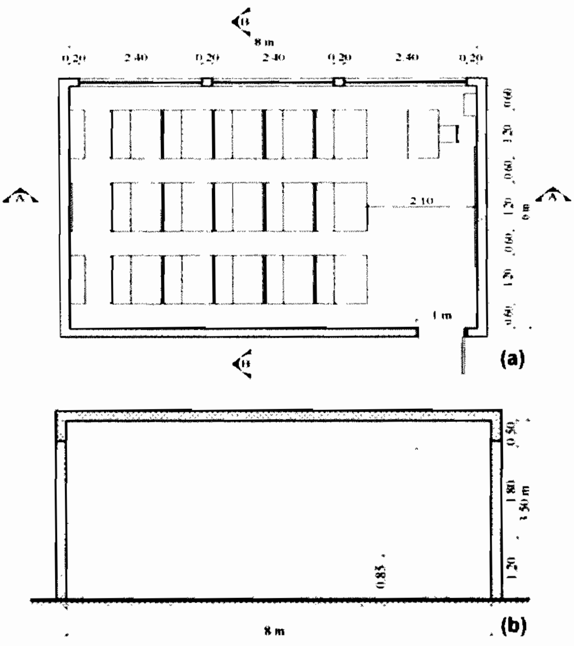


Figure 4: Plan (a), section (b) of a typical classroom in Libya (source: Drawing made by author).

7 Artificial Lighting System

Following is a description of the Artificial Lightig system used in Primary school Buildings.

Even though primary school buildings are mainly used during the day, an artificial lighting system may have to be used in case of insufficient daylight. In the prototype projects, the classroom is fitted with six lights, each using two 58W tubular fluorescent lamps. The lights are fitted on two rows perpendicular to the windows. Both rows are connected to one single switch (see Figure. 5).

Schools are usually not equipped with an automatic lighting control system or a control according the availability of natural daylight. Obviously, a substantial amount of energy could be saved if the use of light was made strictly according to the occupancy rate of the rooms (Rea, M.S., Dillon, R.F. et Levy, A.W, 1987).

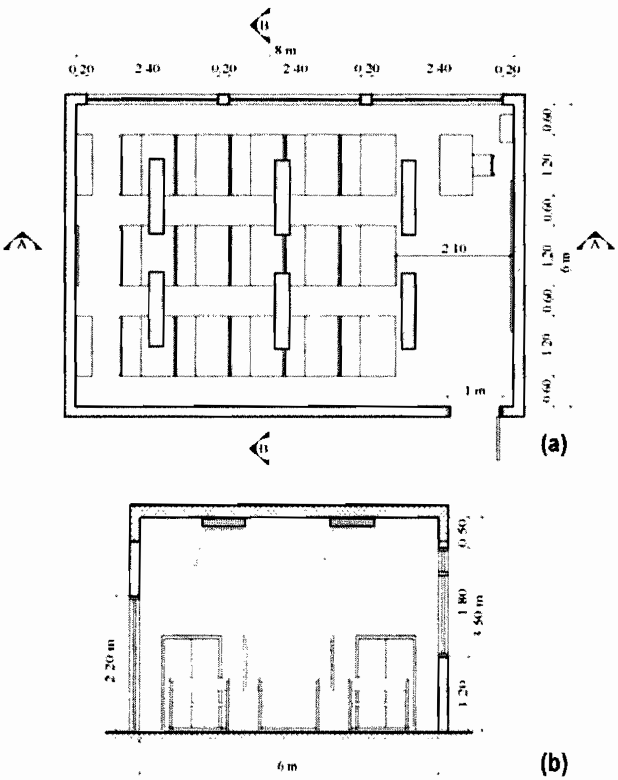


Figure 5: Plan (a) and section (b) of the artificial lighting system of a typical classroom in Libya (source: Drawing made by author).

8 Prediction and Assessment Method

The objective of a method designed to assess the lighting level within a certain space is to determine the quantity and distribution of the penetrating natural daylight (Konya, A, 1984). Under clear skies, the quantity and quality of the light are continuously changing. Indeed, within less than 12 hours, a space is often lit by several sources (sun, sky vault, reflected light, etc.) with sunbeams coming from different directions (see Figure. 6).

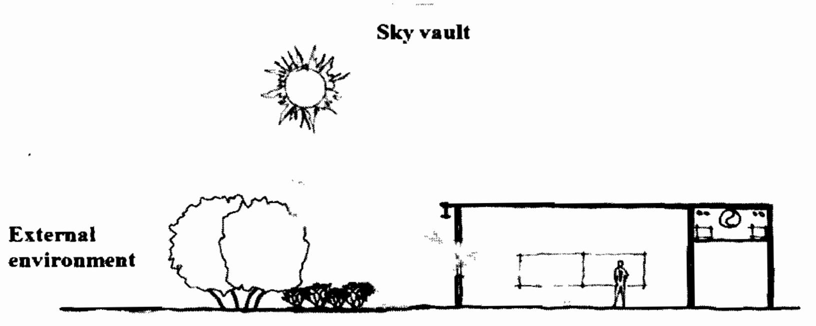


Figure 6: The different external daylighting sources in a building.

In desert areas, the direct light radiation is combined with the reflected radiation. The sky can be described as clear, blue and cloudless. Thus, in such a physical environment, the direct sources of natural daylight present a tremendous importance.

It is thus crucial to stop direct sunshine penetrating in the classrooms during class hours, generally, between 8:00 and 3:00 p.m. Protections designed on the specific dates of 22 June and 22 December (summer and winter solstices) during the above-mentioned hours, will be efficient all year-round (see Figure. 7).

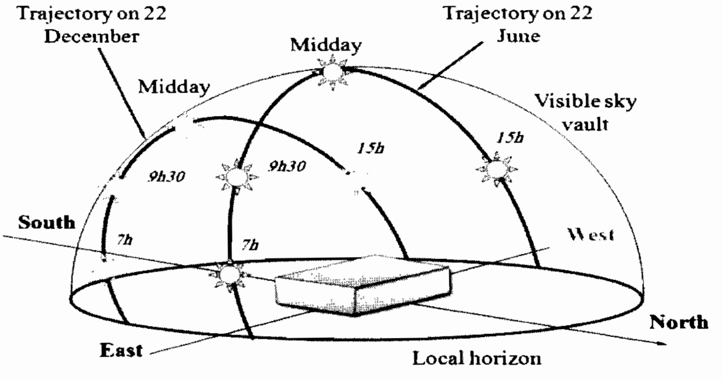


Figure 7: The visible movement of the sun.

8.1 Daylight Factor (DF)

For the evaluation of the day-lighting conditions prevailing in classrooms, where the adequacy of daylight is the main objective, the daylight factor was considered as the most appropriate parameter for indicating the quantity of admitted daylight and consequently the efficiency of the day-lighting design. The daylight factor values (CIE overcast sky) were calculated using DIAL-EUROPE software (see Figure. 8).

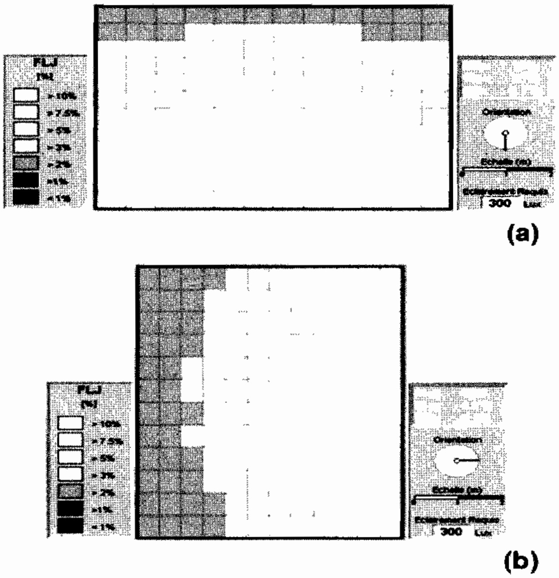


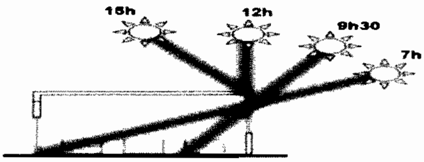
Figure 8: Distribution of daylight in a South (a) and East (b) oriented classroom.

One notes through Figure 8 that the percentage of the DF near the windows and in the middle of the classroom exceeds the reference value of 2%, which can create situations of backlighting, strong glare and of overheating due to the penetration of the sun in the classroom.

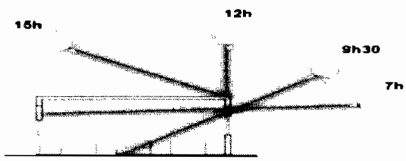
8.2 Scale model simulation

Scale model simulation is a technique used to assess natural day-lighting linked to sunshine in indoor spaces. This simulation method, still widely recognized today, is nevertheless an old method and has been used since 1920 (Willbold-Lohr, G, 1988). The scale model simulation for the evaluation of the lighting does not pose a problem because the length of visible light wave is very short compared to the dimensions of the object to be studied. The scaling down of the simulated item will only slightly modify this relationship and does not affect the internal or external lighting conditions (Papamichael, K. et Beltran, L, 1993).

The scale model was designed on the basis of a typical classroom. The use of a scale model was first preferred to digital simulation because of the sensitive aspect of the atmosphere images that they produce, reconstituting a better feeling of indoor atmospheres. The model allows identifying the secondary effects of sunlight penetration in the classrooms, such as the glare induced by solar stains on the desks, chalkboards and walls (see Figure. 9).



30N.22/June, East orientation.



30N.22/December, East orientation.

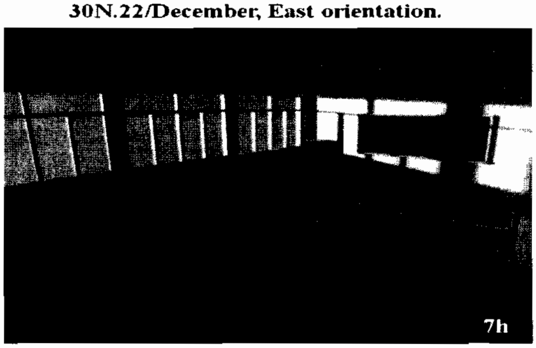


Figure 9: Use of scale models for day-lighting simulation (diagram of the penetration of direct sunlight in a classroom, 30° N latitude), (source: Drawing made by author).

One notes through Figure 9 that the East oriented classroom benefits from the morning sun but the solar radiation is then difficult to control because the sun is low on the horizon. During the winter months, the sunlight is not as strong but penetrates farther into the classroom than in summertime when the sun is high in the sky. On the other hand, in summer, the eastern orientation presents a higher solar exposure than the southern orientation, therefore, there is a real risk of glare and the sun can induce a significant overheating, which is not conducive to the student's best interest.

9 Conclusion

From these models, one can note that the studied classroom poses problems in terms of luminous comfort and overheating necessitating a reconstruction of the design of teaching spaces while better controlling the luminous qualities of the spaces. These initial results induce the hope to explore other solutions that will result from the study of the architectural devices implemented in the traditional Libyan style of building and to research how they can be used in a modern context with newly evolved construction methods and materials.

This study will provide the appropriate daylight strategies that achieve the quality of light needed in order to improve student's academic performances as well as saving electrical funds.

In conclusion, this study presents a serious endeavor to apply sustainable architectural design strategies to utilize natural daylight. With an ever-growing energy demand, rapidly developing countries such as Libya require ecological building strategies that will improve the illumination in classroom-like environments. This equilibrium is thus obtained while still achieving important human satisfaction and productivity.

The concept of sustainability has to go beyond the exclusive optimization of ranging energy performance factors which lead to a reduction of consumption and environmental impacts. It must also acknowledge the physical, physiological and psychological human needs. Sustainability calls for long-term changes through the interplay of several interconnected systems, adopting an integrated approach to architecture where a decision in one area can influence another. In this context, daylight is an intriguing aspect of design in which environmental, energetic, aesthetic, social, cultural, financial and human aspects simultaneously work together.

Thus, this first study makes it possible to develop various evaluation methods that are simple to implement and provide easily workable results for the natural lighting of classrooms from a quantitative and qualitative point of view.

References

Association Française de l'Éclairage (AFE). (1995). Vocabulaire de l'éclairage, Paris : Société d'Éditions Lux.

Boyce, P., Hunter, C., Howlett, O. (2003). The benefits of daylight through windows. Troy (NY): Lighting Research Center.

Guzowski, M. (2000). Daylighting for sustainable design. New York: Mc Graw-Hill.

Heschong Mahone Group. (1999). Daylighting in schools: An investigation into the relationship between daylighting and student performance. Report submitted in The Pacific Gas and Electric Company on behalf of the California Board for Energy Efficiency Third Party Program.

Karanikoloudis G.(2005). Study of design strategies for the improvement of daylighting in a typical classroom. Diploma thesis submitted in the Department of Civil Engineering, Aristotle University of Thessaloniki.

Konya, A. (1984). Design Primer for Hot Climates. Architectural Press, London.

Kramer, H. (2001). Mastering office lighting. International Lighting Review, Philips Lighting.

M. Bodart, A. De Herde. (1987). Global energy savings in offices buildings by the use of daylighting, Energy and Buildings 34.

Mc. Nicholl, A. and Owen L. J. (Eds). (1994). Daylighting in Buildings. Maxi-Brochure prepare par Energy Research Group University College Dublin pour European Commission DG XVII for Energy.

Page, J et al. (1994). Daylighting developments .A European Perspective. Proceedings European Directory on Energy Efficient Buildings.

Papamichael, K. et Beltran, L. (1993). Simulating the daylight perfomance of fenestration systems and spaces of arbitrary complexity: The IDC method. Proc. of 3rd Int. Conf. Building Simulation'93, 16-18/08/93, Adelaide, Australia.

Rea, M.S., Dillon, R.F. et Levy, A.W. (1987). The effectiveness of light switch reminders in reducing light usage. Lighting Research and Technology.

Scartezzini. (1991). L'éclairage naturel dans le bâtiment. Proceedings CISBAT'91, 10-11/10/91, EPFL, Lausanne.

Tuaycharoen, N., Tregenza, P.R. (2007). View and discomfort glare from windows. Lighting Research and Technology, 39.

Veitch, J. A. (2004). What's new in lighting research? The broad view, Proceedings of International Symposium on Workplace Lighting, Dublin, Ireland.

Wienold, J., Christoffersen, J. (2006). Evaluation methods and development of a new glare prediction model for daylight environments with the use of CCD cameras. Energy and Buildings, 38.

Willbold-Lohr, G. (1988). Scale model as design tool. Proc. Of Building 2000, Barcelona.

Sustainable Construction Materials & Technologies

Although the construction industry is often (inappropriately) labeled 'a mature industry' with the implication that it does not deserve government investment in R&D, the papers in this section demonstrate a diversity and vitality to pressing societal problems. The material consequences of how a society builds have a large impact on all the pillars of sustainability - social, economic and ecological. The choice of materials, techniques and technological processes needs to be appreciated as a significant dimension for creating sustainable development - at macro and micro levels - with continuing impacts over the whole life of the building. Some of the many issues embrace the longevity, durability and robustness of the built environment, the diverse ecological impacts triggered by the choice of materials, the affordability of materials, the end of life questions (demolition, deconstruction and reuse or decomposition), the mass flows that the built environment represents, as well as the capacity of materials to passively moderate the indoor environment (particularly when integrated with design). Far from being well understood, more applied research, development and demonstration are needed if societies are to meet the many challenges presented by the aspirations of sustainable development, including mitigation and adaptation to climate change.

The nine papers (five in this chapter and four in chapter 1, Volume II) are a snapshot of a much wider and deeper emerging literature, but nonetheless provide a number of insights and raise a number of challenges. The range of issues and scales of focus varies across embodied energy and carbon, improved use of appropriate resources and technologies, biodegradable materials, the provision of adequate housing, reduction of waste, improved integration of technologies into the design and construction process. More significantly, the focus embraces the physical properties materials (whether earth construction, roundwood timber, paper-based walls, phase change materials, etc) as well as the application of materials in the actual contexts of construction, codes and regulation, inhabitation and operation. There is a balance between the application of some existing materials and techniques and new materials and techniques (e.g., paper-based walls, phase change materials, thin materials for facades, using waste to strengthen existing materials, etc).

Collectively, these papers provide useful explorations into alternatives to some wasteful and expensive materials and techniques that have predominated in many parts of the world for the past 60+ years. They demonstrate the potential for an increased range of potential solutions - drawing both on traditional methods that are validated or updated as well as new materials and construction techniques.

Serious and urgent implied questions arise about whether the choices surrounding materials and construction processes ought to be incorporated explicitly into the definitions, criteria, tools and evaluation processes for sustainable buildings. Both conceptually and practically, the recognition of the economic, social and particularly ecological consequences of materials (whether embodied energy, pollution, use of scare resources, end of life disposal, etc) deserves more integration into our collective thinking. A re-examination of the criteria for what constitutes successful sustainable building would be appropriate.

Richard Lorch
Editor, Building Research & Information

Performance of Mud Bricks with Shred Tires as Sustainable Construction Materials

Hamed Niroumand, Khairul Anuar Kassim
University Technology Malaysia

Abstract

This paper presents a survey on the role of the shred tires in the mud brick compressive strength. Mud brick construction is very compatible with the laws of ecology and harmonizing with the environment. Mud brick consists of clay, water and other different materials. The massive implementation of mud bricks in construction can make an evolution due to its low cost and its high compressive strength compared to concrete blocks, which are massively used nowadays. Many experiments have been recently conducted on mud blocks without additional materials, and they resulted in weak compressive strength. Therefore, many testing in mud bricks with different material were needed. Experiments on the role of shred tires in the compressive strength of the mud bricks were performed. The survey used this cheap material in the experiments, since it's considered as part of the environmental pollution and is not very used after the consumption in the automotive industry. The results showed an increase in the compressive strength of the mud bricks with shred tires.

Keywords *Shred Tires, Kaolin, Mud Bricks, Sustainable Materials, Recycle*

1 Introduction

Mud architecture is a traditional natural as a construction material, has a worthy status in terms of environmental impact. Due to the environmental friendly design, mud architecture gains advantages in saving natural resources such as mountains and forest, by using neither cement nor rock and sometimes only little wood. It saves the usage of other building materials, since it mainly consists of mud mixed with water. Mud construction offers durability and recycling ease, due to the subordinate materials that are mostly garbage for recycling (bottles, cans and newspapers). As a sustainable material, it has minimal energy demand, due to the cool interiors offered during the summer, by obtaining temperatures approximately 24°c to 26°c. Automatic temperature, which create warm interior in the winter are controlled by a passive cooling system. Minimal financial needs and an ease in construction makes it affordable for everyone. On the other hand, humidity is a crucial factor that causes damage and sometimes even fungus to the mud construction.

Mud bricks should be prepared in ideal conditions by using mud, which contains clay content in a percentage of not more than 80% and not less that 50%, while the rest consists of sand and granular material. The crystal structure of clays is very important to be understood, since it affects directly the performance of the mud brick resistance. Clay minerals are the hydrated aluminum silicates, which are classified into three main groups: the kaolin group, the montmorillite group and the illite group. Generally clay is characterized by an expanding crystal structure. The montmorillite group and the illite have an expanding crystal structure, while the kaolin clays do not have this kind of structure. Clays with expanding crystal structures expand in volume, when water is added to them and after water is evaporated, drastic shrinkage and cracking occurs. Thus, the mud bricks made of mud that contain kaolin clay (even in a high percentage) can cause only little cracking, since they don't have an expanding crystal structure. They are also very strong and offer a high heat resistance. Due to its not expanding structure it can show only little water damage, even if they get wet shortly after they have been made. Pure kaolin is white and usually is found at the subsurface of clay.

Mould consists in four boards nailed together with handles attached at either end. Firstly a selection should be done between a single and a multiple mould. The first choice is the single brick moulds, because it offers the possibility to tramp the soil very firmly. A special consideration should be given also to the size of the brick. In this research the brick used for the tests and experiments, were 0.1m high, 0.1m long and 0.1m wide.

Tire shreds are typically shaped and they have size variations that range from 0.01m to 0.25m long. The shredding process usually exposes the tire's internal steel belt or bead, particularly along the edges of the shreds. The average loose density of the tire shreds typically ranges from 39.88 kg/ to 55 kg/ . The average compacted density ranges from 63.39 kg/ to 87.8 kg/ . Shred tires, are linked together by earth and they support the tensile strength in the mud bricks. Figure1 shown shred tires that used in tests.

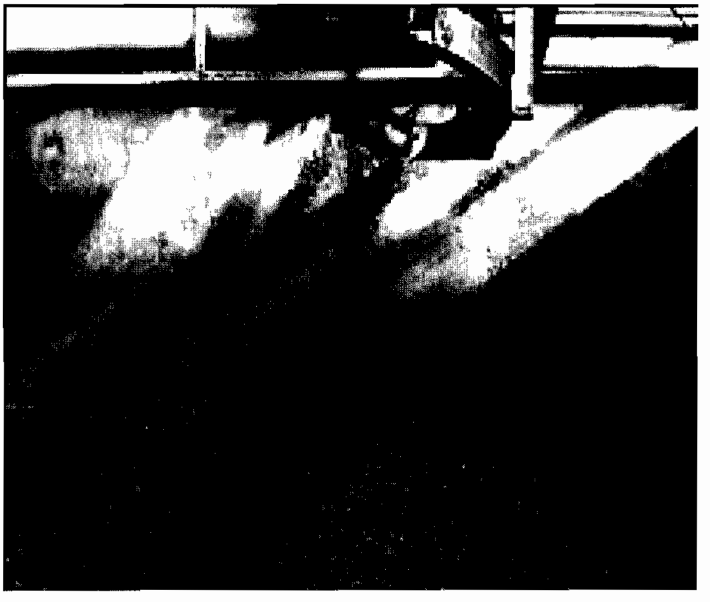


Figure1.View of Shred Tires

This research tested on compressive strength of shred tires reinforced mud architecture with moisture content of 20% in pure kaolin due to compaction tests on kaolin with different water content in geotechnical laboratory that they shown in Figure2.

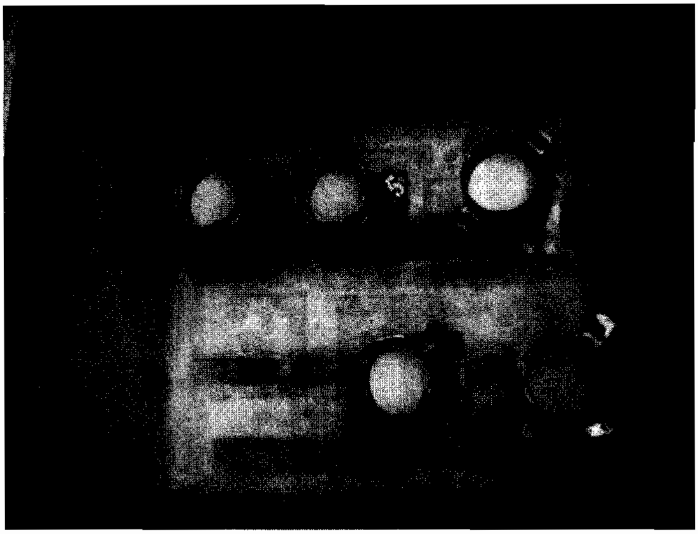


Figure2.Compaction Test of Kaolin

2 Experimental Test

2.1 Materials

The materials used in the test, conducted in this research were: pure kaolin, shred tires and water.

The Shred tires used were of the same size, since they were cut by a shredder tire. The shred tires were obtained from deterioration tires that are used in the vehicles, mainly cars. They consisted of cotton, which can be used for the tension condition in mud bricks. Tire recovery is the process of the recovery of the vehicle tires that cannot be used any more, due to the wear or any irreparable damage. These tires are among the largest and most problematic sources of waste, due to the large volume produced and their durability. The same characteristics that make waste tires so problematic also make them one of the most re-used waste materials, as the rubber is very resilient and can be reused in many other products. Approximately one tire is discarded per person on one year.

Most of the cost of these scrap tires were used to make automotive and truck tire re-treads with landfills, minimizing their acceptance of whole tires and the health and environmental risks of stockpiling tires. Thus many new markets have been created for scrap tires. Growing markets exists for a majority of scrap tires produced every year and they are supported by the State and Local Government [2]. Tires are also often recycled for use on basketball courts and new shoe products. However all the material recovered from the waste tires, known as "shred" is generally only a cheap "filler" material and is rarely used in high volumes.

The tire crumb in applications such as basketball courts could be better described as reused" rubber rather than "recycled".

The Kaolin used in the tests was pure one, without any addition material. It consists of a clay mineral with the chemical composition $Al_2Si_2O_5(OH)_4$. Kaolin is a layered silicate mineral, with one tetrahedral sheet linked through oxygen atoms to one octahedral sheet of alumina. Kaolin-type clays undergo a series of phase transformations upon thermal treatment in the air at atmospheric pressure. Endothermic dihydroxylation (or alternatively, dehydration) begins at 550-600 °C to produce disordered metakaolin, $Al_2Si_2O_7$, but continuous hydroxyl loss (-OH) is observed up to 900 °C and has been attributed to gradual oxolation of the metakaolin. Because of historic disagreement concerning the nature of the metakaolin phase, extensive research has led to general consensus that metakaolin is not a simple mixture of amorphous silica (SiO_2) and alumina (Al_2O_3), but rather a complex amorphous structure that retains some longer-range order (but not strictly crystalline) due to stacking of its hexagonal layers.

$$2\ Al_2Si_2O_5(OH)_4 \rightarrow 2\ Al_2Si_2O_7 + 4\ H_2O$$

Further heating to 925-950 °C converts metakaolin to a defect aluminuim-silicon spinel, $Si_3Al_4O_{12}$, which is sometimes also referred to as a gamma-alumina type structure:

$$2\ Al_2Si_2O_7 \rightarrow Si_3Al_4O_{12} + SiO_2$$

Upon calcination to ~1050 °C, the spinel phase ($Si_3Al_4O_{12}$) nucleates and transforms to mullite, $3\ Al_2O_3 \cdot 2\ SiO_2$, and highly crystalline cristobalite, SiO_2:

$$Si_3Al_4O_{12} \rightarrow 2\ Si_2Al_6O_{13} + 5\ SiO_2$$

2.2 Mixing of Different Materials

The Figure3 shown combination of dry kaolin with the optimum moisture content, due to compaction test in different tests and then it is mixed by kneading until cohesive soil is reached.

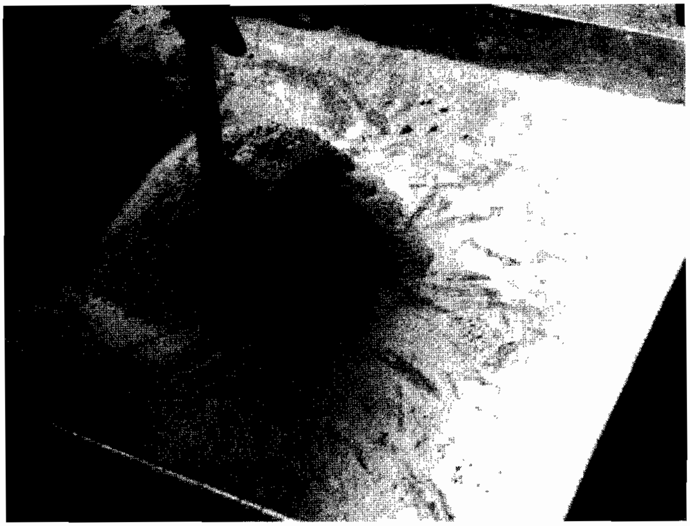


Figure 3.Mixing of Kaolin with optimum moisture content

2.3 Preparation of Mud Bricks

The dimensions of the bricks used for the test were $0.1m \times 0.1m \times 0.$. The mixture prepared before, is placed in three layers in steel moulds. It consists of two layers of shred tires that are placed at the height 1/3 and 2/3 in the brick. The Figure4, Figure5 and Figure6 shown prepare procedure of mud bricks with shred tires.

Figure4.View of Different Steps in Compressive Test

Figure5.View of 1/3 Layer of Mould

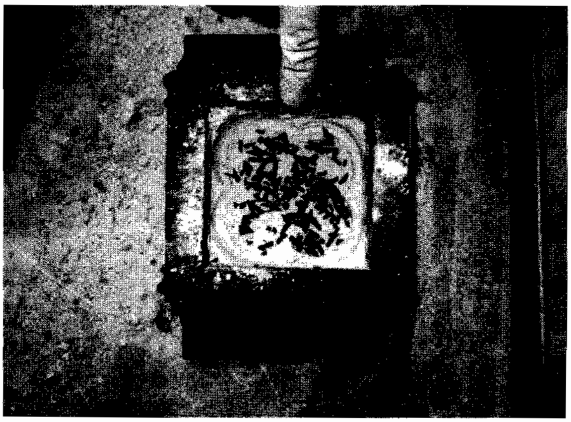


Figure6.View of Shred Tires In 1/3 Layer of Mould

2.4 Test of Mud Bricks

The mud bricks were prepared for 4 tests. After preparation, they were taken out from the moulds, and they were tested for their compressive strength in different days that tests shown in Figure7 and Figure8. The results of the tests of the compressive strength on mud bricks with shred tires obtained in days 3th, 7th, 14th and 21th are illustrated at table 1.

Table 1.The results of compressive test of mud bricks with shred tires

Type	**Days**				**Water absorption (%)**	**Loss of weight (%)**	
	3	7	14	21	3 days	4 - 14 days	15 - 21 days
Kaolin(10kg) + Water(2kg) +Shred Tires(0.06kg)	2.19 N/m	2.62 N/m	3.91 N/m	4.28 N/m	20.14	6.5	1.25

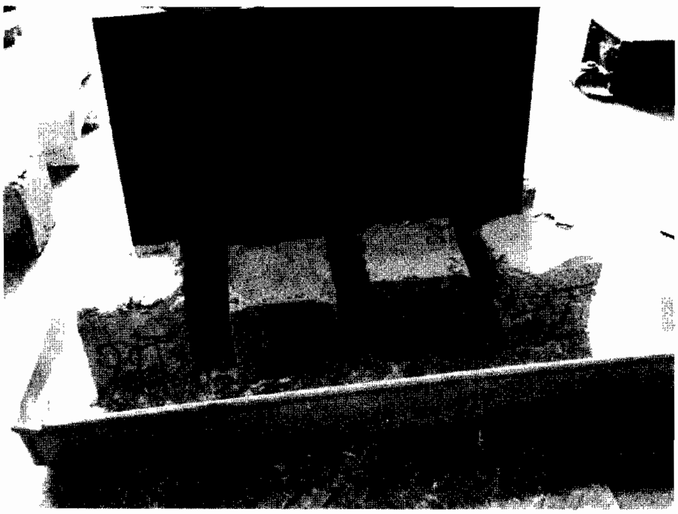


Figure 7.View of Different Cases in Compressive Test

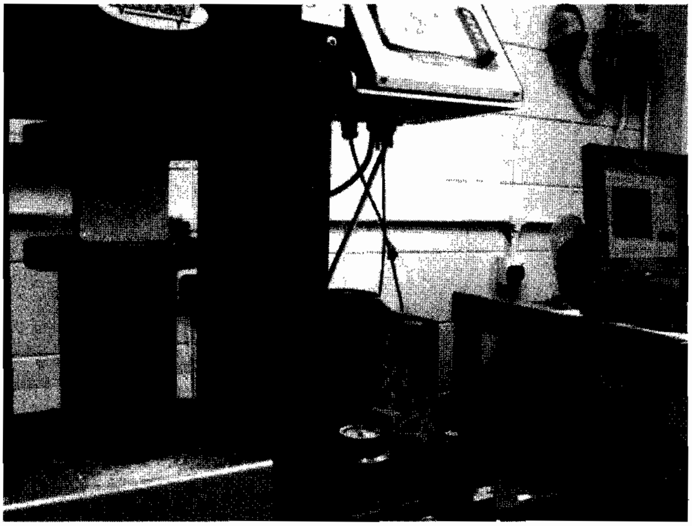


Figure 8.View Compressive Test in Lab

3 Conclusion

The result of the compressive strength test conducted on the mud bricks with shred tires are illustrated in table 1. These results showed that the compressive strength of the mud bricks that contain shred tires increases with time. Shred tires increased the status of tension in mud bricks. In different cases shred tires increased the properties of the compressive strength of the mud bricks. It was observed that the interface layers of shred tires materials increased the compressive strength and geometrical shape gave the best result and this kind of mud bricks can be formed into different shape and size depending upon requirements, rendering it efficient as a sustainable material. The performance of the mud bricks without any additional material was very bad in the case of the earthquake that happened in Boroujerd (Iran) in 2007. We hope that the shred tires will be part of a massive implementation in the mud construction so it can offer a higher carrying out capacity in the future.

References

Bellotto, M., Gualtieri, A., Artioli, G., and Clark, S.M. (1995). "Kinetic study of the kaolinite-mullite reaction sequence. Part I: kaolinite dehydroxylation". *Phys. Chem. Minerals* 22: 207-214.

Liu,H., Mead, J., Stacer, R. Chelsea Center For Recycling And Economic Development. (1998). Environmental Impacts of Recycling Rubber in Light Fill Applications: Summary & Evaluation of Existing Literature University of Massachusetts

Niroumand, H.," Mud Bricks with Shred Geogrids as Sustainable Materials", *ICESGBT 2010, Tamil Nadu, India,* 15-17 March 2010

Niroumand, H.," Earth Bricks with Wood Chips", *CAAS 2010, Singapore*, 26-28 Feb 2010

Niroumand,H.(2006), Soil Stabilization by Lime, Persian language, *Naghoos Publisher* , Iran

Recycling of Waste PET Bottles as a Voluminous Alternative Material for Making Composite Panels

Mohammad Arif Kamal[1], Syed Javed Rizvi[2]
[1]*Department of Architecture, King Fahd University of Petroleum & Minerals, Saudi Arabia*
[2]*Department of Petroleum Studies, Aligarh Muslim University, India*

Abstract

PET Bottles are finding more and more applications in disposable packaging mainly in beverage segment. As on today not only cola companies are using PET bottles but also fruit juice, mineral water and liquor industries have accepted PET bottles for packaging of their product. The transparent polyethylene terephthalate (PET) bottles have become increasingly common and are used for mineral water, soda waters and soft drinks. These bottles are of – course, very user friendly but environmental hazards are associated with PET Bottles. Huge consumption of these commodities causes volumetrically large PET wastage on daily basis. They contribute a large part in urban garbage. In this paper, an effort has been made to recognize the possible application by recycling waste PET bottles for manufacturing of composite panels. These panels can be manufactured using waste PET bottles as a low cost voluminous filler alternative material instead of costly foam core. PET bottles have a good compatibility with many other matrix materials. These composite panels can be manufactured under different sizes and modules and hence they can be used for various economically feasible architectural and building applications. Various building applications of these composite panels have also been discussed in this paper.

Keywords: *Recycling, PET Bottles, Composite Panels*

.

1 1 Introduction

PET is used as a raw material for making packaging materials such as bottles and containers for packaging a wide range of food products and other consumer goods. Examples include soft drinks, alcoholic beverages, mineral water, detergents, cosmetics, pharmaceutical products and edible oils. PET is one of the most common consumer plastics used (Wikipedia, 2010). For the first time PET soda bottles were introduced by Pepsi and then followed soon by Coca-Cola in America, but PET Bottles (Polyethylene Terephthalate) were introduced for soft drink packaging first time in India in around mid nineties and since then they have revolutionized the way of packaging for beverage segment. The recent development in PET – PEN blends have made it possible for beer packaging too. Most containers are glossy clear transparent, while some are green in colour. These bottles are use and throw in nature ranging from 250ml to 2.5 liters in size.

The low weight of these PET bottles helps to reduce transportation costs and its convenience has gained it higher consumer acceptance than glass. As a result PET is substituting glass in packaging all over the world as well as in India. As mentioned in wikipedia that worldwide, approximately 1.5 million tons of PET is collected per year. Petcore, the European trade association that fosters the collection and recycling of PET, forecasts that in Europe alone, collection will exceed one million tons by 2010. The estimated increase in consumption in India is about 45,000 tonnes. Huge consumption of these commodities causes volumetrically large PET wastage on daily basis, hence there is a need to manage the large amount of PET waste that would be generated (Narayan, 2001). Alongside efforts to prevent global warming by reducing CO2 emissions, waste treatment has become widely recognized as an important issue for building a recycling- oriented society (Hotta, 2003).

2 Recycling and Sustainable Development

Recycling turns materials that would otherwise become waste into valuable resources. In addition, it generates a host of environmental, financial, and social benefits which are necessary for sustainable development. Sustainability is a relationship, or balancing act, between many factors (social, environmental and economic realities and constraints) which are constantly changing. The sustainability concept, as described in the Common Future (Brundtland Commission Report, 1987) states that:

Sustainable development is a process of change in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations. Sustainable development "...meets the needs of the present without compromising the ability of future generations to meet their own needs."

Jain and Lee (2009) mentioned that previously, the primary factors in materials selection for engineered systems were based on performance requirements and economics (e.g., construction and maintenance costs). The sustainability approach to design and construction challenges architects and engineers to weigh environmental factors, energy/resource consumption, social factors, economic considerations, and performance criteria. When identifying appropriate metrics for sustainability, one is likely to encounter a myriad of proposals and ideas each potentially yielding unique results; however, in general, measures are typically centered on factors that account for the following:

- Minimum resource use
- Low environmental impact
- Low human and environmental health risks
- Sustainable site design strategies
- Higher performance

3 Recycling of Waste PET Bottles as a Lost Cost Voluminous Filler Material for Composite Panels

Polyethylene Terephthalate (PET) is a thermoplastic material, but it cannot be straightway reprocessed to make new bottles. The increase in Acetal Aldehyde content while melting PET in recycling extruder causes serious objection for packaging of soft drinks etc. Another problem with PET bottles is their large volume to mass ratio. According to Central Pollution Control Board of India, a 10,000 tonnes capacity exists for manufacturing of PET bottles and assorted containers. Because of durability and glass-like clarity of PET bottles and containers, a major share of these becomes a long-term asset for the users. However, around 50 per cent of current consumption of PET bottles used is available for recycling. Considering the average weight of 27 g per bottle, 3000 tonnes of PET would amount to 115 million numbers of bottles going into waste that largely remains uncollected and unsold. This figure will multiply many times by 2010 (CPCB, 2010).

Although waste PET bottles can be recycled by special recycling plants situated at Madras, Gajraula, Kanpur and Mumbai, but we emphasized on the use of complete bottle (along with caps) to produce some economically feasible product, without any change in its physical form. These panels can be a very durable solving five issues at the same time (Nienhuys):

- Reduction in waste PET Bottles (environmental waste).
- Thermal insulation of houses and installations.
- No importation and transportation of expensive insulation materials.

- Reduction in the cost of energy used for heating and cooling of buildings.
- No burning of waste causing air pollution.

3.1 PET Bottles as a filler material

There are a number of filler insulation materials, which can be being used in manufacturing composite panels. They are:

- Rigid polyurethane (PUR)
- Rigid polyisocyanurate (PIR)
- Extruded polystyrene (EPS)
- Expanded polystyrene (XPS)
- Phenolic foam
- Mineral fibre

Of these, only rigid polyurethane and polyisocyanurate insulation (collectively called urethanes) expand and autohesively bond to the faces during the manufacturing process. A separate adhesive has to be used to bond the other insulation materials. The autohesive properties make urethane particularly suitable for filling panel profiles and edge details and it is therefore the most commonly used core for composite panels. All the rigid foam insulation materials are produced using chemical blowing agents (Brydson, 1995).

But in our case the waste PET Bottles has replaced the costly foam core. PET Bottles can be considered as "Voluminous Filler Material" and hence they will reduce the amount of matrix material. Another main advantage of waste PET Bottles is that these empty bottles contain large volume of air, which acts as insulating material and provides excellent thermal insulation.

3.2 Compatibility of PET Bottle with matrix materials

As given by (Olesky, 1964), the compatibility between the matrix material and filler material is governed by the thermodynamics. A negative value of Gibb's free energy ($-\Delta G$) is essential thermodynamic condition for compatibility. On detailed investigation we can conclude that if the solubility parameters (δ) are in close range, we can expect the compatibility between matrix material and filler. The solubility parameters for some of the well-known polymers are given in Table 1.

Table 1: Solubility Parameters of various polymeric materials

S. No.	Polymer Matrix Material	δ	S. No.	Polymer Matrix Material	δ
1	PP	7.9	12	Polysulphide Rubber	9.0 – 9.4
2	PE	8.0	13	Polycholoroprene Rubber	9.2 – 9.4
3	PS	9.1	14	Polyvinylidene Chloride	9.8–12.2
4	PMMA	9.2	15	Acetal Resin	11.1
5	PC	9.5	16	ABS	6.05
6	PVC	9.5	17	SAN	5.2
7	Nylon – 6,6	13.6	18	HIPS	5.2
8	Polyisoprene (NR)	8.1	19	PAN	15.4
9	SBR	8.4	20	EVA	8.6
10	Polybutadine (PB)	8.4	21	PVA	9.5
11	PTFE	6.2	22	CA	10.9

The value of solubility parameter (δ) for PET is approximately 10.7. It has been found that Waste PET Bottles do not have good compatibility with Plaster of Paris and cement – mortar mixture. But when the matrix of waste PET bottles is tied up with thin wires of steel and encapsulated with either Plaster of Paris or cement – mortar mixture there was considerable improvement in panel's strength. Steel wires tied over PET bottles; act as linkage between matrix of PET bottle and matrix material. Steel wire mesh also can be used for better strength of panel.

4 Design Details of a Composite Panel

Nowadays Structural Insulated Panels (SIPs) are getting wide acceptance among architects because of their thermal efficiency and faster construction of buildings. They are prefabricated insulated structural elements for use in building walls, ceilings, floors and roofs. SIPs are usually foam core panels, covered with suitable skin materials on both sides as shown in Fig. 1. The most common types of sheathing or skins materials are Oriented Strand Board (OSB) and plywood. Some manufacturers produce panels with fiber-cement sheathing. Composite panels can have facing made up of 3mm ply or veneer and the edging made up of aluminum sections or PVC profiles (Fig. 2).

The shape and size of PET bottles composite can be square or rectangular in nature. They can be prefabricated in different sizes such as 300mm X 600mm, 300 X 900mm, 450mm X 600mm, 450mm X 900mm, 600mm X 600mm, 600mm X 900mm etc. The total thickness of the panel comes out to be approximately 100mm (Fig. 3).

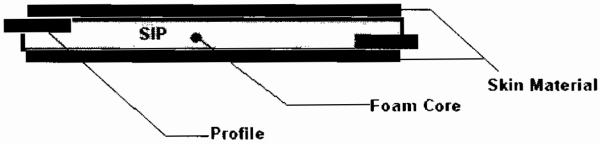


Figure 1: Conventional Structural Insulated Panel

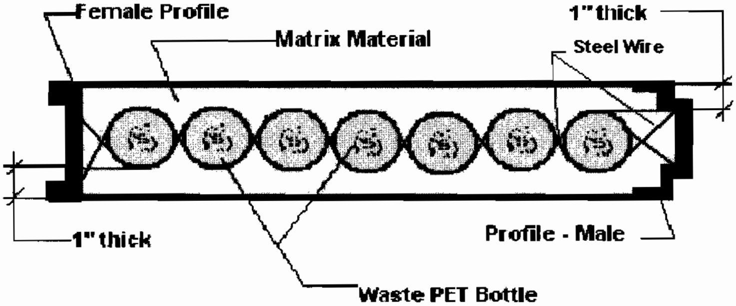


Figure 2: Structural Insulated Panel using Waste PET Bottles as Voluminous Filler

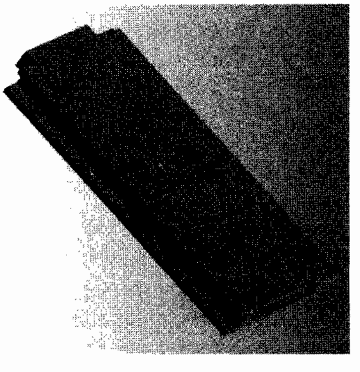


Figure 3: Three-Dimension model of a Composite Panel

5 Building Applications Of Composite Panels

PET Bottles composite panels can be pollution free and environment friendly composite material to a large extent. Due to its lightweight, high strength to weight ratio, corrosion resistance, low manufacturing cost and other advantages, PET Bottles based composites can be an important composite material in architectural applications, construction industry and civil engineering works. These panels can be manufactured in various modular sizes and can be used in many applications as per requirement. Some of the possible applications have been summarized as follows:

Low-density insulation boards, medium-density boards, hard boards, block board and other building components such as walling units and roofing panels can be manufactured using PET Bottles composites.

An important application can be for roof terracing. These panels can be laid over the Reinforced Cement Concrete (R.C.C) roof slab and panel joints can be finished with epoxy or cement mortar. This will eliminate the traditional cumbersome method of roof terracing i.e. laying of brick tiles over the mud phuska. This will act as thermal insulation on the roof top, which heats up the inerior space and thus it helps in natural cooling and conservation of energy.

They can also be used in cladding of wall exteriors, especially on the south or southwest facade of the building in hot & dry and composite types of climate to provide thermal insulation to the building facade from the direct solar radiation. They can be installed or erected on a framework as architectural treatment of façade like aluminum composite panels are used nowadays and can also be as vary therm wall.

These panels are expected to be used in place of galvanized iron and asbestoses sheets. Their thermal insulation is better than these conventional sheets. System is ideally suited for providing durable and economical roofing / flooring in the low cost houses especially for economical weaker section of society in rural / urban areas or hilly regions.

They can also be used as shuttering panels for formwork in reinforced cement concrete construction as substitute for steel panels or ply board sheets.

They can be used as lightweight partitions, false ceiling, colorful laminated panels and lining in interior decoration in buildings.

They can also be used for providing temporary shelters during the rehabilitation work in the case of natural disasters such as Earthquakes, Cyclones and Tsunamis and during the organization of some Indian religious congregations such as Kumbh and Maagh Mela etc.

6 Technological Gap and Future Research

The PET bottles composite panels should not be used as substitutes for conventional structural systems. The concept must exploit the advantages offered by composite panels in terms of lightweight, tailorability, and connectability. In developing innovative design concepts, the way in which performance specifications on structural sub-systems can be utilized needs to be further studied.

The performance and cost of complete PET Bottles composite panels are controlled by their connections and joineries, and little research has been performed to develop connection strategies and details which in the end do not form the weak link in the overall structural system and which are simple, durable and strong. In the research and development of connections, emphasis must be placed on developing light weight, modular, simple, and reliable connectors which can be assembled quickly in order to benefit the construction and assembly process. The economic impact of design concepts in which significant savings can be realized due to systems that reduce assembly costs should be studied. The use of computer simulation to demonstrate new construction methodologies that can show economic advantages should be explored. Industry & design experts are of the view that with the adoption of advanced technologies and some extent of standardization, these problems could be easily taken care of.

7 Conclusion

Waste PET bottles composite panel can be an economical alternative material for various architecture, building and civil engineering applications. Still more research and development is required for the prefabrication to the finalization of the complete process for upscaling of technology from lab scale to commercial level.

Acknowledgements

The author acknowledges the support and contribution of Department of Architecture at King Fahd University of Petroleum & Minerals for facilitating the research.

References

Brundtland Commission Report (1987). Our Common Future, *Report of the World Commission on Environment & Development*, Oxford: Oxford University Press.

Brydson, J.A. (1995). *Plastic Materials*, Fourth Edition, London.

Central Pollution Control Board. (2010). *Plastic Waste Management*, http://cpcbenvis.nic.in/newsletter/plasticwastesept1998/sept98v.htm, Accessed March 5, 2010

Hotta, H. (2003). Recycling Technologies for Promoting Recycling-oriented Society, *NKK Technical Review*. No. 88, 160

Jain, R. & Luke, S. Lee. (2009). The role of FRP composites in a sustainable world. *Journal of Clean Technology and Environmental Policy*, 11, 248.

Narayan, P. (2001). Plastic Waste Management in India. *M. Sc. Thesis. Lund University.*

Nienhuys, S. *Plastic waste insulation for high altitude areas*, http://www.packagingconnections.com/downloads/download132_0.pdf, Accessed March 7, 2010

Olesky, S.S. & Mohr, J.G. (1964). *Handbook of Reinforced Plastics*, The Society of Plastics Industries Inc., New York

Wikipedia. (2010), *Pet Bottle Recycling*, http://en.wikipedia.org/wiki/PET_bottle_recycling.htm, Accessed March 8, 2010

Technologies Using Phase Change Materials (PCM) for Building Passive Cooling.

André Bontemps[1], Laurent Royon[2]
[1] *Université Joseph Fourier, Grenoble, France.*
[2] *Université Denis Diderot, Paris VII, France.*

Abstract

In many regions, it is sometimes difficult to reach acceptable thermal comfort without continuous energy consumption for Heating, Ventilating and Air-Conditioning (HVAC) inside buildings. This paper describes some strategies and some technologies to naturally improve comfort without or with reduced air-conditioning. These strategies are based on using Phase Change Materials (PCM) incorporated in building structures. The PCMs used in this study are described and characterized and a new composite material (polymer/PCM) is proposed. Among the several types of structures that have been studied, a brick filled with this new material has been chosen. The responses to temperature and heat flux variations have been studied. It is shown that the brick thermal inertia is strongly increased and that this construction component presents no PCM leaks.

Keywords: *Heat storage, Phase Change Material, PCM, Building air conditioning.*

1 Introduction

To conserve energy and reduce GHG effects, it has become necessary to seek effective means of reducing peaks in power consumption. However, reducing power consumption can affect thermal comfort in buildings. The development of improved means to manage power consumption and to insure comfortable indoor conditions at the same time is a challenge for the next years, along with the integration of these new solutions in a sustainable architecture which consider the effects on people and the environment.

One way to reduce energy consumption is to use large thermal storage devices, especially in climates where daily temperature variations require both heating and cooling over the same 24 hour period. It is the case in many desert or semi-desert regions, where a very large range of daily temperature can be observed between nights and days for given seasons. Buildings designed to make use of thermal storage include systems which increase their thermal mass. These systems may be used for storage only, or may serve both as storage and as structural elements.

A significant building thermal capacity should contribute in stabilizing the large daily temperature fluctuations and should increase the lag time between the external and internal temperature peaks. Massive construction materials, such as stone, have long been used for this purpose. However, lighter thermal storage materials would be more attractive to consumers. In this objective, Phase Change Materials (PCMs) can be used for thermal storage. Ideally, such materials should be incorporated inside building components. However this technique had limited success because it is difficult to incorporate these materials into existing building substances. The utilization of Phase Change Materials in active and passive cooling/heating of buildings has been a major research topic for the last three decades. Many papers have been published on this subject and their main results can be found in recent reviews (Zalba *et al.*, 2003, Khudair & Farid, 2004; Tyagi & Buddhi, 2007).

The incorporation in construction elements has been carried out in several ways including (i) direct incorporation or impregnation of the construction material, (ii) incorporation of PCM capsules in building components, (iii) manufacturing new panels with PCMs to replace classic wallboards, and (iv) incorporation in a heat exchanger plate to improve performance of a HVAC system.

Many researchers have worked on impregnation of plasterboard or concrete with PCMs (Salyer *et al.*, 1985; Shapiro *et al.*, 1987; Babich *et al.*, 1994; Banu *et al.*, 1998) in order to store / release the energy coming from solar or internal sources. However, this technique can induce several problems. One of them is PCM migration through the walls and subsequent leakage when the PCM is in liquid state. To overcome this problem two types of solutions are proposed: (i) incorporation of PCMs in micro- or macro-capsules (ii) realization of a composite material by embedding paraffin in a matrix. Hawes *et al.*(1993) have considered several means of PCM incorporation, and they have concluded that the PCM must be encapsulated. So, PCMs can be packaged inside containers of

1 cm^3 to few dm^3 (as manufactured by Cristopia) or a plastic panel can be directly filled with PCMs (Ahmad *et al.,* 2006).
A recent process is microencapsulation. Paraffin can be incorporated inside a polymer solid shell whose diameter is varied from 1 to 100 μm. The resulting product appears as dry powder or as emulsion which can be applied in building materials (Jahns, 1999). Recently, Cabeza (2007) has worked on the introduction of a microencapsulated PCM into concrete walls. The PCM melting temperature was 26 °C and its latent heat 110 kJ/kg. This experiment, located at Lleida in Spain, consisted in two test-cells and it has been shown that the indoor and wall surface temperatures were reduced. The author observed that the introduction of microcapsules in concrete did not alter its mechanical properties.
As the thermal conductivity of PCMs is not large enough, a strategy to increase it could be to form a composite with highly conducting materials. Such an approach has been presented in several publications (Melhing *et al.*, 1999; Py *et al.*, 2001).
In this communication, we present several applications of a new material which can be used in several ways such as (i) incorporation in a brick to build a wall, (ii) incorporation in a panel to make a light wallboard, (iii) incorporation in a heat exchanger plate to improve performance of a HVAC system.
After reviewing the different uses of several PCMs, we will present results obtained in our laboratories. The studies allowed us, (i) to measure thermal properties of materials and associated components (Heat capacity, Latent heat, Thermal conductivity), (ii) to measure the thermal response of a brick and of a panel with prescribed periodic boundary conditions in order to evaluate their capability in reducing energy consumption.

2 Phase Change Materials and Previous Studies

2.1 Criteria for choosing a PCMs

Several criteria have to be fulfilled by PCMs to be of interest. They are summarized in the following table:

- thermodynamical criteria:	Phase change temperature adapted to applications High latent heat of fusion High sensible heat to provide additional heat storage No subcooling during freezing
- heat transport properties	High thermal conductivity to diminish temperature gradients required to charging and discharging the material
- mechanical properties	Small volume change during phase transition

- chemical properties	Chemical stability Chemical compatibility with construction materials Non-flammable and non-explosive Non-toxic or poisonous
- economical properties	Available in large quantities Cheap

It is difficult to find a material capable to satisfy all these criteria. Moreover, the chosen PCM must be conditioned in a manner that avoids leaks and contacts with the environment.

The adopted strategy was the following:

- to choose PCMs allowing a comfort temperature about 23 °C,
- to measure their thermophysical properties (thermal conductivity and specific heat capacity)
- to choose a mode of packaging and eventually to build a construction component or a wallboard
- to measure the response of the construction component or the wallboard to temperature variations.

In an attempt to fulfil most of the above criteria, several ways have been followed

- filling liquidtight panels with PCMs,
- using PCMs incorporated inside granulates or microcapsules,
- manufacturing a composite material.

2.2 Previous studies

2.2.1 Panels filled with PCM

To reach a comfort temperature of about 23 °C, three types of PCMs have been tested (PolyEthyleneGlycol 600, Fatty acid mixture, Paraffins) to fill PVC and polycarbonate panels used as wallboards (Figure 1)

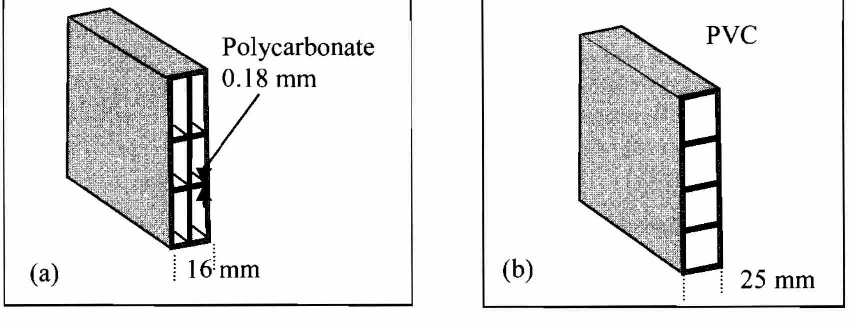


Figure 1: Structure of tested panels: (a) polycarbonate and (b) PVC panel.

To study the panel performances, a linear or a periodic variation of temperature was imposed on one side of the panels, while flux and temperature were measured on the other side. The experimental setup will be described in details in section 3.

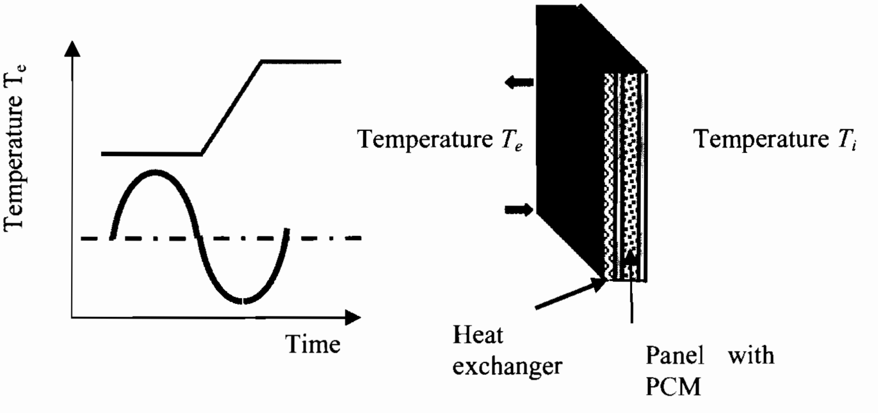


Figure 2: Sketch of the experimental set-up. Imposed temperature variations.

Obtained results are reminded and can be summarized as following (Ahmad *et al.*, 2006):
- An appreciable attenuation of temperature amplitude has been observed on the opposite side
- Due to low thermal conductivity of used PCMs a strong superheating was observed whilst one part is not completely molten
- In some cases, wall cracks occurred and the liquid PCM flowed outside the panel.

2.2.2 PCM embedded in granulates

To avoid liquid leaks, use of granulates as means of packaging PCMs was tested. Samples constituted by a mixture of granulates (from Rubitherm) containing a PCM (paraffin) and gypsum have been realized with a phase change temperature of 26 °C (Ahmad *et al.*, 2006).

It has been observed that the presence of granulates incorporating a PCM in the wallboard does not bring a significant improvement in the attenuation of the amplitude of the temperature oscillations compared to the use of an insulating material. However, the amount of PCM available for efficient heat storage was rather small and should be increased. If done, the thickness of the wallboard would have been increased too much and the advantage of a light envelope would have been lost. Another difficulty appeared when using such samples, their durability due to the effusion of paraffin through granulates. So, other types of encapsulation were tested.

2.2.3 Microencapsulation

Microencapsulation is known to be an efficient way to avoid liquid leaks. Microcapsules of paraffin (Melting temperature 28 °C) have been tested in order to be included in plasterwalls. The first task was to measure the equivalent specific heat capacity and phase change temperatures by Differential Scanning Calorimetry (DSC).

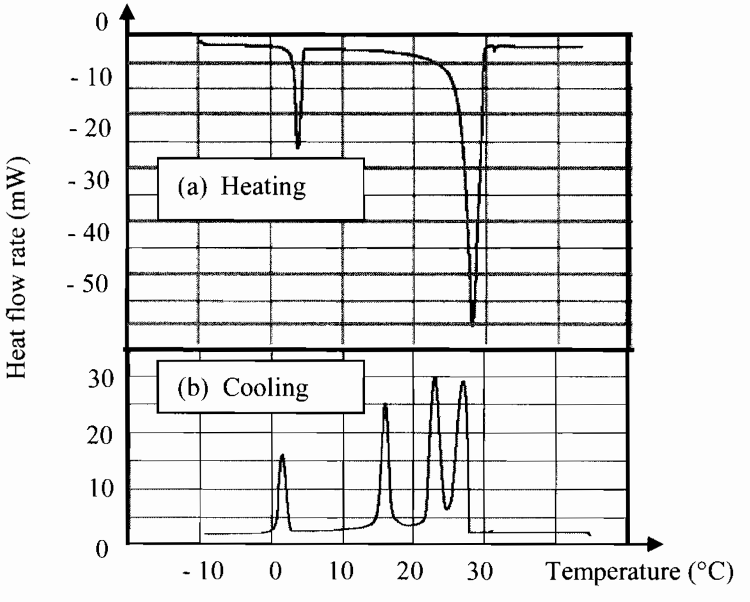


Figure 3: DSC thermograms showing the occurrence of solid – liquid phase transitions of microencapsulated paraffin: (a) sample heating, (b) sample cooling.

On figure 3 are presented typical curves obtained by DSC with a Setaram microcalorimeter when microcapsules are heated (Figure 3(a)) and cooled (Figure 3(b)) at a constant rate of 0.1 °C/min. The curves show the difference in the amount of heat required to increase or decrease the temperature of the sample compared to a reference as a function of temperature. The horizontal axis indicates temperature, and the vertical axis indicates heat flow rate. Peaks indicate the phase change temperature zones and correspond to an endothermal process for heating and exothermal process for cooling. For the heating process one peak is observed near the expected fusion temperature. The peak area allows us to determine the latent heat. Another peak is seen near 0 °C probably due to presence of residual water. Several peaks are seen in the cooling process which indicate presence of residual water and a probable subcooling due to the small dimension of the microcapsules. This mode of packaging has been used by several authors, but in our case, due to the occurrence of several peaks during the cooling process, we have preferred the use of paraffin composite material as described in the following section.

3. The new polymer – paraffin composite material

3.1 Material preparation

The basic idea is to prepare the Phase Change Material (PCM) by mixing at high temperature (> 100 °C) the paraffin which serves as a latent heat storage material and a styrene-butadiene-styrene (SEBS) block copolymer-polymer leading to a matrix acting as a supporting material. The paraffin is a commercial grade wax obtained from petroleum distillation. This fusible material used here is a combination of $(CH_2)_{12}$, $(CH_2)_{13}$, $(CH_2)_{14}$, and $(CH_2)_{15}$. With a polymer mass weight of 25%, no liquid leakage during its solid-liquid phase change is observed .The PCM mass density is respectively 840 kg/m^3 at $T = 5$ °C and 771 kg/m^3 at $T = 20$ °C..

Thermal properties of the commercial blended paraffin and PCM samples such as phase change enthalpy, specific heat and phase change temperature were measured by using DSC method applied with Mettler Toledo Co instrument though a thermal cycle of cooling-to-heating. Samples of 2 to 8 mg in aluminium pans (hermetically sealed before being placed in the calorimeter) were used and scans were recorded at a heating and cooling rate of 1°C/min with a deionized water pan as reference. The DSC thermal analyses are performed from 50 °C to - 20 °C and then from – 20 °C to 50 °C.

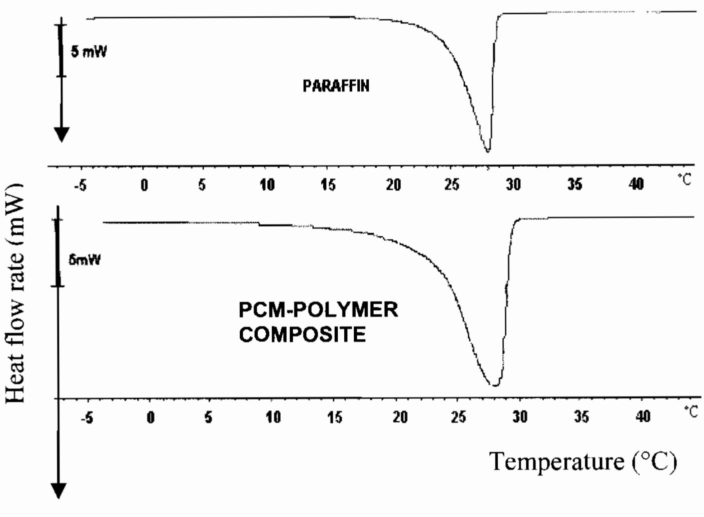


Figure 4: DSC thermograms of the paraffin and the PCM - polymer composite.

During the heating and cooling cycles, if there is no phase change in the paraffin sample pan, the temperature difference between the paraffin sample and the reference sample produced an almost horizontal straight line. If there is a phase change in the paraffin sample pan, a peak in the measured heat flow curve appears. In the present experiment, the peaks which are assigned to endothermal processes are plotted "downwards" (negative direction). The area between the straight line and the curve represents the energy consumed for the phase change, which is integrated by software included into the DSC.

The figure 4 shows a typical DSC thermogram of the paraffin used in the preparation of the composite PCM. One can observe that the melting phase appears within a large range of temperature because of the composition of the paraffin. This result is in agreement with the study of He *et al.* (2004) who have shown that paraffin mixtures melt and freeze within a temperature range and not at a constant temperature. An extrapolated peak onset temperature T_m can be obtained by drawing a line at the point of maximum slope of the leading edge of the regarded DSC peak and extrapolating the base line on the same side as the leading edge of the peak. This temperature is often recommended when reporting the melting and crystallisation peak characteristics. For the paraffin, T_m is estimated to 27.4 °C. The specific enthalpy, calculated as the total area under the peaks of solid-liquid transition by numerical integration, is for the paraffin 165 kJ/kg. For PCM particle including 75 wt % paraffin, the thermogram is broader than that of the paraffin. This result is due to the presence of the polymer. The fusion specific enthalpy of the composite material is 115 kJ/kg.

3.2 Thermal response of the PCM-polymer composite material

Schematic of the experimental set up is presented in figure 5. Water feeds a plate heat exchanger which imposes its temperature to a sample of PCM placed inside insulating foam. The temperature of the water flow is controlled through a thermoregulated bath. The water velocity is large enough so that no temperature difference can be observed between inlet and outlet.

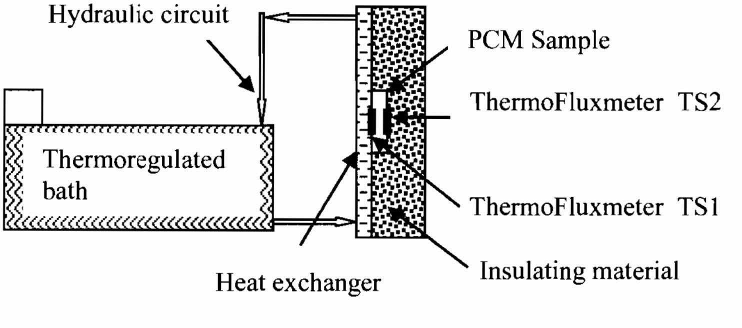


Figure 5: Schematic drawing of the experimental set-up to study the thermal response of the PCM – polymer composite.

Temperatures together with heat fluxes are measured on both sides of the composite material sample (Thermofluxmeters TS1, on front side, and TS2 on back side, measuring temperatures and heat fluxes, from Captec).

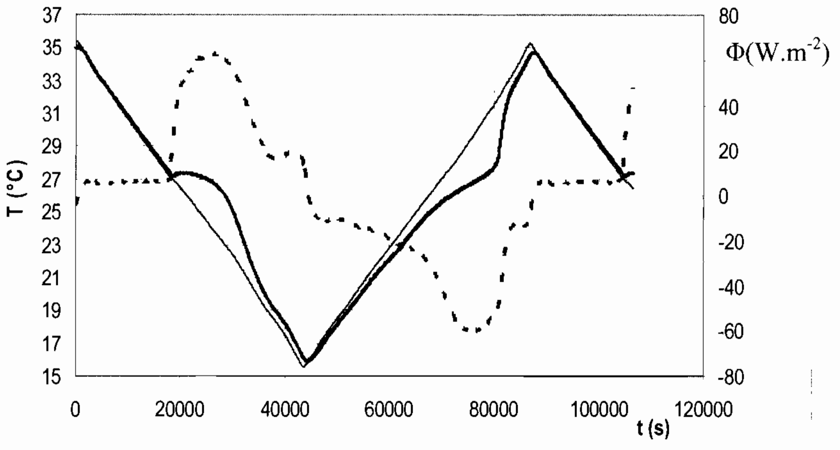


Figure 6: Temperature profiles and heat flux variations for test cycles of PCM-polymer composite material.

In Figure 6, the temperature variations measured at both sides of the composite material sample are presented. A cyclic temperature variation is imposed on the front side of the sample (thin full line). Temperature variation is linear during heating and cooling and its period is 24 hours. The temperature on the back side (thick full line) shows a characteristic "flattening" due to phase-change both during cooling and heating. During cooling a slight subcooling phenomenon is also apparent. A strong increase in heat flux (dotted line) is observed at the phase-change occurrence.

By integrating the heat flux curves, the heat stored and released by the material is evaluated as 127 kJ/kg for crystallisation and 133 kJ/kg for fusion in agreement with values obtained by DSC. During these cycles no leaks were observed when paraffin was in liquid state.

4. Bricks filled with PCM-polymer composite: fabrication and tests

4.1 Fabrication method

A paraffin-polymer mixture was introduced during its preparation inside cavities of commercial hollow bricks whose dimensions are 11cm x 21.5 cm x 15 cm.

Each cavity is a parallelepiped which has a section of 2.5 cm x 2.5 cm and a height of 15 cm. Figure 7 presents a picture of two bricks which have been tested: Cavities of the brick on the left hand side are filled by the composite material, the ones of the brick on the right hand side are empty. The volume proportion of composite material is 26 %.

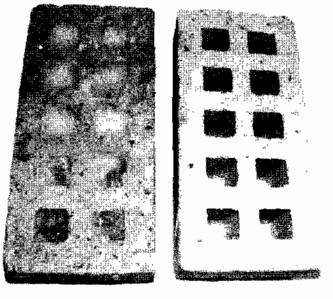


Figure 7: Picture of tested bricks. Right: hollow brick. Left: brick filled with the PCM – polymer composite.

4.2 Experimental set-up and procedure

An experimental device, adapted from those of figure 2 and 5 has been developed to apply identical temperature variation to the bricks with and without PCM (Figure 8).The front side temperature (T_1) is imposed by the plate heat exchanger. The opposite side is adjacent to a room in which temperature T_4 is kept constant. Temperature at the internal surface of a brick cavity is also measured. Temperatures T_2 and T_4 are measured by type K thermocouples. Temperature T_1 and T_3 are measured together with surface heat fluxes, Φ_e and Φ_S (Figure 8).

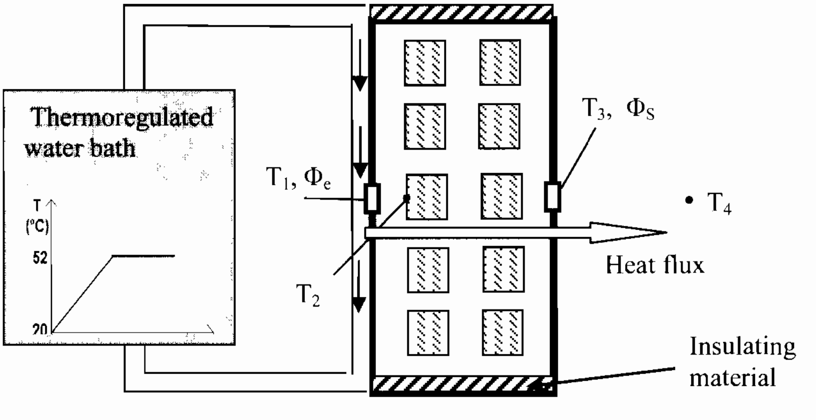


Figure 8: Experimental set-up to test thermal response of bricks.

The imposed temperature variation is presented in Figure 9. It comprises a linear variation from 21 °C to 52 °C during 6 h followed by a stabilization of temperature at 52 °C during 6 hours. The other side is in contact with the room atmosphere stabilized at nearly 21 °C.

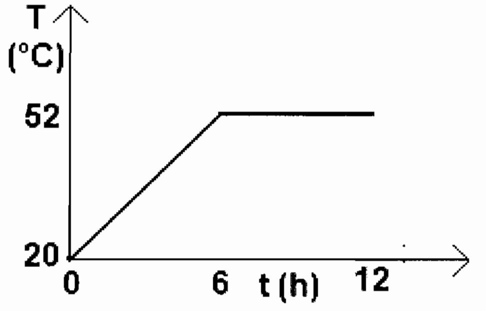


Figure 9: Variation of the imposed temperature as a function of time.

4.3 Results and discussion

Figure 10 shows temperature variations (T_1, T_2, T_3, T_4) during 12 hours. The T_2 curve given by the thermocouple which is inside the brick and in contact with the composite material shows during the first phase a slope modification at about 26 °C which corresponds to the fusion temperature of paraffin. On the back side the T_3 limiting temperature of the brick containing the composite material is lower than that of the hollow brick by about 3 °C.

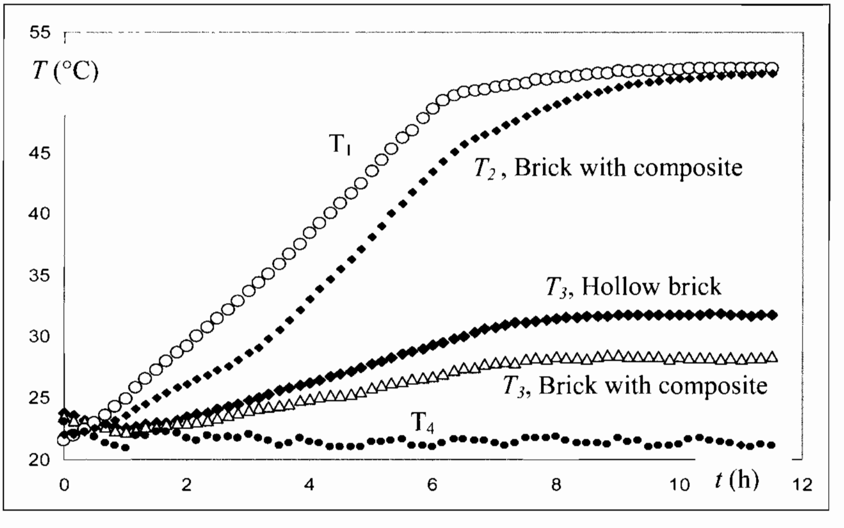


Figure 10: Temperature variations as a function of time: T_1: Imposed temperature on the front side. T_2: Temperature at the cavity wall. T_3: Surface temperature at the back side. T_4: Ambient temperature.

This experiment clearly shows the PCM role on brick thermal inertia: The brick with PCM inside reaches its limiting temperature more slowly than the hollow brick. On the back side the temperature level reached after 12 hours is lower if the brick contains the composite material.

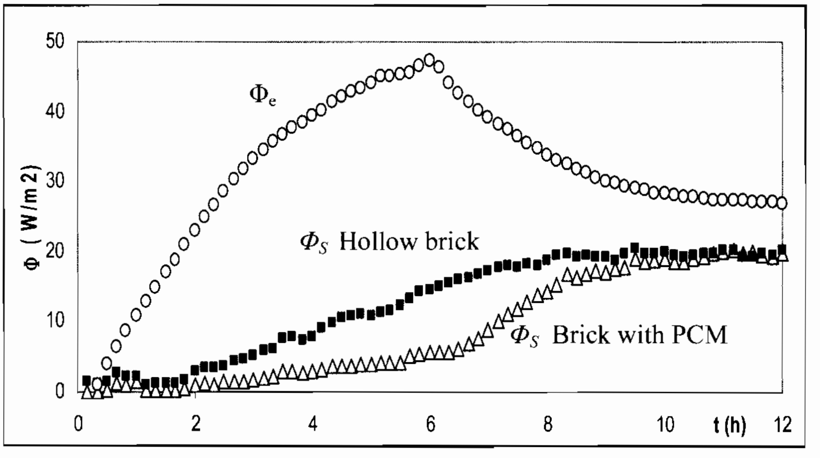


Figure 11: Heat flux variation as a function of time. Φ_e: Heat flux at the front side. Φ_S: Heat flux at the back side.

In figure 11 are presented heat flux variations at the front (Φ_e) and back (Φ_S) sides. Each brick is submitted to an identical heat flux Φ_e on its front side. On the back side, the heat flux coming out from the hollow brick tends more rapidly to its limiting value than that coming from the brick filled with composite material. The difference between the two Φ_S heat fluxes (Figure 12) allows us to calculate, by integration, the heat stored by the composite material.

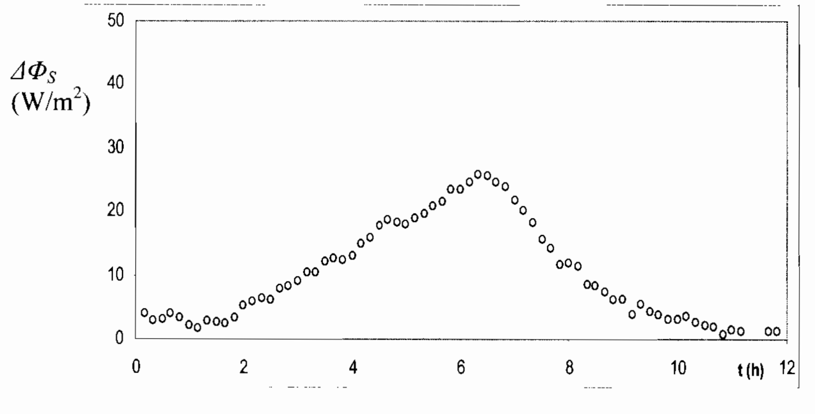


Figure 12: Difference between heat fluxes at the back side of a brick filled with PCM-polymer composite material and of a hollow brick.

For this experiment, about 12 kJ have been stored in the composite material, corresponding to 17 % of the available latent heat. This low value probably results from the low conductivity of the composite material and the next step will be the optimisation of the brick geometric form.
If we compare our experiment with a real case in which a solar flux is applied on the front side (external side) of a brick wall, the temperature on the opposite side (internal side) would be lower if the bricks are filled with a PCM-polymer composite.

5. Conclusion

Use of renewable energy sources such as solar heating, night air cooling, etc. for indoor air conditioning needs for an adequate choice of construction materials. The works presented here aim at describing some ways to obtain passive regulation of indoor temperature by artificially augmenting the heat capacity of materials. This can be done by incorporating phase-change materials inside building elements.
One of the practical problems when using PCMs is to avoid leaks when they are in the liquid state. Then, PCM packaging is a question of utmost importance. Several types of packaging have been tested, panels and microcapsules. The retained solutions are the use of a PCM-polymer composite and its incorporation in the cavities of bricks. The chosen PCM was Paraffin whose melting temperature is about 27 °C. Physical properties (thermal conductivity, specific heat capacity) of the composite material have been measured and its latent heat was found to be 115 kJ/kg. Preliminary tests have shown that PCM remained incorporated in the polymer matrix by capillarity when in liquid state.
Several tests have been carried out to find the thermal response of the composite alone and of bricks when a temperature variation was imposed on one side. Obtained results show that the temperature reached on the other side is lower with a brick filled with a composite than with a hollow brick. If a wall is built with such bricks, it could store solar energy to avoid large increase of indoor temperature during the day and release it during the night.
Several walls have been built with PCM bricks to study their behaviour in real climatic conditions. This is the next step of this study.

References

Ahmad, M., Bontemps, A., Sallée, H., Quenard, D., (2006), Experimental investigation and computer simulation of thermal behaviour of wallboards containing a Phase Change Material (PCM) for the light envelope of buildings, *Energy and Buildings*, 38(4), 357-366.

Babich, M.W., Benrashid, R., Mounts, R.D., (1994), DSC studies of energy storage materials. Part 3.: Thermal and flammability studies, *Thermochimica acta,* 243, 1994, 193 – 200.

Banu, D., Feldman, D., Haghighat, F., Paris, J., Hawes, D., (1998), Energy storing wallboards: flammability tests, *Journal of Materials and Civil Engineering*, 10, 98 – 105.

Cabeza, L.F. Castellón, C., Nogués, M., Medrano,M., Leppers, R., Zubillaga, O., (2007), Use of microencapsulated PCM in concrete walls for energy savings, *Energy and Buildings*, 39(2), 113-119.

Hawes, D.W., Feldman, D., Banu, D., (1993), Latent heat storage in building materials. *Energy and Buildings*, 20 (1) 77-86

He, B., Martin,V., Setterwall, F., (2004), Phase transition temperature ranges and storage density of paraffin wax phase change materials, *Energy*, 29, 1785 – 1804.

Jahns, E., (1999), Microencapsulated phase change materials, Proceedings of the 4th workshop of IEA ECES IA Annex 10, Bendiktbeuern, Germany.

Khudair,A.M., Farid,M.M., (2004), A review on energy conservation in building applications with thermal storage by latent heat using phase change materials, *Energy Conversion and Management*, 45, 263 – 275.

Lai, C., Chiang, C., (2006), How phase change materials affect thermal performance: hollow bricks, *Building Research & Information,* 34 (2), 118 – 130.

Melhing, H., Hiebler, S., Ziegler, F., (1999), Latent heat storage using a PCM-graphite composite material: advantages and potential applications, Proceedings of the 4th workshop of IEA ECES IA Annex 10, Bendiktbeuern, Germany.

Py, X., Olives, R., Mauran, S., Paraffin/porous-graphite-matrix composite as a high and constant power thermal storage material, *Int. J. Heat Mass Transfer*, 44, 2727 – 2737.

Salyer, I.O., Sircar, Chartoff, R.P., Miller, D.E., (1985), Advanced phase change materials for passive solar storage applications, in *Proceedings of the 20 th Intersociety Energy Conversion Engineering Conference*, Warrendale, Pa, USA, 699 – 709.

Shapiro, M., Feldman, D., Hawes, D., Banu, D., (1987), PCM thermal storage in drywall using organic phase change material, *Passive Solar Journal,* 4, 419 – 438.

Tyagi, V.V., Buddhi, D., (2007), PCM thermal storage in buildings: A state of art, *Renewable & Sustainable Energy Reviews*, 11, 1146 – 1166.

Xu, X., Zhang, Y., Lin, K., Di, H., Yang, R., (2008), Modeling and simulation on the thermal performance of shape-stabilized phase change material floor used in passive solar buildings *Energy and Buildings*, 37(10), 1084-1091

Cited industrial companies

Captec : www.captec.fr; Cristopia : www.cristopia.com; Mettler Toledo : www.mt.com; Rubitherm : www.rubitherm.de; Setaram: www.setaram.fr

Investigating the Use of Softwood Poles for 'Massive' Elements in Timber Commercial Buildings.

John Chapman
University of Auckland, New Zealand.

Abstract

A recent project at the School of Architecture & Planning, University of Auckland, is the study of using poles in 'massive' timber building. Over the last 50 years pinus radiata poles have been used extensively as foundation piles, power poles, and as the members of retaining walls.

In Europe, 'massive' or 'cross-laminated' timber construction has proved successful for a variety of reasons, including the environmental advantages. Because the panels are 'thick', the stresses in them remain relatively low. Thus, lower grades of wood can be incorporated in the panels, which is less wasteful and reduces cost. New Zealand produces a large quantity of wood from plantation forests, mainly in the form of pinus radiata softwood. Our study sees the potential of arranging readily available and moderately priced radiata poles as the floor panels in 'massive' type timber construction.

This paper shows how timber poles are traditionally utilised in New Zealand and, also, interesting recent developments for their use. It simply explains the proposed system for using poles in 'massive' type construction to 6 levels.

Keywords: *ecological, timber, pole, commercial, buildings, structure*

1 Introduction

Round Timbers, in building, are tree stems that have had their bark removed by peeling or shaving. Over the last 50 years pinus radiata poles have been used extensively in New Zealand as foundation piles, power poles, and in retaining walls. They exist under continual and often a reasonably high state of compressive or bending stresses. Due to a minimum of in-service problems radiata poles have gained the reputation as a competent structural product.

Historic Japanese and Chinese temples often used round timbers for the main structural elements. Some of these buildings are over a thousand years old, and because of their prudent construction and maintenance, are functioning in good condition.

Round timbers are a relatively stable form of wood, with typically higher characteristic failure stresses and modulus of elasticity (Timber Design guide, 2007). They require the minimum amount of machining and are available, in the shaved form, at considerably less cost than sawn lumber. Disadvantages of round timber as structural elements include the irregular and circular surface and a lack of solutions for effective jointing.

The paper discusses recent developments in pole structures including use in Polynesian architecture; highway bridges in Australia; and 'uniform diameter round wood' where the radiate stems are peeled to form a consistent and uniform diameter.

Future possibilities for pole structures are discussed including the feasibility of using timber poles for the joists in commercial building floor systems to resist the transference of inter-storey noise.

2 Pole Structures in New Zealand over the last 50 years

Over the last 50 years pinus radiata poles, with CCA treatment, have been used extensively, in New Zealand, as foundation piles, power poles, and as the members of retaining walls. Due to a minimum of in-service problems radiata poles have gained the reputation as a competent structural product.

2.1 Retaining Walls

Timber pole retaining walls, as shown in figure 1, are particularly common in New Zealand for retaining up to 3m high. These walls exist under a continual, and often a reasonably high state, of bending stress. The calculated maximum bending stress in the main vertical pole members of retaining walls is around 20mPa. It is impressive to think that poles continuously support this stress, some of them for at least 50 years. Typically the vertical poles are embedded in the ground, into concrete filled augured holes, to a depth which is approximately the same as the retained height.

2.2 House Piles

Over 90% of houses in NZ are timber construction, and most are supported on timber pile foundations. These piles are either a polc or a small diameter pole which has been four sided to produce a square cross-section. Figure 2 shows a pile driver. The steel weight is dropped from a height and drives the timber pole into the ground.

2.3 Pole Platforms

Pole platforms are useful for supporting light wooden houses on steep sites, as can be seen in figure 3. The pole posts are typically 175 - 250mm diameter, spaced around 3.5m and are concreted in augured holes which are around 2m deep.

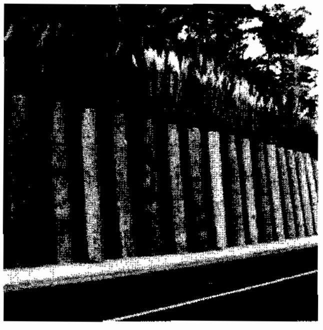


Fig 1: 4.8m pole retaining wall.

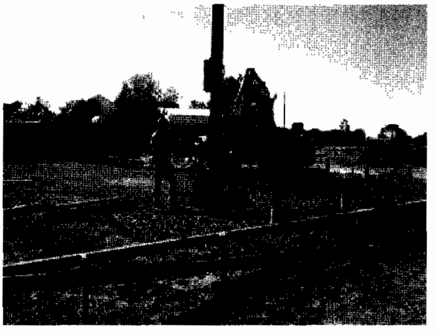


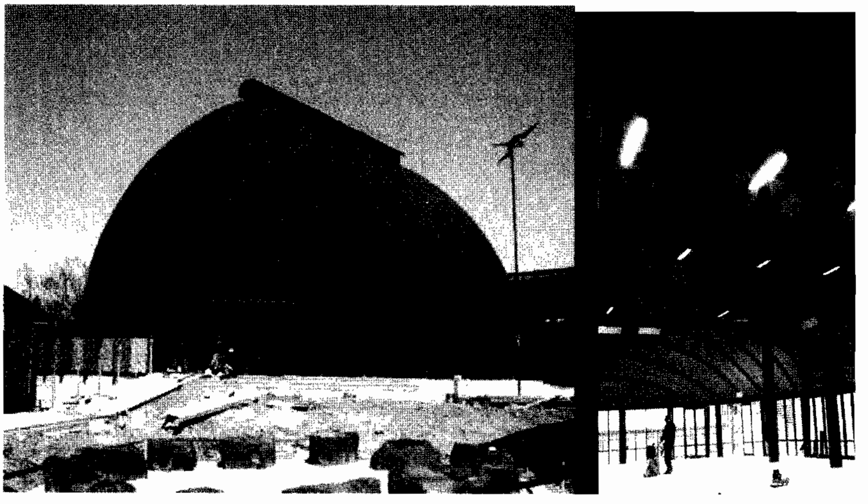
Fig 2: driving short house piles.

Fig 3: Pole platform on steep site

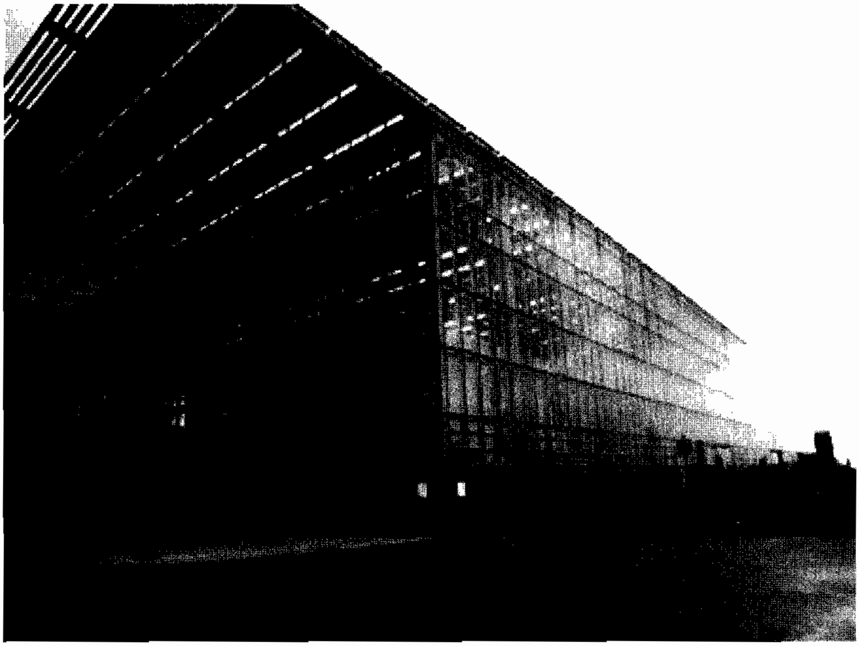
3 Recent Developments in Pole Structures

3.1 Poles in modern architecture

Round timber elements are being used more and more by Architects. This is evident when looking through New Zealand Architecture or similar journals. The appearance of round timbers is organic, unobtrusive, and reflects a relaxed and informal 'Polynesian' style. They remind the viewer of trees and nature. There are the environmental advantages of poles of minimal waste and reduced heat for manufacture. They also have important properties in that bowing is unlikely, and fibre density increases towards the outer surface where the bending stresses in structural elements are greatest. Pole columns and roof beams are used extensively in Auckland in Pacific Island churches which are affectionately known as 'coral cathedrals'. A significant example, as shown in figures 4 & 5, is the 'Fale Pacifica' building. Also, round timbers are presently being used with significant architectural effect in contemporary European buildings (Charleson, 2002). The example shown is the Mount Cenis Academy (1993) by Jourda & Perraudin.



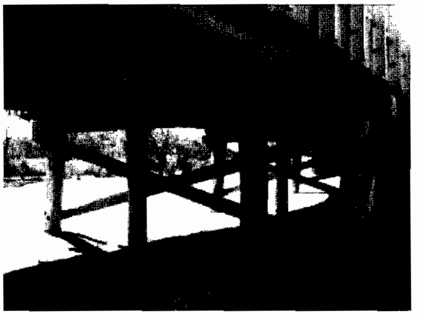
Figs 4 & 5: Fale Pacifica building, University of Auckland.



Figs 6: Mont-Cenis Academy (1999), Jourda & Perraudin

3.2 Highway bridges in Australia.

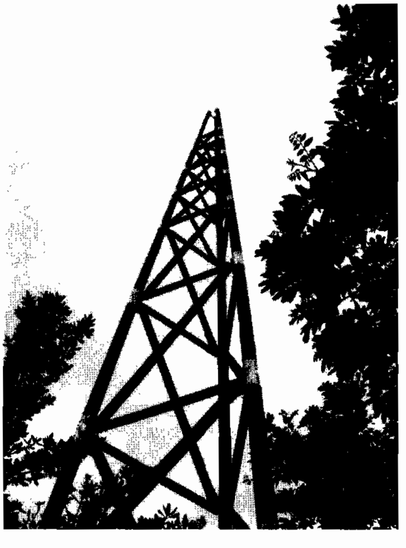
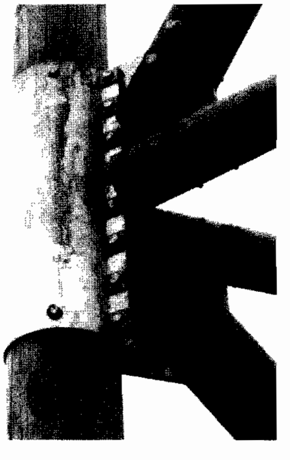
A new highway bridge on the B400, a few kilometres north of Robinvale, as shown in figures 7 & 8, uses Eucalypt poles for the main girder beams, corbels, and foundation piles. Robinvale is situated on the Murray River, north of Melbourne. Sawn Eucalypt is used for the bearers and diagonal bracing. The deck is 100mm thick planking with a reinforced concrete topping. There are closely spaced bolts through the girder beams, which may be anchored into the RC deck, and be creating a shear key. An interesting feature of this bridge is the extensive use of galvanised steel sheathing to prevent rainwater entering into any bolted joints. I observed 3 bridges, in good condition, in South Australia and Victoria, which supported open road traffic for over 100 years. These very long lasting bridges all had galvanised steel cappings over the bolted joints, which kept the joints dry. It is unlikely to be able to use pinus radiata poles in this way because stems with the required diameter are not readily available. However, it may be possible to make bridge beams out of poles stacked and adequately shear keyed together to form a deep beam member.

Figs 7 & 8: B400 Pole Highway Bridge, Robinvale, Murray River

3.3 Uniform diameter roundwood

A recent trend, in New Zealand, is the peeling of poles to achieve an element with a uniform diameter (Walford, Reelick, 2006). Uniform diameter roundwood (UDR) overcomes the problem of the uneven surface of a typical pole. This allows for standardised connection details, predictable thickness for assembly, and a smoother appearance. Jayanetti and Follett consider this process, by decreasing the diameter and removing the densest wood fibres, reduces the pole strength by around 40% (Jayanetti, L., Follet, P., 2000).

Figures 9 & 10: 32m high, UDR, telecommunication tower

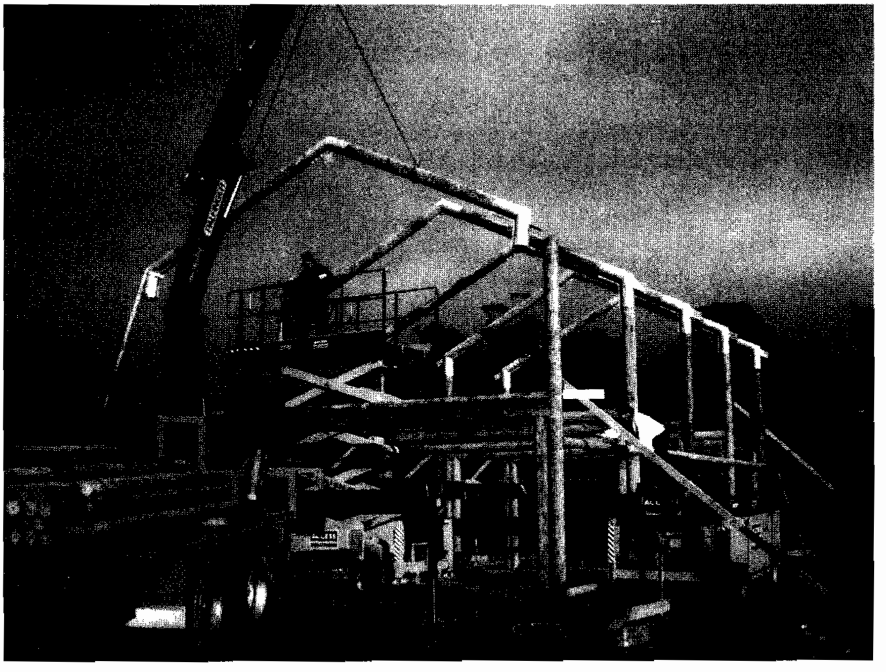


Figure 11: UDR portal structure for 2 storied building

Uniform diameter roundwood construction is a private sector initiative where jointing technologies have been developed to produce 30m high tele-communication towers (figures 9 &10) and portal frame buildings to two storeys (figure 11) (www.unilog.co.nz). Tele-communication towers have been erected in Tonga where the design wind speed is 200km/hr. The resulting tension forces in the pole elements are up to 34 tonne, which is very high for timber construction (Reelick, Reelick, 2004). Joint brackets are made up of mild steel circular hollow sections, which have been cut along their vertical axes, with flanges that bolt together, as can be seen in the above images.

4 Possible Six Level Timber Building System with Poles as the Predominant form of Structural Timber

4.1 Research aim

There have been projects at the University of Auckland to investigate the feasibility of 6 storey timber buildings with radiata pole structural elements (Chapman, 2009). The most recent example is shown in figures 12 & 13. Also, considerable work has recently been carried out in testing various timber floor configurations including one using pole joists (Chapman, Dodd, 2008). The overall aim of the research is to develop a viable timber structural system for commercial buildings up to 6 levels. The system that is presently being studied is described in the following sketches (figures 13 to 16). It is being considered from multiple viewpoints which is a balanced approach to assist a viable solution. The aspects that are being considered are:

Architectural elegance and usefulness
Structure and construction details
Economics
Environmental advantages
Sound and thermal insulation
Prefabrication and transportability
Fire & moisture protection
Comparisons of timber building with reinforced concrete equivalent

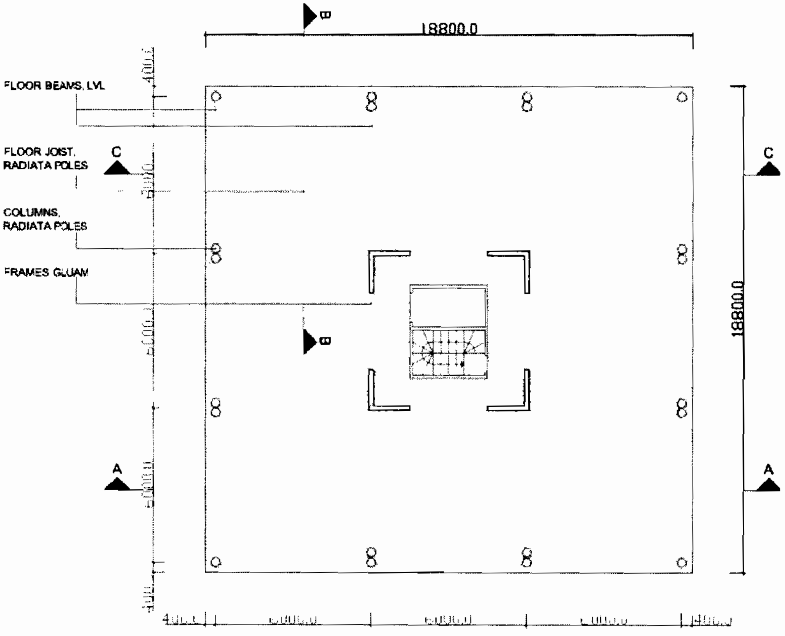


Figure 12: Prototype timber commercial building, floor structure plan

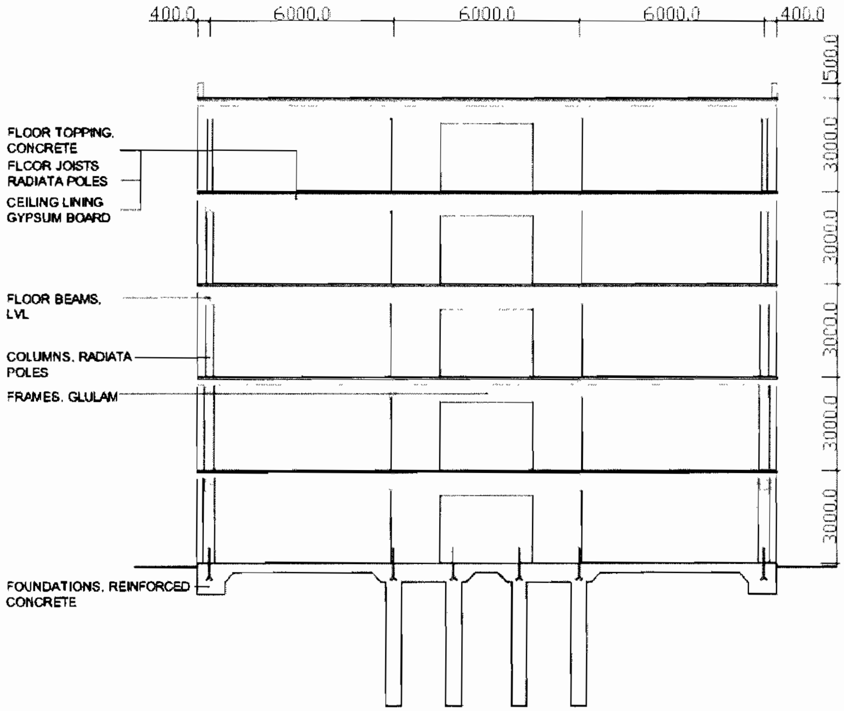


Figure 13, Prototype timber commercial building, cross-sections, A-A & C-C

4.2 Architectural elegance and usefulness

Multi-level building design is typically a compromise between using expensive 'frames' and economical 'vertical shear walls'. 'Frames' enable open and flexible floor plans, but 'vertical shear walls' interrupt floor plans and are more restrictive. The proposed solution for this project is a central core enclosing the lifts and stairs which utilises a minimal number of four large 'frames'. The floor spaces around the core are open, allowing an infinite variety of floor plans.

The central floor bay, enclosed by the four frames, contains the lift core and stairs and can be configured for either residential apartments or office space. For residential apartments, the space around the lifts and stairs forms a lobby with the apartment doors opening off it. For commercial offices, lobby space is replaced by toilets and storage.

4.3 Structure

The 'central core', located in the middle of the building, supports the lateral wind and earthquake loads on the building. Each of the four sides of the central core is a frame of deep glulam columns and beams. For earthquake events, the joints between the columns and beams will be designed to allow for energy absorption and to relocate the building back to original alignment. The floor areas around the central core are simple post and beam construction.

4.4 Economics

Many forms of wood are being specified for the structure and their selection is mainly based on economics. The forms of the timber structural elements and the volumes used in the prototype building, and as percentages of total wood volume are as follows:

Glulam -	columns, central core frames,	38cu.m (9%)
LVL -	floor beams,	24cu.m (6%)
Poles -	floor joists,	280cu.m(71%)
Framing -	external and internal walls	55cu.m (14%)

Poles, at 71% of the total structural wood content, is the predominant wood product. Non-wood materials used to assist insulation for fire, water ingress, and sound and heat are plasterboard for wall linings, and 65mm thick concrete floor toppings. Unrefined poles, available at around US$80 per cu.m., is a particularly economic form of wood. Because the maximum expected bending stress in the pole joists is small, around 4mPa, most poles would be suitable. The pole floor joists, before being made into panels, need to be slowly kiln dried to around 14% moisture content and then machined to be 200mm deep and 175mm wide. Keys are specified for shear jointing the poles to the concrete floor topping. Presently the poles are detailed as being bolted together to form floor panels similar to those used in European 'massive' timber buildings. Because the jointing of the poles together to form panels is a temporary requirement until the concrete topping cures, a cheaper form of joining the poles together will hopefully be devised.

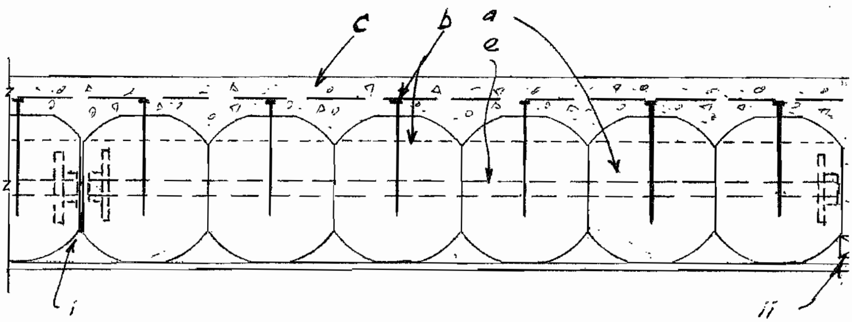
The pole joists could be replaced by a lumber mill floor made up of 180 deep * 45wide joists glued together. The stresses would be similarly small and thus wood could be used that just failed to make the lowest 'structural' grade according to the relevant code, NZS3603. This wood, as sticks of lumber, should be relatively cheap to buy, perhaps around US$200 per cu.m. Also, the core glulam frames perform at low stresses and can mostly be made of wood with properties just below the current minimum structural grade requirements.

4.5 Environmental advantages

Timber is a 'carbon neutral' product, whereas reinforced concrete buildings, during manufacture, discharge around 50 kg of carbon in the form of CO_2 into the atmosphere for each square metre of floor space. The energy required for the manufacture of a timber building is approximately 40% of that required for a reinforced concrete equivalent (Chapman, 2002). It is these significant environmental advantages that motivate these research projects in timber commercial buildings.

4.6 Sound and thermal insulation

Achieving inter-storey sound insulation has proved a major issue for multi-level timber buildings. However, recent research at the School of Architecture & Planning, in association with the Acoustic Research Centre at the University of Auckland, has produced timber floors with pole joists which have complied with the NZ acoustic code requirements (Chapman, Dodd, 2008). This was an important breakthrough, but the floors lacked construction simplicity and were slightly more expensive than the equivalent reinforced concrete floors. Our latest floor design, as shown in figure 14, is informed by the successful ‘massive timber’ floor developments in Europe. We expect the new design to fulfil the requirements of the NZ building code and be as economical as a reinforced concrete floor. Sound insulation for party walls is to be achieved through two closely spaced but independent walls with sound blanket and plasterboard linings. The solutions for sound insulation will be also useful for achieving thermal insulation. However, for the external walls, the thermal insulation requirements will be more significant.



a, 200mm small end diameter pinus radiata poles; trimmed to be 200mm deep and 175mm wide

b, cut-outs in tops of joists & fixings for shear connection between pole joists and concrete topping

c, 65mm thick reinforced concrete topping

d, plasterboard ceiling

e, mild steel rods to join poles into ‘massive’ floor panels

(i) Gib sound seal in small gaps

(ii) Box and concrete fill larger gaps between floor panels

Cross-Section through Pole Massive Floor Panel

Prototype timber commercial floor system

School of Architecture & Planning, University of Auckland.

Figure 14: Prototype timber commercial building, floor structure cross-section

4.7 Prefabrication and transportability

Effort is being made to ensure that the structural elements of this prototype timber commercial building are simple, can be factory manufactured in New

Zealand, and easily erected on site. The 'massive' glulam elements of the proposed building system have maximum lengths, depths and widths, of 15m, 1.5m, and 180mm respectively, which are suitable dimensions for the New Zealand timber industry to manufacture. The LVL floor beams and pole floor panels are also suited for fabrication by local companies. The proposed system does not require panels to be made to the same precision as the European 'massive' timber building systems and expensive milling machines are not needed. For this prototype building the columns are spaced at 6m in both directions. This module produces beams at 6m length and columns around 3m length, which will transport efficiently in 20 feet (6.1m) long containers.

4.8 Fire and moisture protection

An advantage of the 'massive' pole floors with 65mm thick concrete topping is the excellent fire resistance produced. The floor beams, columns, and central core frames are glulam or built-up LVL which also possess good fire resistance properties. Where needed, plasterboard linings provide additional fire protection. The concrete floor toppings ensure moisture protection due to taps left running etc. Vertical cavities are to be included in the outer faces of external walls to avoid moisture ingress.

5 Conclusions

Over the last 50 years pinus radiata poles have been used extensively in New Zealand as foundation piles, power poles, and in retaining walls and have gained the reputation as a competent structural product. Recent developments in pole structures include use in Polynesian architecture; highway bridges in Australia; and 'uniform diameter roundwood' structures where the radiata stems are peeled to form a consistent and uniform diameter. Round timber elements are being used more and more by Architects. Their appearance is organic, unobtrusive, and reflects a relaxed and informal 'Polynesian' style. They remind the viewer of trees and nature. There are the environmental advantages of timber poles of zero carbon release, minimal waste, and reduced heat for manufacture.

There have been recent projects at the University of Auckland to investigate the feasibility of 6 storey timber buildings with radiata pole structural elements. Also, considerable work has been carried out in testing various timber floor configurations including one using pole joists. The floor with pole joists complied with the New Zealand codes for both impact and airborne sound insulation, but the floor lacked construction simplicity and was slightly more expensive than the equivalent reinforced concrete floors. This is why the 'European' type solid timber floor is favoured as it is simpler and possibly more economical. The overall aim of the research is to develop a viable timber structural system for commercial buildings up to 6 levels. A 'central core', located in the middle of the building, supports the lateral wind and earthquake loads on the building. Each of the four sides of the central core is a frame of deep glulam columns and beams. The floor spaces outside the core are 'open', allowing a variety of floor plans. The proposed floor panels are poles, bolted together and with a concrete topping, similar to the recent European 'massive' lumber floor panels with concrete topping. Poles, at 71% of the total structural wood content, is the predominant wood product in the proposed timber commercial building system. Unrefined poles, available at around US$80 per cu.m., is a particularly economic form of wood. Because the maximum expected bending stress in the pole joists is small at around 4mPa, lower structural grade poles would be suitable.

It is hope, that after the above aspects of this research project are complete, a full understanding of the timber commercial building system will have been reached and will be used to attract the attention of those building developers who are interested in environmentally responsible building.

Glossary of Forms of Wood

Glulam or glued laminated timber is a structural timber product composed of several layers of dimensioned timber glued together

LVL or laminated veneer lumber is an engineered wood product that uses multiple layers of thin wood assembled with adhesives

Framing is the term given to '4 by 2' upright studs and horizontal nogs that is the main method of building walls for houses in New Zealand.

Massive timber construction is the term used for a recently devised highly successful building system in Europe that uses solid panels made of glued horizontal and vertical layers of wood.

Poles are the round tree stems that have had their bark removed by peeling or shaving.

Acknowledgements

I thank Julius Natterer for his 'education' into the simplicity of 'massive' timber building systems. Also I thank George Dodd for his guidance with making timber floors sound resistant; and to Kerimcan Apak for his help with the construction arrangements and detailing of the proposed timber commercial building system.

References

Chapman, J.B., Dodd, G. (2008). Improved sound insulating floors for a proposed demountable timber building system to 6 storeys. 10th World Conference on Timber Engineering, Japan: Miyazaki

Chapman, J.B., (2009). Timber Pole use in New Zealand, past and future. International Symposium Timber Structures from Antiquity to the Present. Turkey: Istanbul.

Chapman, J.B., (2002). A Preliminary Investigation into Medium Rise (6 storey) Residential Units Using Pinus Radiata Timber Poles as the Main Structural Members. Association of Collegiate Schools of Architecture; Technology and Housing Conference. USA: Portland Oregon, 43-47

Charleson, A. (2002) Beyond Utility (part 2). NZ Timber Design Society Journal issue 3 vol 11, 9-16.

Jayanetti, L., Follet, P. (2000) Timber Pole Construction. UK: International Technology Publications.

New Zealand Standards Association (1993). Timber structures standard. (Publication no. NZS3603). Wellington: NZ Standards Council.

Reelick John M, Reelick John C M. (2004) Unilog Cell Phone Towers. NZ Timber Design Society Journal issue 3 vol 12, 14-17.

Buchanan, A., (2007) Timber Design Guide. Wellington: New Zealand Timber Industry Federation Inc.

Walford, B. & Reelick, J. (2006) Structural possibilities using poles of uniform diameter. 9th World Conference on Timber Engineering. USA: Portland, Oregon.

Towards Sustainable Earthen Architecture, with Special Reference to Iran

Pirooz Hanachi[1], Mohammad Taleghani[1], Susan Shannon[2], Peter Hind[3]
[1]Faculty of Architecture, University of Tehran, Iran
[2]School of Architecture, University of Adelaide, Australia
[3]College of Architecture, University of Nebraska- Lincoln, USA

Abstract

The concept of sustainable building incorporates and integrates a variety of strategies during the design, construction and operation of building projects. The use of green building materials and products represents one important strategy in the design of a building. In most countries of the world, it is possible to mould earth with sophisticated or primitive tools to construct buildings. The range of the technical, constructional and architectural possibilities of earth is extremely wide. This wide constructional potential has enabled the construction of modest shelters, village houses, urban blocks and religious edifices, as well as palaces and entire cities. Building with earth materials can be a way of helping with sustainable management of the earth's resources as they can be built using simple machinery and human energy. Earth buildings avoid deforestation and pollution, and can achieve low energy costs throughout their lifecycle - in the initial manufacture and construction, occupancy, and eventually in their recycling back to the nature. This paper will review the literature of sustainable materials at first, and then, earthen materials will be the main goal. Comparing earthen materials with other ones and their categorized advantages will introduce this kind of materials as a sustainable material. In this regard, reviewing two special Iranian earthen buildings (refrigerator and wind catcher) will introduce us with the function of earth as a sustainable material in Iran. Finally, reviewing German regulations for construction with earthen materials is the key part of this paper.

Keywords: *sustainable materials, earthen architecture, earth methods, earth advantages.*

1 Introduction

"Currently it is estimated that one half of the world's population—approximately three billion people on six continents—live or works in buildings constructed of earth. (Rael, 2008)

Nowadays, buildings are responsible for approximately 40% of the total world annual energy consumption (Omer, 2007). Environmental and human health impacts of the choice of materials are a hidden cost of our built environment.

Impacts during its manufacture, transport, installation, use and disposal of construction materials can be significant, yet often invisible (Calkins, 2009). A broad and complex web of environmental and human health impacts occurs for each of the materials and products used in any built environment. Construction materials might be manufactured thousands of miles from a building project which affects ecosystems at the extraction and manufacturing location. Moreover, transportation throughout all phases consumes fuel and contributes pollutants to the air. Furthermore, disposal of manufacturing waste and used construction materials will affect other environments.

This paper will review the literature of earth as a sustainable material. Different common earthen building techniques will be defined as well as the advantages and disadvantages of earthen materials. Case studies concerning two traditional building in Iran will be introduced. Finally, the paper considers German regulations for earth building.

2 Sustainable Materials

As the earth's population continues to explode and most nations begin to use their share of the world's resources, it is necessary to ascertain how we, as a planet, use our earth's precious resources. During construction or at the end of useful building life, construction materials and components are often discarded with construction debris accounting for nearly 28 percent of landfill waste in this country. Inappropriate use of building materials that emit chemicals can pollute the indoor air quality with some new building chemical concentrations up to 100 times greater than outside levels.

Sustainable or environmentally friendly materials can help create more sustainable, healthful, and ecologically sensitive buildings. This is achieved through environmental material assessment and green building specifications (Froeschle, 1999).

Green building materials are composed of renewable, rather than nonrenewable resources. Green materials are environmentally responsible because impacts are considered over the life of the product. Depending upon project-specific goals, an assessment of green materials may involve an evaluation of one or more of the criteria listed below.

- Recycled Content: Products with identifiable recycled content, including postindustrial content with a preference for postconsumer content.
- Natural, plentiful or renewable: Materials harvested from sustainably managed sources and preferably have an independent certification (e.g., certified wood) and are certified by an independent third party.
- Resource efficient manufacturing process: Products manufactured with resource-efficient processes including reducing energy consumption, minimizing waste (recycled, recyclable and or source reduced product packaging), and reducing greenhouse gases.
- Locally available: Building materials, components, and systems found locally or regionally saving energy and resources in transportation to the project site.
- Salvaged, refurbished, or remanufactured: Includes saving a material from disposal and renovating, repairing, restoring, or generally improving the appearance, performance, quality, functionality, or value of a product.
- Reusable or recyclable: Select materials that can be easily dismantled and reused or recycled at the end of their useful life.
- Recycled or recyclable product packaging: Products enclosed in recycled content or recyclable packaging.
- Durable: Materials that are longer lasting or are comparable to conventional products with long life expectancies.
- Energy efficiency: Materials, components, and systems that help reduce energy consumption in buildings and facilities.
- Affordability: can be considered when building product life-cycle costs are comparable to conventional materials or as a whole, are within a project-defined percentage of the overall budget (calrecycle, 2009).

3 Different kinds of Earth Construction

3.1 Adobe

Adobe is a building material composed of water, sandy clay and straw or other organic materials, which is shaped into bricks using wooden frames and dried in the sun. Adobe buildings also offer significant advantages in hot, dry climates, as they remain cooler as it stores and releases heat very slowly. In more modern usage, the term "adobe" has come to mean a style of architecture that is popular in the desert climates of Middle East, especially in Iran.

Adobe structures offer many advantages. Clay soil suitable for adobe is found in many places of the world, making it a local material, saving transportation energy and costs. Another benefit of adobe is its low embodied energy production because it is not fired. Moreover, when an adobe structure is no longer in use, it can be returned back to nature (as soil).

3.2 Compressed Earth Blocks (CEB)

The compressed earth block is the modern descendent of the molded earth block, more commonly known as the adobe block. The idea of compacting earth to improve the quality and performance of molded earth blocks is, however, far from new, and it was with wooden tamps that the first compressed earth blocks were produced. This process is still used in some parts of the world. The first machines for compressing earth probably date from the 18th century. In France, Francois Cointeraux, inventor and fervent advocate of "new pise" (rammed earth) designed the "crecise", a device derived from a wine-press. However, it was not until the beginning of the 20th century that the first mechanical presses, using heavy lids forced down into moulds, were designed. Some examples of this kind of press were even motor-driven. These kinds of blocks are stronger, more dense and uniform to adobe blocks as a result of compression of the mix during manufacture (Maini, 2005).

Since its emergence in the '50s, compressed earth block (CEB) production technology and its application in building has continued to progress and to prove its scientific as well as its technical worth.

3.3 Rammed earth

Rammed earth construction is an old building method that has seen a revival in recent years as people seek low-impact building materials and natural building methods. Traditionally, rammed earth buildings are common in arid regions where wood is in scarce supply. Rammed earth construction shares the benefits of low embodied energy, local materials, low resource use and recyclability (Calkins, 2009; Easton, 2000).

Walls are constructed from a mixture of earth that has suitable proportions of sand, gravel and clay sometimes with an added stabilizer. Traditional stabilizers such as lime or animal blood were used to stabilize the material, but cement has been the stabilizer of choice for modern times.

One of the significant benefits of rammed earth constructions is its excellent thermal mass; it heats up slowly during the day and releases its heat during the evening. This can even out daily temperature variations and reduce the need for air conditioning and heating. On the other hand, rammed earth is not a good insulator. Like brick and concrete (which also have excellent thermal mass), rammed earth must be insulated in colder climates. The thickness and density of the walls lends itself naturally to sound proofing and the materials used in the walls make them virtually fireproof.

3.4 Cob

3.5 Super adobe

Super adobe (sandbag and barbed wire) technology is a large, long adobe. It is a simple adobe, an instant and flexible line generator. It uses the materials of war for peaceful ends, integrating traditional earth architecture with contemporary global safety requirements. Long or short sandbags are filled with on-site earth and arranged in layers or long coils (compression) with strands of barbed wire placed between them to act as both mortar and reinforcement (tension). Stabilizers such as cement, lime, or asphalt emulsion may be added.

This concept was originally presented by Iranian architect Nader Khalili to NASA for building habitats on the moon and Mars, as "Velcro-adobe". It comes from years of meditation, hands-on research and development, and searching for simple answers to build with earth. It comes from the concerned heart of someone who did not want to be bound to any one system of construction and looked for only one answer in human shelter, to simplify.

4 Advantages of Earthen Materials

Earth has been a tried and tested natural building material for thousands of years, and in combination with modern techniques can be used for modern ecological buildings. Building with earth materials can be a way of helping with sustainable management of the earth's resources. They can be put in place using simple machinery and human energy. Earth buildings avoid deforestation and pollution, and can achieve low energy costs throughout their lifetime - in the initial manufacture and construction, in their use as homes, and eventually in their recycling back to the earth.

Earth is more sufficient and time-consuming than today's conventional construction material, however for rural owners, the time covered in earth building may be less value than the money cost of current materials. In addition, earthen buildings will last for many years with minimal repairs necessary. However, when repairs are needed, they are simple and cheap to make. Even in areas of substantial rainfall, vertical surfaces with rain up to 25 inches per year will only erode about 1 inch in 20 years (Steen, 1994). In addition, earthen structures are not limited to residential housing. There are many examples of mosques, public baths, schools and different kinds of buildings which had been made by adobe. Here, advantages of earthen materials are categorized into two parts:

4.1 Environmental advantages

- Earthen materials do not consume any non-renewable energy. All they need are solar and human energy.

- It produces no industrial or chemical waste and has the additional advantage of being almost entirely recyclable.
- Earthen materials are not only non-polluting in their use. They also guarantee the absence of harmful effects in the context of daily life such as the absence of gaseous emissions or other toxic chemical components, radioactive emission etc.
- The surface textures, color, form and luminosity of earthen material make it an attractive material for buildings without ruining the natural environment.

4.2 Economical advantages

- Earthen materials do not consume any non-renewable energy. All they need are solar and human energy.
- Earthen material is often comparable in cost with, or indeed more economical than competing technologies. It requires no major financial transport costs because it's generally light production infrastructure.

4.3 Climatic advantages

- As a high mass material earth evens out temperature fluctuations by time-delayed releasing of absorbed solar energy thus providing a stable and comfortable internal temperature (passive solar heating).
- Earth has the great ability to absorb and release moisture from the indoor air thus stabilizing humidity inside rooms and providing a healthy living environment (http://www.solidearth.co.nz/earthbuilding-advantages.php).

Despite many advantages of earth, some preventable disadvantages warn us to use this material carefully. As an illustration, thick structures (like bearing walls) without any reinforcement caused many catastrophic events within Iranian earthquakes. In addition, designers faced some limitations with openings and proofing outdoor earthen material against water. The other disadvantages of earthen construction are:

- Earth construction is labor intensive,
- Construction dependency on weather conditions,
- Structural limitation,
- Need high maintenance and water resistance.

The disadvantages stated above are derived and mentioned from the experience of un-stabilized earth construction. According to Cassell (1993), the two historical disadvantages to rammed earth has been water damage and labor intensity. The Australians have solved the water damage problem by spraying the wall with a transparent plastic ideal for wall cleaning with a hose or damp sponge. Labor intensity has been solved by the use of gasoline and pneumatic powered tamping devices. Moreover, vernacular earthen houses located in seismic areas are at risk because of their inherent structural vulnerability, and it is possible to provide reinforcement to earthen buildings in order to improve their structural performance and to prevent their collapse during earthquakes. Furthermore, it is important to take note from the disadvantages to earth construction mentioned above that lack of durability and structural limitations of earth construction are emphasized by most of the authors. Therefore it is important to look at the research and up to date development and review literature on contemporary stabilized earth construction on seismic response, durability and structural achievement in brief. The following section reviewed literature on seismic response, durability and structural achievement of contemporary stabilized earth construction.

5 Sustainability in Earthen Materials- Case Study: CSEB

This section of paper is going to analyze critically the existing literature particularly on the environmental benefits of contemporary compressed earthen materials (as one of the different earthen materials) in construction.

According to Maini (2005), some studies have shown that, in the Indian context, building a square meter of masonry with CSEB (compressed stabilized earth block) consumes 5 times less energy than a square meter of wire cut bricks masonry and 15 times less than country fired bricks. Maini (2005) also stated that the compressed stabilized earth blocks are more eco-friendly than fired bricks and their manufacture consumes less energy and pollute less than fired bricks (Zami and Lee, 2009).

Table 1: A comparative analysis of energy consumption and carbon dioxide emission of four types of building materials (Maini, 2005).

Product and thickness	Number of Units (per square meter)	Energy Consumption (MJ per square meter)	Carbon dioxide emission (KG per square meter)
CSEB (24 cm)	40	110	16
Wire Cut Bricks (22 cm)	87	539	39
Country Fired Bricks (22 cm)	112	1657	126
Concrete Blocks (20cm)	20	235	26

Table 1 shows a comparative analysis of energy consumption and carbon dioxide emission of four types of building material. According to the numerical data shown in Table 1, CSEB consume the lowest energy and lowest carbon dioxide emission if compared with Wire Cut Bricks, Country Fired Bricks, and the Concrete blocks.

Adam and Agib reported that compressed stabilized earth blocks were successfully used for low cost housing in Sudan (Hadjri, 2007). According to Adam and Agib (2001), low energy input in processing and handling soil - only about 1% of the energy required manufacturing and processing the same volume of cement concrete. This aspect was investigated by the Desert Architecture Unit which has discovered that the energy needed to manufacture and process one cubic meter of soil is about 36 MJ (10 kwh), while that required for the manufacture of the same volume of concrete is about 3000 MJ (833 kwh) (Adam and Agib, 2001). According to Vroomen (2007), there are two important aspects playing a role in the ecological impact of a construction technique, and they are:

The energy required constructing a house and carbon dioxide emission resulting from the total process. In order to be able to assess the performances of the construction materials on the above aspects, a computation is made in Vroomen's (2007) research and to make the computations as transparent as possible, the values that were applied in different construction materials are given in Table 2.

Table 2: The characteristics of the materials as applied in the computation (Vroomen, 2007).

Material	Energy required (MJ/Kg)	Carbon dioxide emission in Kg
Gypsum	1	0.01
Cement (adobe machine)	4.8	1.25
Soil (adobe machine)	0.028	0
Fired Bricks	3.16	0.19

Table 3: The total of the environmental computation (Vroomen, 2007)

	Adobe	CSEB	Fired Brick	Hollow concrete blocks	Gypsum
Energy Required (MJ/fu)	36	233	1026	390	191
Carbon dioxide emission (Kg/ fu)	0	55	118	98	2

It is notable from this section that contemporary stabilized earth construction is environmentally sustainable compare to the conventional (fired brick, concrete, etc.) building materials. Promotion and adoption of stabilized earth as an alternative construction material is worthwhile and significantly helpful in achieving environmental sustainability (less carbon dioxide emission and less energy used).

6 Earth Buildings in Iran

Earth has been used in many different ways around the world for thousands of years. A large part of the world's rural population still lives in earth buildings. The first tokens of settlements in the central plateau of Iran dates back to 7000 BC. Shaped-up masses of mud set beside each other to construct the first human habitats (Hanachi et al, 2009).

Although ten thousand years has passed since the first settlements were constructed, the mud is still used as the suitable bonding agent, inexpensive and available material which has materialized the comfort and repose of the Iranians in a span of millennia.

The result of such continuity in the usage of mud and sun-dried mud-bricks in a period of ten thousand years has been houses, temples, prayer-houses, castles, palaces, and several towns, which still exist in this land. These are the symbols of the history of this nation. In this section of paper, we will review two kinds of earthen buildings in Iran.

6.1 Ancient refrigerator (Yakhchal)

By 400 BC, Persian engineers had mastered the technique of storing ice in the middle of summer in the desert. The ice was brought in during the winters from nearby mountains in bulk amounts, and stored in ice-pit. These ancient refrigerators were used primarily to store ice for use in the summer, as well as for food storage, in the hot, dry desert climate of Iran. The ice was also used to chill treats for royalty during hot summer days and to make ice cream. Aboveground, the structure is comprised of a large adobe and cob dome, often rising as tall as 60 feet tall.

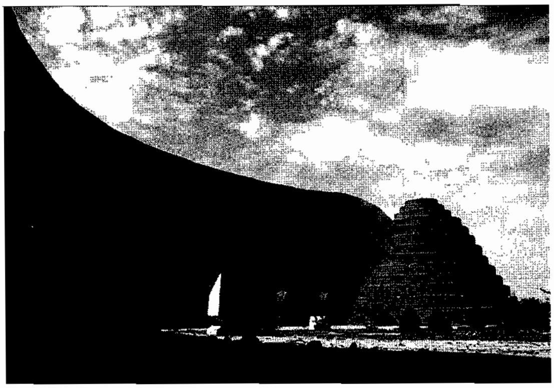


Figure 1: An ancient refrigerator in Kerman, Iran (photo from authors).

The Yakhchal have thick mud brick walls that are up to two meters thick at the base, made out of a special mortar (composed of sand, clay, egg whites, lime, goat hair, and ash in specific proportions, and which was resistant to heat transfer). This mixture was thought to be completely water impenetrable.

The massive insulation and the continuous cooling waters that spiral down its side keep the ice stored there in winter frozen throughout the summer. These ice houses used in desert towns from antiquity have a trench at the bottom to catch what water does melt from the ice and allow it to refreeze during the cold desert nights. The ice is broken up and moved to caverns deep in the ground. As more water runs into the trench the process is repeated.

6.2 Wind Catcher (Bad-Gir)

Wind catcher or what is called Bad-Gir in Persian language was a main component of buildings in central region of Iran and hot areas near the Persian Gulf. A wind catcher is a tower used to capture wind from external air stream and induce it into the building in order to provide natural ventilation and passive cooling. Due to geographical coordinates of the region, wind power and the direction of blowing wind, wind catchers are employed in different heights, cross sections of the air passages and the places and the number of the openings. The one-sided wind catcher has only one channel as a passage of induced air and is often related to the areas where there is prevailing wind. These wind catchers are employed to catch the wind blowing at higher elevations and direct it to the building, causing it to leave through windows, doors or other exhausted segments (Montazeri and Azizian, 2008).

The wind catcher functions on several principles:

In fact, wind catchers have the opposite function to chimneys. They are built with their long ventilation shafts positioned to catch any hint of a passing breeze to channel down into the house. The interlinking rooms of old buildings were designed to circulate the air that fluted down the wind catchers.

The sun-dried adobe bricks that were used to build the buildings retained their coolness in the summer and their warmth in the bitter winters. The air was channeled all the way down to the elaborate function rooms built in the basement where the family would mostly live in the stiflingly hot summers.

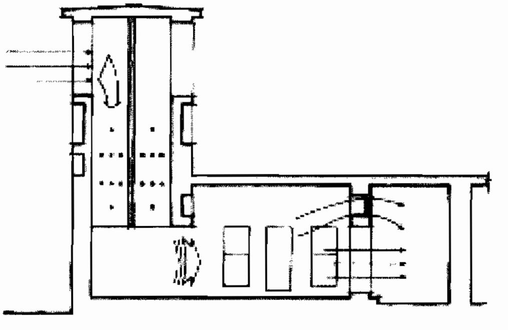


Figure 2: A cross section of a wind catcher (draw by authors).

Finally, in a windless environment or waterless house, a wind catcher functions as a stack effect aggregator of hot air. It creates a pressure gradient, which allows less dense hot air to travel upwards and escape out the top. This is also compounded significantly by the day-night cycle mentioned above, trapping cool air below. The temperature in such an environment cannot drop below the nightly low temperature. These last two functions have gained some ground in Western architecture, and there are several commercial products using the name wind catcher (Hanachi et al, 2009).

In these two examples of Iranian earthen buildings, we can distinguish the role of earthen material. As a high mass material earth evens out temperature fluctuations by time-delayed releasing of absorbed solar energy thus providing a stable and comfortable internal temperature (passive solar heating).

7 The Future of Earth Materials

Construction with earth is definitely an appropriate, and cost and energy effective technology. Clearly, one has to know the material and master its disadvantages, which normally are variations in the soil quality and hence the block quality, shrinkage cracks, lower strength than high quality fired bricks or concrete, production of the blocks on site, etc (Maini, 2005).

Since half a century, research and development has proved the potential of earthen techniques. Earth can be used as a quality and modern building material almost everywhere in the world. One of the main key points for a general revival and dissemination of earthen techniques is respect for Nature and management of limited resources.

Another important parameter is the training aspect. Quite a few training centers are blossoming all over the world, but it appears that government organizations have an essential role to play. They should bring awareness, from the schools to the masses, and give a political direction for the implementation of the research and development done by the best research and training centers.

In this regard, the paper offers a well known regulation for earth building in the world.

8 The German Regulations for Building with Earth

8.1 Din Codes

The German Regulations for Building with Earth, the Lehmbau Regeln, reflect the current situation of earth building in our country. In comparison to the DIN-codes from the post-war period, there is one important difference: at that time, earth was used predominantly for load-bearing walls using different traditional earth building techniques such as rammed earth, adobe and cob. Today, the use of earth for load-bearing walls is only one comparatively minor aspect of the use of earth as a building material in Germany. Earth is now used in a wide variety of techniques, and is also used in combination with other 'established' construction materials such as timber, brick and concrete.

8.2 Ecological Features

A growing tendency in the German building sector is the increasing consumer orientation towards healthy and environmentally-sound building materials. These demands are particularly well fulfilled by naturally-preserved earthen building materials. A key aspect in this respect is that unmodified earth hardens when exposed to air, and softens again when wet. This quality means that the life cycle of earthen building materials is energy-effective – very little energy is required to recycle earth or to return it to the earth. As a result, the German Earth Building Regulations do not govern the use of earthen building materials that have been chemically-stabilised with binders such as cement. This does not mean that their use is prohibited or restricted. At this time, there is little market for stabilised materials in Germany. In addition, the regulations recommend the open declaration of all aggregates and additives used by manufacturers of earthen building materials.

The structure of the Lehmbau Regeln is organised according to the stages in which earth is processed, i.e. a self-sustaining life cycle, one of the most important features of ecological building (Fig. 2):

- prospecting, extraction and classification of soil,

- preparation, forming, drying of earthen materials,
- manufacture and application of earthen building materials,
- use and maintenance of earthen buildings,
- demolition, disposal or recycling of earthen buildings.

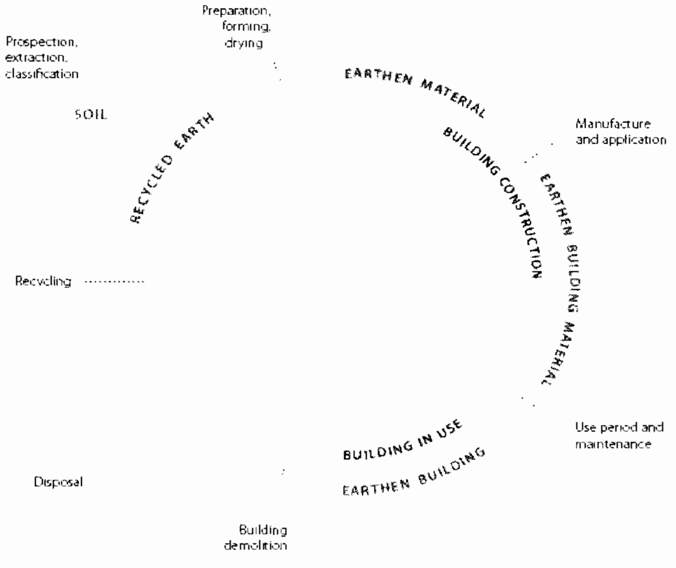


Figure 3: Building with earth presented as self-sustaining life cycle (Duchverband Lehm, 2004)

8.3 Soil classification

The first section of the German regulations identifies the soil types suitable for earth building purposes using a cohesion or 'binding force' test (according to NIEMEYER). The tensile strength of an 8-shaped test sample of pre-defined test consistency is determined and classified by assessing its binding force on a scale from "lean / poor" to "fatty / clayey". Recommendations are made for the optimal binding force for the production of each different earth building material. In this way it is possible to 'adjust' a sub-optimal binding force through the addition of appropriate aggregates.

Alternatively, soil classification according the Plasticity Index IP is also possible. The Plasticity Index IP is a main parameter of the internationally-recognised geotechnical soil classification system.

8.4 Earthen building materials

The second section of the German Earth Building Regulations describes the different earth building materials, their consistency, the suitable clay types and aggregates required to optimise the desired material parameters, as well as the addition of water where appropriate. The regulations describe the following earth building materials which are available as shaped or unshaped materials, and are applied wet or dry according to the parts of the building where they are used (Fig. 4):

- ready-mixed plasters and mortars (unshaped),
- ready-mixtures for light earth or rammed earth (unshaped),
- adobe blocks or panels in a large variety of different sizes, natural additives and densities (shaped).

	Rammed earth	Mud	Clay straw	Light clay	Loam filling	Earth mortar	Earth blocks	Earth panels
Floor	O				O			
Wall loadbearing	O	O				O	O	
Wall freestanding	O	O	O	O		O	O	O
Ceiling & Roof			O	O	O		O	O
Dry board cladding							O	O
Plaster			O	O		O		

Figure 4: Earth building materials according to the parts of the building they are used the unshaped ready-mixtures are available loose or packaged in sacks, wet or dry (Duchverband Lehm, 2004).

8.5 The use of earthen building materials in the building

The third section of the German Earth Building Regulations describes the possible usage of appropriate earth building materials for each application in the building, e.g. the building technology, construction details, renovation aspects, test procedures, drying, etc. Fig. 3 shows the respective fields of use:

- floors (new in 3rd edition 2007)
- walls
- vaults
- ceiling and roof infill material
- plasters

Walls are divided into load-bearing walls and non-load-bearing walls and infill methods for timber-frame constructions. The load-bearing walls are divided according to the technology used into adobe, rammed earth and cob walls. The non-load-bearing walls include different traditional infill methods for timber-frame constructions including wattle and daub, light earth using a supporting framework, adobe, the lining of existing supporting walls with different earthen materials for improving thermal insulation, walls made with clay panels and lightweight clay building boards.

9 Conclusion

Humans have been building homes out of earth for thousands of years. While earth structures are the oldest construction system, earth construction is perceived as an alternative building material for construction. Many engineers, designers, contractors, and clients misperceive earthen materials. And therefore, it limits using this material. However, rising fuel prices coupled with environmental and human health concerns of building materials are causing a return to this old construction material.

Moreover, some different techniques for earthen construction were described in part 4. These techniques mainly associated with processes using moulds, shuttering and direct shaping are "adobe", "rammed earth", "cob" and "compressed blocks". In this regard, the paper reviewed two Iranian earthen buildings (ancient refrigerator and wind catcher) which are sustained with adobe and cob material for the specific function of these buildings (cooling in summer).

Consequently, earthen architecture has some advantages which are related to sustainability issues. These advantages are explained in section 6 and 7. The most important ones are:

- Building material costs for earth structures can be lower than for other materials, especially if the input materials (soil, water and etc.) are derived from the same site.
- Earthen construction needs low energy input in processing, manufacturing and handling soil.
- Earth material is not only non-polluting in its use, it also guarantees the absence of harmful effects in the context of daily life such as the absence of gaseous emissions or other toxic chemical components, radioactive emission etc.
- As a high mass material earth evens out temperature fluctuations by time-delayed releasing of absorbed solar energy thus providing a stable and comfortable internal temperature (passive solar heating).

Acknowledgements

All texts regarding German regulations are belong to Dr Horst Schroeder, Ulrich Roehlen and Franz Volhard. The authors appreciate them for their favour.

Refereces

Adam, E. A. and Agib, A. R. A. (2001). Compressed Stabilised Earth Block Manufacture in Sudan. Printed by Graphoprint for the United Nations Educational, Scientific and Cultural Organization. France, Paris, UNESCO.

Calrecycle Centre (2009). http://www.calrecycle.ca.gov/GreenBuilding/materials/ Retrieved (26/09/2009)

Calkins, Meg (2009). Materials for Sustainable Sites, New Jersey: Wiley.

Cassell, R. O. (1993). A traditional research paper: Rammed Earth Construction, The compaction of successive layers of earth between forms to build a wall. http://webs.ashlandctc.org/jnapora/hum-faculty/syllabi/trad.html, 12.08.2007.

Dachverband Lehm e.V. (Ed.), (2004). Building with Earth. Consumer information, Weimar Press.

Easton, D. (2000). "Rammed Earth" Alternative Construction: Contemporary Natural Building Methods. Ed. L. Elizabeth, and C. Adams. New York: Wiley.

Froeschle, Lynn M., (1999) "Environmental Assessment and Specification of Green Building Materials," The Construction Specifier. Paper presented at Green Building Challenge 98, Canada.

Hadjri, K., et al., (2007). Attitude towards earth building for Zambian housing provision. Proceedings of the ICE institution of civil engineers, engineering sustainability 160, issue ES3.

Hanachi, Pirooz, et al., (2009), "Permanency, as a new understating of sustainability", International conference of SHGES in Italy, 06-08 November.

Maini, S. (2005). Earthen architecture for sustainable habitat and compressed stabilised earth block technology. Progrmmae of the city on heritage lecture on clay architecture and building techniques by compressed earth, High Commission of Ryadh City Development. The Auroville Earth Institute, Auroville Building Centre – INDIA.

Montazeri, H. And Azizian, R (2008). Experimental study on natural ventilation performance of one-sided wind catcher, Building and Environment, No 43.

Omer, Abdeen Mustafa (2007). Energy, environment and sustainable development, Renewable & sustainable energy reviews, No 12.

Rael, Ronald, (2008), Earth Architecture, Princeton University Press, USA.

Solid earth Institute (2010). (http://www.solidearth.co.nz/techniques-rammed-earth-cob-wattle-daub.php#cob). Retrieved (02/02/2010)

Steen A.S, et al., (1994) The Straw Bale House. Green Publishing Company, Chelsea.

Vroomen, R. (2007). Gypsum stabilised Earth - Research on the Properties of cast Gypsum-stabilised Earth and its Suitability for Low Cost Housing Construction in Developing Countries. Final thesis for MSc Architecture, Building & Planning, Eindhoven University of Technology, The Netherlands.

Zami, M. S. and Lee, A. (2009). Contemporary Earth Construction in Housing-Stabilised or Un-stabilised. International Conference on Housing and the Credit Crunch, Glasgow, Scotland.

Low Energy Architecture

The topic of Low Energy Architecture is of theoretical and practical interest to the sustainable development. Buildings account for over one third of global energy use and associated greenhouse gas emissions worldwide. In the UK, over 40% of the energy consumption is building related. This produces about 50% the nation's CO2 emissions and other pollutants which contribute to global warming. Reducing energy use by buildings is therefore an essential part of any strategy to reduce greenhouse gas emissions, and thereby lessen the likelihood of potentially catastrophic climate change. The most cost-effective steps toward a reduction in a building's energy consumption usually occur during the design process. To achieve efficient energy use, zero energy design departs significantly from conventional construction practice. Four interesting papers in this session examine the concept of low energy architecture.

Wael Salah Eldin Bahlol explores smart glass system which is capable of adapting to changes in the environment. This system can help the design team to achieve sustainability's goals by reducing energy consumption used to lighting, heating, cooling as well as reduce costs and improving the health and well being of occupants.

El Hadi Bouguerra, Abdelkader Hamid and Noureddine Retiel investigate the effect of phase change material (PCM) integration in building components in the Mediterranean's mild climates with the aim to reduce cooling energy. The study has found that the PCMs have better performance in non-insulated buildings and the best position is on surfaces that undergo the widest temperature variation. It has also found that incorporating PCMs on the ceiling give the best compromise gain.

Hans Rosenlund, Tareq Emtairah and Florentine Visser examine the post construction evaluation of the actual energy performance of the Aqaba Residential Energy Efficiency Pilot Project and evaluate the real costs and benefits. The study analyse several low-cost measures including potential renewable technologies that could well improve the energy efficiency of the built environment in Aqaba project.

Islam Abohela, Neveen Hamza, and Steven Dudek explore the key issues that face the multidisciplinary design team when considering the integration of wind turbines in the built environment. The study argues for the need to holistic sustainability assessment of integrating wind turbines in the built environment to include environmental, economic, technical and social acceptance.

Dr Mohamed El-Haram
Dundee University, UK

Smart Glazing Systems for Low Energy Architecture

Wael Salah Eldin Bahlol
Misr University for Science and Technology, Egypt

Abstract

The industrial and technological development in the twentieth century caused the increased emissions and heat, thus increasing the temperature of the Earth's climate.

The increase in temperature of the Earth's climate led to a negative impact on energy consumption. That caused increasing rates of energy consumption to overcome the high temperature change. So, the researchers concerned since the twentieth century; with minimising energy consumption by developing smart materials that were used in the construction and finishing of buildings to save energy consumption.

Smart materials in architectural definition is high technological materials that when placed in a building they respond intelligently with the climatic change, with different seasons either the environment is hot or cold to comfort or to get the human needs.

This research aims to introduce one of smart materials; smart glass which was used in the construction and finishing of buildings and the different benefits in terms of: saving energy, comfort for users of the building, raising the efficiency of production and maximising the technical performance.

Keywords: *Smart Glass, Energy Consumption, Modern Technology Materials, Daylighting.*

1 Introduction

The last few years have witnessed gradual increase in environmental problems. Global warming due to the increase of carbon dioxide emission was one of the major problems that appeared and threatened our environment in many aspects. Buildings account for about 43% of carbon dioxide emissions that cause the gradual increase of global warming. Recently architecture tried to find smart solutions to overcome these environmental hazards and problems specially those concerning energy consumption. One of these smart solutions was inventing smart glazing systems that help in the process of energy control inside buildings. Smart materials are emerging in technology with numerous potential applications in industries as diverse as consumer, sporting, medical and dental, computer, telecommunications, manufacturing, automotive, aerospace, as well as civil and structural engineering.

Smart glazing systems, similar to living beings, have the ability to perform both sensing and actuating functions and are capable of adapting to changes in the environment. In other words, smart glazing systems can change themselves in response to an outside stimulus or respond to the stimulus by producing a signal of some sort. Hence, smart glazing systems can be used as "sensors", "actuators" or in some cases as "self-sensing actuators" in general. By utilizing these materials, a complicated part in a system consisting of individual structural, sensing and actuating components can now exist in a single component, thereby reducing overall size and complexity of the system. However, smart materials will never replace system fully; they are usually part of some smart systems.

2 Buildings and Energy Consumption

We are living in a critical time. Energy security and climate change are two of the most important challenges of our lifetimes, and need urgent attention. The decisions we make and the paths we take now will determine the future health, security and well being of our Nation and the world. It is clear that there is no single solution to the problem. The challenge is so massive and urgent that it requires multiple simultaneous responses and solutions. Reducing energy consumption in buildings by using smart material must be part of the solution.

The great increase of the carbon dioxide emission in the last years as shown in (figure 1) caused the greenhouse gas (GHG) effect, which has a direct impact on environment and energy consumption. Buildings are number one in global CO2 emissions as shown in (figure 2). In the United States, people spend an average of 90% of their lives in buildings. Buildings are an important target of the clean technology movement. According to the U.S. Green Building Council, buildings in the United States account for 39% of energy use, 71% of electricity consumption, 40% of non-industrial waste and 38% of carbon dioxide emissions (USGBC Research Committee, 2008).

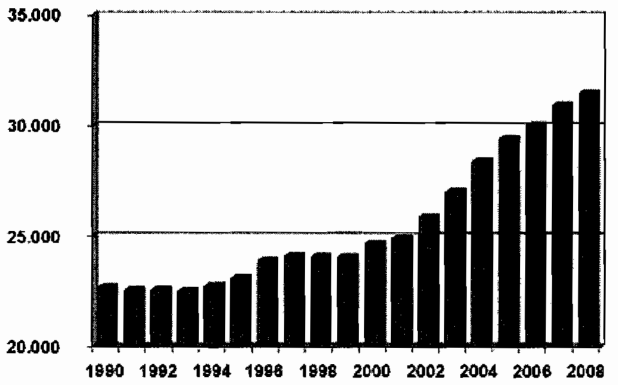


Figure. (1): Showing the increase of global CO2-Emissions [Mio.t].

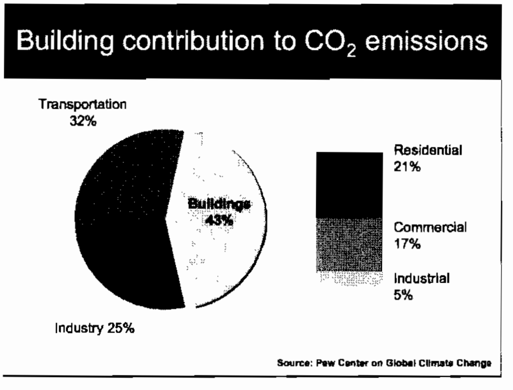


Figure. (2): Showing the amount of co2 emissions comes from buildings.

Also, the World Energy Report 2004 declared that the world energy demand will rise by 60% by 2030 with two thirds of the additional needs will come from developing countries (World Energy Report, 2004).

Buildings use energy for heating, cooling and lighting, add to the problems of exhaustion of fossil fuel supplies and environmental pollution. In order to make buildings more energy-efficient an extensive set of "energy-saving building components" has been developed that contributes to minimize the energy need of buildings, that helps buildings to access renewable energy sources, and that helps buildings to utilize fossil fuels as efficiently as possible. Examples of such energy saving building components are advanced glazing systems, thermal insulation layers, photovoltaic etc.

In general, buildings use energy in two different ways: first type is known as Envelope Load Dominated Building (ELDB) such as houses; and the second, Internally Load Dominated Building (ILDB) such as offices, schools, libraries, airports and stores (Ternoey S.E., 1999). The bulk of energy uses in the ELDB are lights, appliances and hot water whereas, ILDB mainly lights, computers, photocopying machines and air-conditioning. In offices, the artificial lighting accounts for about 50% of the total energy use and a significant portion of the energy utilized in other non-residential buildings.

So, by following a careful design and choice of smart materials, it is possible to produce buildings that use substantially less energy without compromising occupant comfort or the building's functionality. Whole-building design considers the energy-related impacts and interactions of all building components, including the building site; its envelope (walls, windows, doors, and roof); its heating, ventilation, and air-conditioning (HVAC) system; and its lighting, controls, and equipment.

Finally, by actively managing lighting and cooling, smart glass in windows could reduce peak electric loads by 20–30 percent in many commercial buildings, increase daylighting benefits, improve comfort, and potentially enhance productivity in homes and offices. These technologies can provide maximum flexibility in aggressively managing demand and energy use in buildings in the emerging deregulated utility environment. They can also move the building community towards a goal of producing advanced buildings with minimal impact on the nation's energy resources.

3 Daylighting

There are few conditions in the history of humankind as pervasive as the need for natural light and the desire to control it. Daylighting involves the purposeful introduction of natural light, also known as daylight, into the interior of a building.

Varying perspectives on daylighting exist within this broad context. In a study of mostly North American and Australian design professionals, an architectural definition of daylighting that involves "the interplay of natural light and building form to provide a visually stimulating, healthful, and productive interior environment" was deemed the most relevant. However, daylighting definitions pertaining to other orientations such as lighting energy savings and building energy consumption also were considered relevant to some (Reinhart C.F., Mardaljevic J. & Rogers Z., 2006).

The strategic application of daylighting primarily involves shading from the sun, protection from glare and the redirection of natural light (International Energy Agency, 2000). Studies examining the effect of daylighting strategies signal both economic and human benefit. Properly designed daylighting systems in retail, educational and workplace settings have been associated with dramatic increases in individual well being and productivity.

The sun provides bountiful energy. Harvesting this energy through daylighting strategies offers the opportunity to reduce the use of interior electric lighting, lower heating and cooling costs, increase occupant well being and health, and minimize environmental impact (Loveland J., 2003). Driven by a combination of energy efficiency goals and human well being desires, demand for daylighting solutions is growing. Some of these solutions are passive in nature and involve decisions as fundamental as the sitting of a building or the size and placement of conventional windows. Others are of a more active nature, integrating daylighting products and processes with computerized building control systems. Effective use of both active and passive solutions will help to advance the sustainability of buildings (Collins B.L.)

According to the U.S. Department of Energy (DOE). The DOE projects energy costs in U.S. buildings to exceed $400 billion in 2010. Windows are central elements of a building's design. They contribute aesthetically and support occupant comfort by introducing natural light and preserving views. "Smart glass" gives users the ability to "tune" the amount of light, glare and heat passing through windows, skylights, doors and other fenestration products.

Daylighting is a technical term given to a common centuries-old, geography and culture independent design basic by 20th century architects, many of whom who had made inadequate use of the design due to low cost and ignorance of global warming issues.

The benefits of considering architectural daylighting:

Utilization of natural light entering the interior of a building to:

- Reduce energy used for artificial lighting (US DOE Goal: By 2025, 50% reduction in the energy used to illuminate buildings).
- Lower heating and cooling costs.
- Increase occupant well being and productivity.
- Decrease environmental impact.

4 Smart Materials and Smart Glass

The Encyclopedia of Chemical Technology defines smart materials as objects that sense environmental events, process that sensory information, and then act on the environment. The second definition refers to materials as a series of actions. Smart materials in architectural definition is high technological materials that when placed in a building they respond intelligently with the climatic change, with different seasons (summer and winter) either the environment is hot or cold to comfort or to get the human needs. (M. Addington, D. L. Schodek, 2005)

The term „Smart Material" is applicable to materials and systems that can responsively react to changing environments through material properties or material synthesis. Their interactions stem from physical and/or chemical influences, such as change in temperature, pressure or exposure to radiation, magnetic or electric fields. One of the most important smart materials used in buildings is smart glass.

4.1 Overview of smart glass

Smart glass is a category of glazing materials that changes its light-control properties in reaction to an external stimulus (Sottile G.M., 2007), known also as switchable glazing. Smart glass is a relatively new category of high performing glazing with significant clean technology characteristics. It can be used in a wide range of everyday products such as windows, doors, skylights, partitions, sunroofs, sun visors and more. Expectations for growth in smart glass demand are very high (Sottile G.M., 2008).

Smart Glass can be manually or automatically "tuned" to precisely control the amount of light, glare and heat passing through a window. While glass is a favoured product for use in building facades; glare, solar heat gain and UV exposure are problematic and can often make the use of glass impractical resulting in the need to invest in expensive solar shading devices. Glass facades using smart glass technology reducing the need for air conditioning during the summer months and heating during winter. The ability to instantly switch the glass to maximize daylight when it's really needed and to provide controllable solar shading during peak light conditions is valuable and unique.

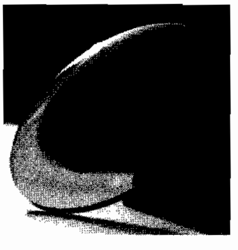
4.1 Types of smart glass

4.1.1 Passive smart glass

Does not involve an electrical stimulus. Rather, it reacts to the presence of other stimuli such as light (Photochromic Glass) or heat (Thermochromic Glass).

Photochromic Glass (PC)

That changes color when exposed to light, Photochromic materials absorb radiant energy which causes a reversible change of a single chemical species between two different energy states, both of which have different absorption spectra. Photochromic materials absorb electromagnetic energy in the ultraviolet region to produce an intrinsic property change (Farghaly Yasser, 2009). Depending on the incident energy, the material switches between the reflectively and absorptively selective parts of the visible spectrum (figure 3).



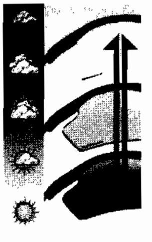


Figure. (3): Sample of uses of Photochromic Glass

Thermo chromic Glass (TC)

Thermo chromic materials change colour due to temperature changes. It absorbs heat, which leads to a thermally induced chemical reaction or phase transformation. They have properties that undergo reversible changes when the surrounding temperature is changed (figure 4).

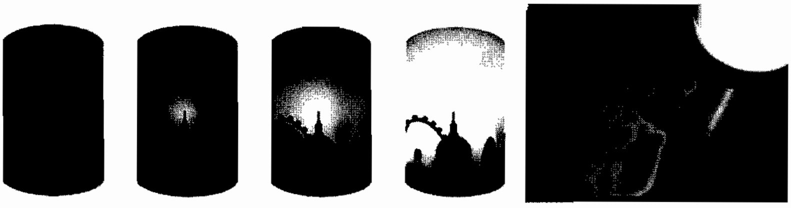


Figure (4): Shows the effect of thermal heat on Glass

4.1.2 Active smart glass

Active smart glass named also switchable glass that changes light transmission properties when voltage is applied. Active smart glass is now being offered as an innovative design solution for products ranging from aerospace windows to architectural skylights and automotive sunroofs.

Certain types of smart glass can allow users to control the amount of light and heat passing through: with the press of a button, it changes from transparent to opaque, partially blocking light while maintaining a clear view of what lies behind the window. Another type of smart glass can provide privacy at the turn of a switch.

There are three primary types of active smart glass technologies, each with its own unique chemistry, production requirements and performance characteristics; electro-chromic devices(EC), suspended particle devices (SPD), and Polymer dispersed liquid crystal devices (PDLC).

These technologies are not one-constituent materials, but consist of multi-layer assemblies of different materials working together.

Electro chromic devices (EC)

Electro chromic windows center around special materials that have electro chromic properties. "Electro chromic" describes materials that can change colour when energized by an electrical current. Essentially, electricity kicks off a chemical reaction in this sort of material. This reaction (like any chemical reaction) changes the properties of the material. In this case, the reaction changes the way the material reflects and absorbs light. In some electro chromic materials, the change is between different colors. In electrochromic windows, the material changes between colored (reflecting light of some color) and transparent (not reflecting any light).

Electrochromic glass provides visibility even in the darkened state and thus preserves visible contact with the outside environment. It has been used in small-scale applications such as rearview mirrors. Electrochromic technology also finds use in indoor applications, for example, for protection of objects under the glass of museum display cases and picture frame glass from the damaging effects of the UV and visible wavelengths of artificial light.

Electrochromic windows darken when voltage is added and are transparent when voltage is taken away. Electrochromic windows can be adjusted to allow varying levels of visibility.

Like other smart windows, electrochromic windows are made by sandwiching certain materials between two panes of glass. It consists of layers in order from inside to outside as shown in (fig. 5,6):

- Glass or plastic panel
- Conducting oxide
- Electrochromic layer, such as tungsten oxide
- Ion conductor/electrolyte
- Ion storage
- A second layer of conducting oxide
- A second glass or plastic panel

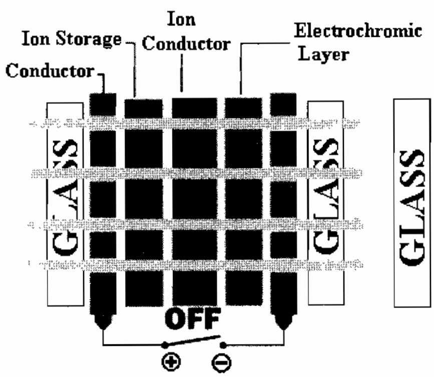


Figure. (5): When switched off, an electro chromic window remains transparent.

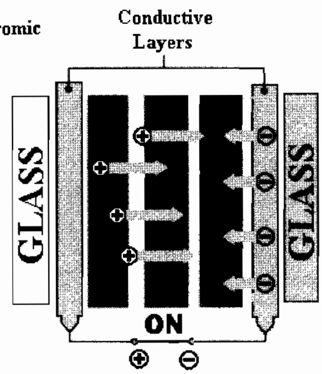


Figure. (6): Shows When switched on, a low volt of electricity makes the electro chromic window translucent.

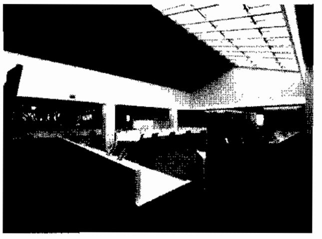


Figure. (7): Electro chromic glass used in sky light in office building

Suspended Particle Devices (SPD)

In suspended particle devices (SPD), a thin film laminate of rod-like particles suspended in a fluid is placed between two glass or plastic layers, or attached to one layer. When the power supply is switched on, the rod shaped suspended particle molecules align, light passes through and the SPD Smart Glass panel clears. When the power supply is switched off the rod shaped suspended particle molecules are randomly oriented blocking light and the glass panel looks dark (or opaque), blue or, in more recent developments, grey or black color. the SPD Smart Glass when becomes dark can blocking up to 99.4% of light. SPD Smart Glass protect from damaging UV when on or off.

So, SPD can be dimmed, and allow instant control of the amount of light and heat passing through. It consists of several layers as shown in (fig. 8,9):

- Two panels of glass or plastic
- Conductive material - used to coat the panes of glass
- Suspended particle devices - millions of these black particles are placed between the two panes of glass
- Liquid suspension or film - allows the particles to float freely between the glass
- Control device - automatic or manual.

Polymer Dispersed Liquid Crystal devices (PDLC)

In polymer dispersed liquid crystal devices (PDLC), liquid crystals are dissolved or dispersed into a liquid polymer followed by solidification or curing of the polymer. Typically, the liquid mix of polymer and liquid crystals is placed between two layers of glass or plastic that includes a thin layer of a transparent, conductive material followed by curing of the polymer, thereby forming the basic sandwich structure of the smart window (Elkadi H. 2006).

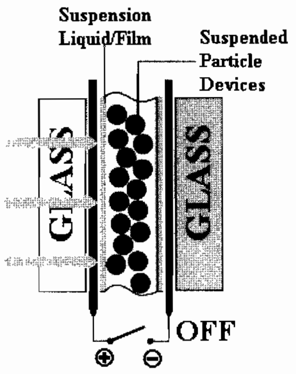


Figure (8): Shows When switched off, SPD window remains translucent.

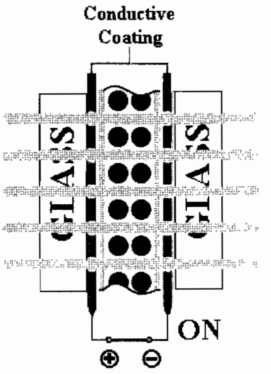


Figure (9): Shows When switched off, SPD window remains transparent.

Figure (10): When SPD Smart Glass off

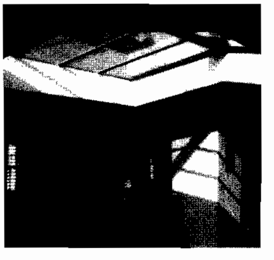


Figure (11): When SPD Smart Glass on

This structure is in effect a capacitor. Electrodes from a power supply are attached to the transparent electrodes. With no applied voltage, the liquid crystals are randomly arranged in the droplets, resulting in scattering of light as it passes through the smart window assembly. This results in the translucent, "milky white" appearance. When a voltage is applied to the electrodes, the electric field formed between the two transparent electrodes on the glass cause the liquid crystals to align, thereby allowing light to pass through the droplets with very little scattering, resulting in a transparent state (fig 12,13). The degree of transparency can be controlled by the applied voltage. This technology has been used in interior and exterior settings for privacy control (for example conference rooms, intensive-care areas, bathroom/shower doors) and as a temporary projection screen.

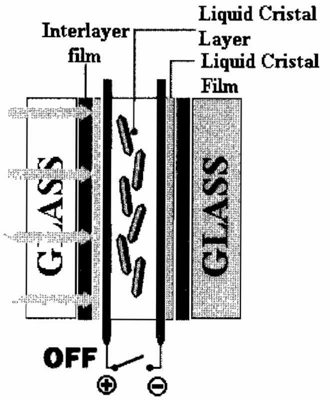


Figure (12): Shows when switched off, PDLCwindow remains translucent.

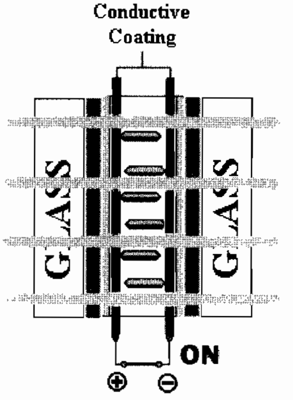


Figure (13): Shows When switched on, PDLC window remains transparent.

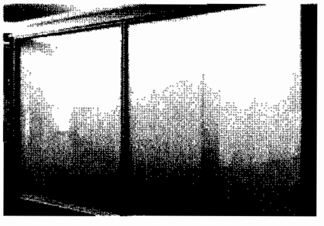


Figure (14): When PDLC Smart Glass off

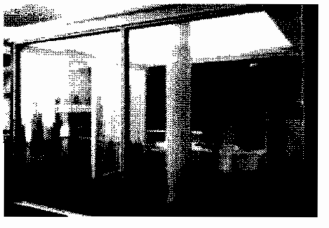


Figure (15): When PDLC Smart Glass on

Also, (PDLC) glass can already be found in offices and homes around the globe. Because it can achieve a translucent setting, PDLC technology is great for homes and offices, you get privacy without sacrificing all light.

Table 1 shows a comparison between the three different kinds of switchable glass (EC,SPD,PDLC) in characteristics and behavior in architectural activities.

	EC	SPD	PDLC
When is transparent?	Switched OFF	Switched ON	Switched ON
Continuous states between opaque and transparent?	Yes	Yes	No

Requires power to maintain the state?	No	Yes	Yes
Shading Benefit	Yes	Yes	Nominal (diffuses light)
Switching Speed	Varies depending upon panel size; May take many minutes for large format Panels	Several seconds regardless of panel size	Milliseconds regardless of panel size
Light-control States	Typically 2 preset levels from dark to clear	Unlimited levels from very dark to clear	2 (translucent and transparent)
Light Transmission in dark/opaque	SHADING: Yes PRIVACY: Typically some view remains	SHADING: Yes PRIVACY: Yes	SHADING: Nominal PRIVACY: Yes
Energy Used to Operate	Very low	Very low	Very low

4.2 The benefits of smart glass

Active smart glass will play an increasingly important role in the world's drive toward sustainability. Requiring very low amounts of power to operate. Architects and designers can integrate smart glass into their projects in ways that offer unprecedented control over incoming light, glare and heat. In doing so, electrical energy consumption can be lowered, cooling loads reduced, environmental impact mitigated and occupant well-being increased. These outcomes can be achieved by the integration of smart glass into various day lighting strategies. Most fundamentally, smart glass transforms conventional windows into smart windows with expanded daylighting utility and value. For example, curtains, blinds and other treatments have traditionally been used to provide shading and glare reduction through incoming windows.

These solutions typically block one's view to the outside, an undesired outcome for many building occupants. Windows with smart glass allow users to control incoming light, glare and heat without the loss of view to the outside.

Generally there are a lot of benefits of using smart glass such as:

- Instant and precise control of light.
- Energy Savings on cooling & lighting costs.
- Eco friendly, reduce building carbon emissions.
- Exceptional optical qualities that reduce glare and eye strain.
- Elimination of the need for expensive window dressings like electronic louvers; blinds and solar shades used in architectural applications.
- High durability, solid-state technology with no moving parts to wear out or break.
- Infinite range of light transmission levels without blocking of view.
- Stable color characteristics for the life of the unit.
- Wide working temperature range from -20°c to +70°c – Ideal for exterior applications, ambient temperature control.
- Wide light transmission ranges.
- Hygienic low maintenance material.
- Reduced fading of carpets, furniture and protect valuable artwork.
- Reduces uncomfortable feeling when living or working in high-density buildings such as apartment blocks or office complexes.
- Protecting skin from damaging UV rays.
- Low working voltage.
- High contrast at any viewing angle and any illumination level.
- Long life – tested to in excess of 100,000 cycles.
- Aesthetically pleasing and cost competitive.

Table 2 shows the wide benefits of using smart glass in smart windows comparative with conventional windows:

Conventional Window with Static Tint and Interior Blind/Shade	**Smart Window**
Static window tint degrades view to outside during low/no-sun periods	View to the outside is optimized even during low/no-sun periods
Partial shading from interior blind obstructs view	Variable shading does not obstruct view
Space consumption is relatively high	Space consumption is relatively low
Shading/privacy requires manual effort to close blinds or activation of expensive motorized shade	Sensors adjust light conditions automatically; manual light-control is as simple as turning a dial
Occupants less likely to control/optimize light levels	Ease-of-use and integration with sensors optimizes light levels
Daylighting benefits are not optimized	Daylighting benefits are optimized

5 Test Model Study

A test model study was carried out at the united states by Lawrence Berkeley National Laboratory (LBNL), division of environmental energy technologies on the electrochromic glass windows capabilities of reducing energy consumption (Lee E.S., DiBartolomeo D. L. & Selkowitz S. E. 2000).

Incorporating Electrochromic glazings could reduce peak electric loads by 20 to 30% in many buildings and increase daylighting benefits. These technologies will provide maximum flexibility in managing energy consumption and will move the building community toward the goal of producing advanced buildings with minimal impact on the energy resources.

Electrochromic windows have been installed in two adjacent office test rooms, enabling researchers to conduct full-scale monitored tests (Figures 16 and 17). Full-scale tests bring laboratory devices one step closer to commercialization by solving key design problems in a short test-evaluate-test iterative cycle of development within a realistic building environment. At this time, large-area windows (90x200 cm) are technically viable.

5.1 Method

Large-area electrochromic windows were installed in two adjacent test rooms in an office building, test objectives included developing control systems, monitoring energy use, and evaluating visual comfort in both cases.

Each test room was 3.71 m wide by 4.57 m deep by 2.68 m high and furnished with nearly identical building materials, furniture, and mechanical systems to imitate a commercial office environment. The conventional and the Electrochromic windows in each room were simultaneously exposed to approximately the same interior and exterior environment so that measurements between the two rooms could be compared. A laminated electrochromic glazing was combined with a low-emittance (low-E) glazing to form a double-pane window with a visible transmittance (Tv) range of 0.14 to 0.51. Each electrochromic double-pane window was then mounted on the interior side of the building's existing monolithic green-tinted glazing (Tv=0.75). The overall composite Tv range was therefore 0.11 to 0.38. Electrochromic windows were placed in an array of five upper and five lower windows to cover the full area of the window opening (3.71 m wide by 2.29 m high) as shown in Figure 6 and all were switched with a voltage between 0-3 V.

The system was automated, switched electrochromic windows integrated with the dimmable fluorescent lighting system to maintain an interior work plane illuminance of 510 lux throughout the day. Daily lighting & horizontal illuminance was measured at a work plane height of 0.76 m in a two by five array of Li-Cor sensors. Window luminance data were collected with a shielded sensor placed on the rear wall of the test room facing the window.

Figure (16) Before direct sunlight enters the windows, The electrochromic windows are in the clear state.

Figure (17) After direct sunlight enters the window, the electrochromic glazing switches to its fully colored state

5.2 Results

The electrochromic window system tested had excellent optical clarity, no coating aberrations (holes, dark spots, etc.); uniform density of color across the entire surface during and after switching, smooth, gradual transitions when switched; and excellent synchronization (or color-matching) between a group of windows during and after switching. The windows had a very slight yellow tint when fully bleached and a deep prussian to ultramarine blue when fully colored.

The glazings were not reflective. To all outward appearances, the Electrochromic windows looked exactly like conventional tinted windows with the exception that one can change their coloration.

Electrochromic glazings save energy by reducing cooling loads and reducing electric lighting energy consumption when dimmable lighting systems are used. In tests conducted during the winter, the focus was on the lighting energy impacts. Ceiling mounted photo sensor controls were used to modulate the glass transmittance and maintain a light level of 510 lux at the work surface. When insufficient daylight was available, the electric lights provided the additional required illuminance. When comparing the electrochromic glazings to a static dark glass (Tv=11%) on sunny and overcast days, the daily lighting energy consumption for the room with the electrochromic windows was on the order of 6 to 24% lower. Whenever direct sunlight enters the room, the electrochromic window switches to its darkest state (11%), so there are no savings relative to the static glazing. But much of the time in the afternoon, there is no direct sunlight on these facades, and under most overcast conditions the Electrochromic window switches to a clearer state, allowing the lights to be dimmed, saving energy (Figure 17).

However, when the electrochromic glass is compared to a higher transmittance glass (Tv=38%), the lighting energy use is actually 0 to 13% greater. This is because the static glazing always transmits as much light as or more light than the electrochromic, which will often be switched to control direct sunlight, thus requiring some added electric light. Overall, however, the high-transmittance static glass is likely to have higher cooling loads and result in more glare problems. And in an occupied space, people would likely have added blinds or shades to control glare, further reducing the apparent advantage of the clearer static glazing (Lee E.S. 2006).

5.2.1 Future directions for Electrochromic glass

Two strategies can improve lighting energy savings with electrochromic glazings: increase the upper Tv limit and decrease the lower Tv limit for glare control. For this test, the upper Tv limit could have been increased if the existing building glazing had been removed. This work also suggests that it may be advantageous for electrochromic devices to have a larger contrast ratio and higher transmission in the bleached state; for example, a device that can switch between Tv=0.06-0.85 will have greater daylight efficacy and control over intense sunlight than the device tested. Additional field tests will be conducted to better understand electrochromic glazing properties, the relationships between these properties and lighting savings, cooling savings, and occupant satisfaction and methods to integrate dynamic control of the window system with whole building energy management systems.

6 Conclusion

The twenty-first century has ushered in a period of pressing threats to the environment, rising energy costs, and a firming resolve that sustainable architectural design can yield dramatic gains in long-term resource preservation and overall quality of life. Supporting all of this is the growing portfolio of clean technology products and processes that not only advance sustainable ideals but do so profitably.

Smart glazing technology is poised to propel sustainability to new levels. Electrochromic windows can deliver significant energy savings, visual comfort, and greater access to view managing direct sunlight and glare.

Smart glass can help the architectural community achieve its sustainability goals by reducing electricity consumption used to power interior lighting, lowering cooling costs and improving the health and well being of occupants. As adoption of smart glass accelerates and prices decline, it is likely the category will move from one being used by early adopters to one being sought after by the mainstream.

Smart glass manufacturers should develop an accurate intermediate-state controller and work toward faster switching speeds, less color in the tinted state, lower minimum transmittance, and reduced manufacturing costs in order to use it widely specially in hot and sunny areas.

References

Collins B.L. *Windows and People: A Literature Review. Psychological Reaction to Environments With and Without Windows.* National Bureau of Standards. Washington D.C.

Elkadi H. (2006). *Cultures of Glass Architecture.* Ashgate publishing limited. Hampshire. England.

Farghaly Yasser A. (2009). *Using Smart Materials to Reduce Energy Consumption in Buildings*, Third Ain Shams University International Conference on Environmental Engineering. Vol II. 14-16 April 2009.

International Energy Agency. (2000). *Energy Conservation in Buildings and Community Systems Programme. Daylight in Buildings: A Source Book on Daylighting Systems and Components.* Report of IEA SHC. Task 21 / ECBCS Annex. July 29

Lee E.S., DiBartolomeo D. L. & Selkowitz S. E. (2000). *Electrochromic Windows for Commercial Buildings: Monitored Results from a Full-Scale Testbed, ACEEE Summer Study on Energy Efficiency in Buildings.* Pacific Grove, CA, August 20-25.

Lee E.S. (2006). *Advancement of electrochromic windows.* Lawrence Berkeley National Laboratory. California. USA. May

Loveland J. (2003). Daylight By Design: Studies From the Better bricks Daylighting Lab in Seattle Illustrate How Daylight Can Be Integrated Into Site And Building Design. *Lighting Design + Application.*

M. Addington & D. L. Schodek. (2005). *Smart Materials and Technologies in Architecture and design professions.* architectural press.

Reinhart C.F., Mardaljevic J. & Rogers Z. (2006). *Dynamic Daylight Performance Metrics for Sustainable Building Design.* Leukos, 3 (1), 7-31.

Sottile G.M. (2007). *Study of United States LEED Accredited Professionals on the Subject of Smart Glass.* 50th Annual Technical Conference Proceedings of the Society of Vacuum Coaters. pp.32-35.

Sottile G.M. (2008). *Cleantech Daylighting Using Smart Glass: A Survey of LEED Accredited Professionals.* The 51st Annual Technical Conference Proceedings of the Society of Vacuum Coaters. Research Frontiers Incorporated, Woodbury, NY, USA.

Ternoey S.E. (1999). *Cool Daylighting the Cornerstone Strategy to Green Buildings, Daylight Every Building.* USA: Light Form LLC.

USGBC Research Committee. (2008). *A National Green Building Research Agenda.* U.S. Green Building Council. November 2007 (Revised February 2008).

World Energy Report. (2004).

Energy Conservation in Buildings with Phase Change Materials in Mediterranean's Climates

El Hadi Bouguerra[1], Abdelkader Hamid[1] and Noureddine Retiel[2]
[1] *Department of Mechanical Engineering, S. Dahleb University, Algeria*
[2] *Mechanical Department, University of Mostaganem, Algeria*

Abstract

The effect of phase change material (PCM) integration in building components is investigated in the Mediterranean's mild climates. Simulations in a typical family house were made and the effect of incorporating PCMs on non-insulated and insulated buildings was analyzed. The position of PCM wallboards giving the better compromise in cost/performance was explored. Obtained results showed relatively mitigated performances because low day/night temperature swings in mild climates make night-time ventilation less efficient to discharging the PCM. Removing heat by mechanical cooling (for discharging PCMs) is relevant only if there is differentiated electricity price for off peak periods. Anyway, reduction of about 20% on energy consumption can be achieved by the PCM integration in non-insulated building. The better position of PCM wallboards is found to be on surfaces that undergo large temperature variations (connected to the outdoor air) like the ceiling for example. This aspect shows their potential use for refurbishment of existing houses which is the weak point of all energy conservation policies.

Keywords: *Low energy buildings, Passive buildings, Phase change materials, Energy conservation.*

1 Introduction

The increasing use of air conditioning in mild and hot climates as in Mediterranean's countries, is a real problem for the global warming. Indeed, CO_2 emissions are mainly caused by fossil energies, in particular for electricity generation. Then, it is essential to reduce the energy consumption in buildings where the biggest potential of savings exists since each saved kWh is a kWh that is not needed to be produced.

The incorporation of phase change materials (PCMs) in building materials to reduce the cooling needs was investigated by many studies especially these last years. An extensive literature review can be found in (Zhu, 2009). Experimental test-rooms with PCM wallboards were investigated by Kuznik (2008), Schossig (2005), Voelker (2008) and Hongim (2009). For heavy structures, Zalba (2004) and Cabeza (2007) tested concrete cubicles impregnated with encapsulated PCMs. But, these studies are generally with light weight constructions (wood structures) or reduced scales. The promising results cannot be generalized and do not permit to conclude about the real benefits in real buildings. The experience conditions lead to a large indoor day/night temperature variation allowing to the PCMs to swing widely around the melting temperature. In this case, charge and discharge cycles are completely accomplished. The night ventilation with cooler outside air is generally sufficient to discharge and remove heat from the PCMs.

On the other hand, Stetiu (1998) has found different reduction levels when using PCMs in the diverse California climates. Significant performances are only in areas with very wide day/night temperature variation. Medved (2008) investigated PCM apparatus in different European cities climates and found that PCMs perform more for cooling in Berlin than Athens. It is interesting to see if the same trends exist in mild climates like the Mediterranean region. These climates are characterized by tempered outdoor temperatures with a low day/night variation. In coastal cities, the temperature swings can be only 3-4°C on hot season. Therefore, night ventilation is expected to be less effective and the higher outdoor night temperature does not allow to the PCMs to discharge completely. Further, high humidity could cause a real discomfort. The resort to mechanical cooling is generally required to provide acceptable summer comfort conditions.

Our aim is to see how PCMs can reduce or delay thermal loads in this kind of mild to hot climates in real buildings and if an active cooling (air conditioning) can act as a cold source to discharge PCMs.

1.1 Energy context in buildings

Roughly speaking, we can consider that the energy demand in the world falls into about 1/3 for the building, 1/3 for the industry/agriculture and 1/3 for the transport. For the transport and industry, the potential savings are low. A great effort was already made in energy conservation.

By contrast, a huge potential of energy savings exists in the building because about 70% of this consumption concerns the heating and air conditioning. For example, every German low energy building "Passivhauss" saves up to 80% on the heating energy and so avoids about 2.4 tons of CO_2 emission each year (Krarti, 2007).

For the new buildings, the actual target is to reach by 2050 a quasi-null fossil energy consumption with the needs reduced by about 70 % and consequently, the renewable energy contributing by 30% (Zero energy concept). Nevertheless, more than a half of 2050's buildings are already built with little (or null) energy preoccupation. Presuming the yearly renewal rate for the housing park between 0.1 and 0.5%, about 200 to 1000 years would be needed to replace the current park of buildings. To fulfil the Kyoto's objectives for CO_2 reduction, it requires besides the transition to 'low energy' of all the new housing which will be meantime built, but also the renovation of the existing sector at 2 to 5% yearly. Those targets are very far because numerous problems of costs and implementation.

1.2 Air conditioning and electricity demand

The total Mediterranean countries' market for room air conditioners can be estimated to 12 million units with a rapid grow of 10% year. In light of their easy implementation in existing buildings and relatively low cost, splits system units continued to be the biggest market segment. Formerly, this equipment was reserved for the service sector only but is now accessible to the residential sector even in countries with lower income.

For the Mediterranean warm to hot climate countries, the problem of summer comfort can become essential. The basics of low energy building design must be modified to take into account the most important contribution of solar irradiation. This heat contribution reduces the thermal loads in winter but increases presently the problems of summer overheating. This aspect is particularly important because due to the endemic crisis of housing in many Mediterranean countries (especially southern seaside), buildings were built without any energy preoccupation. However, with the actual development of the human comfort, these buildings are now equipped with air-conditioning and become very voracious consumers on electrical energy what lead to a boom on demand in the summer period.

World electricity consumption is expected to double by 2025 and a strong growth averaging 3.5 % yearly is projected. Cooling of residential buildings contributes significantly to this increasing electrical consumption with peak demand, mainly due to very poor load factors in milder and hot climates. This simultaneous energy demand in the summer requires utilities to build, operate and maintain peak-power plants with a real risk of blackouts and energy shortage. To attenuate this problem, many countries set up a differential pricing system for the peak and off peak periods of electricity use.

Houses with very low energy consumption are built today and meet some success because the recent technical solutions can be now easily integrated. There is no significant difference about the aesthetics, the rooms' arrangement or the methods of construction. To reach this target of low energy buildings, three ways are followed (Figure 1):

1- Reduction of the energy consumption by the constructive systems, the insulation of the opaque walls and the treatment of the transparent walls (windows).

2- Use of renewable energies, PV (photovoltaic) electricity, combined heating-warm water solar systems, heat storage, heat's micro-networks, etc.

3- Efficient use of the fossil energy, double ventilation with heat recovery, compact HVAC systems, micro-cogeneration etc.

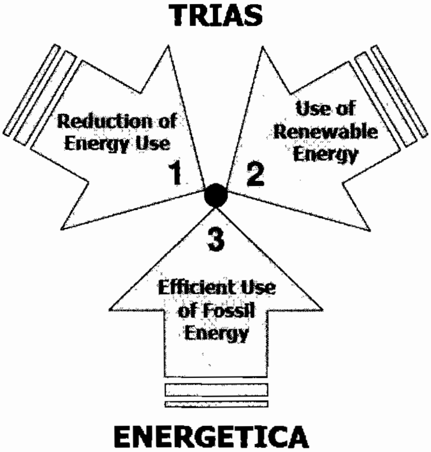


Figure 1. Energy demand reduction is the most important step toward a sustainable energy (De Keulenaer, 2007)

Whatever is the model used, any action must start with an important reduction of the energy demand in the housing. Indeed, by keeping the current building consumption, substituting fossil fuels by renewable energies is technically practicable but economically illusory. Reducing energy consumption is giving a chance of success to the renewable energies.

1.3 PCM in buildings

The main issue with energy conservation and renewable energies is often the heat storage because the needs are not necessarily simultaneous with the availability of the sources. Thermal storage could either take the form of sensible heat storage or latent. Sensible storage is accomplished by increasing a material's temperature, whereas latent heat storage is accomplished by changing the material's physical state. To store the same quantity of energy, smaller quantities of material are required for latent storage. This could be illustrated by using a common building material such as concrete, which can store about 1.0 kJ/kg, whereas a phase change material (PCM) such as calcium chloride hexahydrate can store/release up to 193 kJ/kg of heat on phase transition (Kenneth, 2000).

The order-of-magnitude in the increase in thermal storage capacity of PCMs and their almost isothermal discharge allows the storage of high amounts of energy without significantly changing the temperature of the room envelope. This effect could be exploited to stabilize ambient temperatures inside buildings. Melting temperatures must be in the range that is relevant to housing requirements.

In buildings, thermal mass can be used for storing energy to attenuate indoor temperature fluctuations. By minimizing deviations from the comfortable temperature range, the need for energy intensive heating and air conditioning can be significantly reduced. Nevertheless, the advantages of a thermally massive building often conflict with practical considerations in the design process. Aesthetics and cost pressure require modern buildings to be increasingly lightweight. Solutions that increase the thermal mass of a building without increasing the structural weight, are therefore particularly desirable. Incorporating PCM in buildings is a mean to increase artificially thermal mass of lightweight structures (Zhang, 2007).

The walls and ceilings of a building offer large areas for passive heat transfer storage within every zone of the building. So, it is interesting to incorporate PCM in building material like gypsum wallboards, plaster or concrete to increase the thermal mass. The implementation of PCMs would also permit the thermal storage to become part of the building structure. As heat storage takes place inside the building, where the load occurs rather than externally, additional energy transport is not required.

Phase change materials have to be accessible from the rooms and the molten PCM must not soak construction materials. Therefore, they need some form of containerization to be used for thermal storage in buildings. Encapsulation is a containment method for PCMs to avoid leakage or reacting with material matrix. Several proposed systems encapsulate the PCM in tubes, pouches or spheres. The drawback of this method is the poor heat transfer rate due to the low conductivities: freeze is only near the interface.

Recently, new methods of encapsulation appeared in the market. The micro encapsulated PCMs are made with paraffin waxes embedded within small polymer spheres, about 10-20 μm in diameter. These can be mixed directly into the building material or on facing wallboards (figure 2). Significant PCM mass fractions, up to 30%, are achievable. The PCM is chosen to melt in the working temperature range of the thermal mass. The additional latent heat capacity of the distributed PCM increases the overall effective heat capacity, potentially allowing improved temperature attenuation from a smaller amount of the thermal mass (Khudhair, 2004).

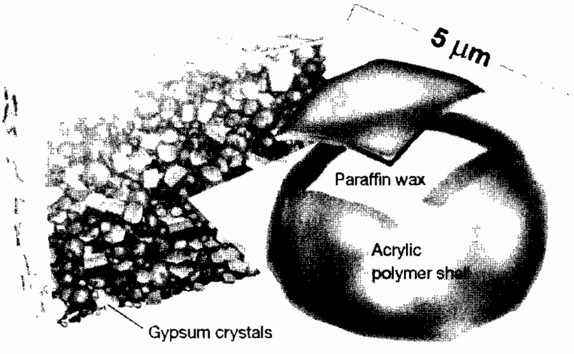


Figure 2. Encapsulated PCM spheres in wallboards (Basf®, 2009)

The micro-encapsulation in small spheres increases also heat transfer area since the surface to volume ratio increase, reducing the PCM reactivity towards the outside variations. Further, plastic encapsulation is safe as PCM is not in direct contact with the material. Incorporating PCM in gypsum plaster or gypsum wallboards has the advantage of great heat transfer surfaces in contact with the indoor temperature and avoids interfering with the structural strength of buildings. As the interior lining is usually made with multilayer gypsum plaster, PCM can be easily added to the plaster and installed both in new constructions and during the refurbishment process of existing buildings with no additional cost.

2 The Building Model

Among the numerous factors that influence energy consumption performance of buildings and PCM integration, we can identify the following as key parameters:

- Local construction systems.

- Local climate: solar irradiation and ambient outdoor temperature.

- Internal loads: the personal occupancy and electrical appliances (lights, TV, computers, etc.).

The studied case is a typical residential single-family house of 4 rooms and about 96 m^2 total area. The constructive system is typical for south Mediterranean countries with a heavy envelope (solid concrete end-terrace roof and brick walls). Windows shading in summertime is by roof eaves and Persian shutters (shade factor G=0.5).

Exterior walls are the traditional double brick walls with an air gap for the standard configuration and 4 cm expanded polystyrene layer for the insulated case (see table 1 for building components thermal characteristics). These levels of insulation seem to be lower in comparison to continental European countries, but they are sufficient in Mediterranean region. When present, the PCM of 26 °C melting temperature is embedded in wallboards of gypsum plaster of 30 mm thickness containing 26% mass fraction of paraffin and are set to the interior wall's face or on the ceiling.

Table 1. Thermal characteristics of building components.

Case	U-value roof W/m^2K	U-value exterior wall W/m^2K	U-value floor slab W/m^2K
Standard	2.70	1.20	4.60
Insulated	0.75	0.64	4.60

The study is carried out for the case of Algiers, a typical coastal city with a mild-warm climate. The day temperatures are not very high even in the summer and the night ones are just lower. Relative humidity is often more than 70% in summer period.

A space can be considered to be thermally comfortable if the perceived temperature experienced by the occupants is within a narrow temperature range around 23°C. The perceived temperature is not only determined by the air temperature, but depends also on diverse factors such as the radiating temperatures of walls, air speed, humidity and occupant clothing. However, it is often approximated by the average of the 'dry bulb' air temperature and the mean radiating temperature of the surfaces in the room (operative temperature). Natural windows ventilation is assumed for the night-time cooling if the temperature of the room exceeds the outdoor one.

Heating is with conventional radiators with 100 W/m^2 power and the temperature is set to 19°C. Cooling is by split system air conditioners with 100 W/m^2 power and is activated when the indoor temperature exceeds 26°C. The home furnishing is typical and the internal charges are fixed to 10 W/m^2 with typical family hourly use distribution. Free ventilation is estimated to 1 volume change per hour.

3 Results and Discussion

The heat and cooling demand were determined by mean of dynamic thermal building simulation software (Valentine®). Different cases of insulation and PCM integration are evaluated with the following criterions:

- Space heat demand: the quantity of energy that need to be supplied to the house during one year to ensure an indoor temperature of 19°C in the building.

- Useful cold demand: the quantity of energy that need to be removed from the building by an active cooling system to confine indoor air temperature to a maximum of 26°C.

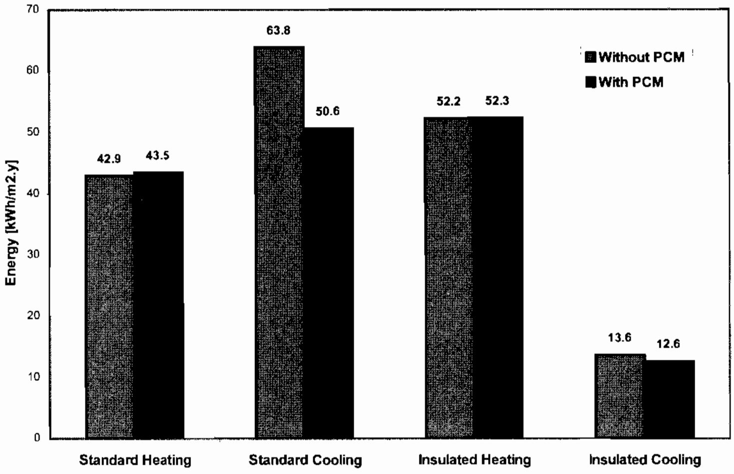


Figure 3. Heating and cooling energy demand for the standard and insulated cases.

Figure 3 shows the heating and cooling energies for the standard case (standard roof and exterior walls) and the insulated case (insulated roof and exterior walls). If PCMs seems to have no influence on heating energy demand, it reduces the cooling energy, especially in the standard case.

For heating, the switch temperature of the PCM is too high (26°C) so it is not reached in winter and then the PCM did not melt. It acts only as sensible heat storage and so is not efficient because of the lower heat capacity of gypsum. In fact, the comfort temperature varies with the season, making the choice of PCM melting point non-trivial. It must be chosen and optimized initially at conception stage for heating or cooling purpose.

The best performances are for cooling in the standard case. The non-insulated roof has a wider temperature variation because it receives solar irradiation during the day and emits to the sky and transmits heat by free convection to the cooler outdoor ambient air at night. This variation is transmitted to the PCM, which undergoes cycles of charge/discharge many days in the year, especially in the mid-season. This effect is lesser in the insulated case because the exterior temperature variations are less transmitted to the PCM due to the additional insulation resistance. However, it should be noticed that insulation reduces widely the levels of cooling needs.

Figure 4 shows the gain of cooling energy by incorporating PCM in different components of buildings and the amount of PCM material used (reference is the standard case without insulation or PCM). The investment cost is directly related to this quantity.

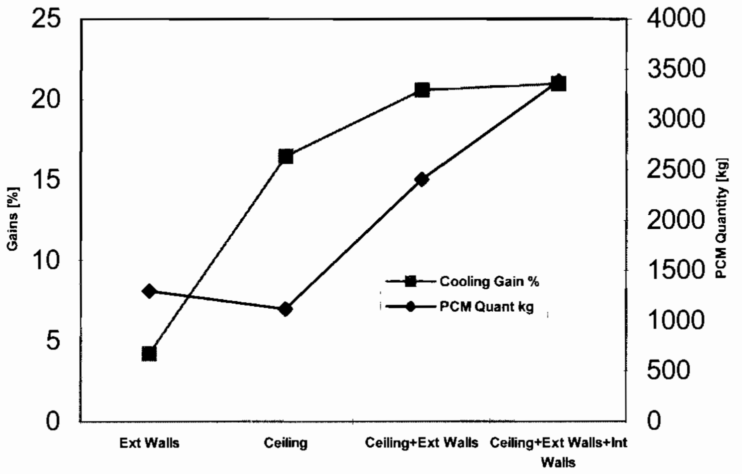


Figure 4. Cooling energy gain and required PCM quantities (Std case).

Better gain/quantity ratio is with PCM incorporated on the ceiling. Adding PCM on the exterior walls do not enhance the gain more than 4% but double the PCM quantity (and then the cost). Adding more PCM on internal walls does not enhance more the reduction. PCM on internal walls acts only as sensible storage since their temperature is affected only by indoor temperature, which is almost constant at 26°C. However, for an economic efficiency analysis and length of the amortization period, rather than percentage of gains, it is the saved energy quantity that is of importance.

The end-of-terrace roof as a flat area is exposed all day long to solar irradiation, unlike the exteriors' walls which are partially irradiated, depending on their orientation. The PCM performs more on the standard roof because the main part of heat enters from there to the building. Further, the ceiling is a clear area and then exchange directly heat by convection with room air without any obstacles. It has also a higher view factor and then a good exchange by radiation to the floor that is the cold source in summer.

Cooling energy demand for some Mediterranean cities with the same house model is shown in Figure 5. In fact, these results are only relative since construction systems are very different for each country. The same level of energy reduction with PCM incorporation is observed (between 20 and 30 %). Even with different levels of cooling demand, identical mechanism of PCM reduction exists.

Somewhat great quantities of PCM are used for about 20% reduction on cooling energy in non-insulated buildings and less than 10% in insulated ones. This relative low performance of PCM in coastal Mediterranean climates is due to low day/night temperature swings. In this situation, night time ventilation strategies do not provide a really effective way for cooling the building and then discharging the PCM. Removing heat by mechanical cooling for discharging PCM is interesting only at periods where electricity energy is cheaper. To completely discharge the PCM, the indoor temperature must be widely down 26°C. This must be done efficiently only at night when the gradient with outdoor temperature is the least.

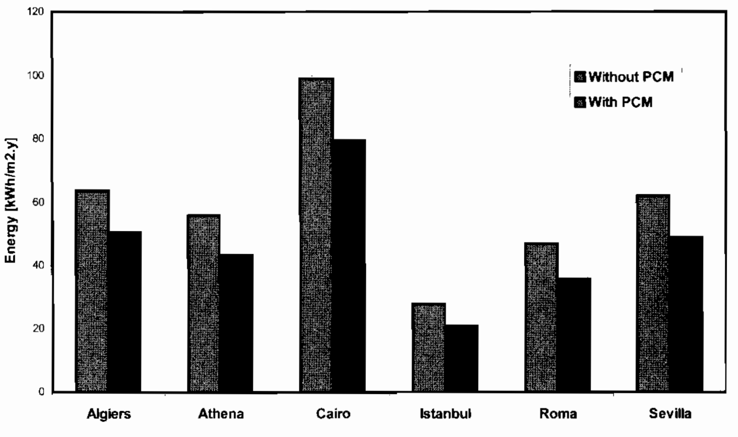


Figure 5. Cooling energy demand with and without PCM in some Mediterranean cities (Std case).

In reality, PCMs have not single switch temperature but a melting temperature range. About 90% of the melting enthalpy is located in a temperature range of 4°C around the melting point. To be efficient, PCMs need to cross plainly on both sides of the melting range. In fact, in most of the days on the year, the PCMs are only partially loaded and discharged that what their theoretical efficiency is diminished. PCMs are efficient only in mid-seasons (May, early June, September and early October) when daytime temperatures are still high but night temperatures become fresher. In fact, PCM can only delay the resort to mechanical cooling for really hot days.

The main problem with gypsum wallboards is their lower heat capacity which is much lower than concrete for example (Baetens, 2010). However, even if the micro encapsulation of PCM in concrete is very effective, it may affect the its mechanical strength. Since energy storage would be significant only in the first few centimeters (Richardson, 2008), adding PCM to concrete at the walls surface seems to be a better solution because it improves the performance of energy storage without affect the structural requirements of the building walls. PCM needs to be applied only in a thin facing layer to achieve the thermal benefits. A solution is to mix PCM with cement mortar for using as wall coating (rendering) which is a common practice in southern countries.

4 Conclusion

In this study, incorporation of encapsulated PCMs in building material as gypsum wallboards was investigated in Mediterranean mild climates in order to reduce cooling energy.

PCMs are found to have relatively mitigated performances because those climates are characterized by low day/night temperature swings, which make night-time ventilation less efficient for discharging the PCM. Removing heat by mechanical cooling for discharging PCM is relevant only if there is differentiated electricity price for off peak periods, otherwise it will be a null energy balance. Phase change materials can only store energy, but not remove it. Anyway, about 20% of cooling energy is obtained but with relative large quantity of PCM. A local economic efficiency analysis must confirm the process profitability.

The PCMs have better performance in non-insulated buildings and the best position is on surfaces that undergo the widest temperature variation (connected to the outside air for example). Incorporating PCMs on the ceiling give the best compromise gain/cost and is relatively easy to realize even in existing houses.

References

Baetens, R. et al. (2010). Phase change materials for building applications: A state of the art review. Energy Buildings, doi:10.1016/j.enbuild.2010.03.026

Cabeza, L.F, Castellón, C., Nogués, M., Medrano, M., Leppers R. and Zubillaga, O. (2007). Use of Microencapsulated PCM in concrete wall for energy savings. Energy and Buildings, 39, 113-119.

De Keulenaer, H. and Van Gerwen, R. (2006). The passive house in the electricity of the future. Belgium : Passive houses symposium proceedings.

Hongim, L. and Hazim, B. (2009). Performance of phase change material boards under natural convection. Building and Environment, 44, 1788–1793.

Kenneth, I. and Gates, J. (2000). Thermal Storage for Sustainable Dwellings. Maastricht, Netherlands. International Sustainable Building proceedings.

Khudhair, A.M. and Farid, M.M. (2004). A review on energy conservation in building applications with thermal storage by latent heat using phase change materials. Energy Conservation and Management, 45, 263-275.

Krarti, M. (2007). Energy audits for building. Handbook of energy efficiency and renewable energy. New York : CRC Press Taylor and Francis Group.

Kuznik, F., Virgone, J. and Roux, J.J. (2008). Energetic efficiency of room wall containing PCM wallboard: A full-scale experimental investigation. Energy and Buildings, 40, 148–156.

Medved, S. and Arkar, C. (2008). Correlation between the local climate and the free-cooling potential of latent heat storage. Energy and Buildings, 40, 429-437.

Richardson, M.J., Woods and A.W. (2008). An analysis of phase change material as thermal mass, Proceeding Royal Society, 464, 1029-1056.

Schossig, P., Henning, H., Gschwander, S. and Haussmann, T. (2005). Micro-encapsulated phase-change materials integrated into construction materials. Solar Energy Materials & Solar Cells, 89, 297–306.

Stetiu, C. and Feustel, H. (1998). Phase-change wallboard and mechanical night ventilation in commercial buildings. Lawrence Berkeley National Laboratory. Report. LBL-38320.

Voelker, C., Kornadt, O. and Ostry, M. (2008). Temperature reduction due to the application of phase change materials. Energy and Buildings, 40, 937-944.

Zalba, B, Marin, JM, Cabeza, LF and Mehling, H. (2004). Free cooling of buildings with phase change materials. Int J Refrig, 27(8), 839–49.

Zhang, Y., Zhou, G., Kunping, Lin, K., Zhang, Q and Hongfa, D. (2007). Application of latent heat thermal energy storage in buildings: State-of-the-art and outlook. Building and environment, 42, 2197-2209.

Zhu, N., Zhenjun, M. and Shengwei, W. (2009). Dynamic characteristics and energy performance of buildings using phase change materials: A review. Energy Conversion and Management, 50, 3169–3181.

http://www.basf.com/group/corporate/en/content/news-and-media-relations/science-around-us/index acceded on November 2009

Performance Evaluation of the Aqaba Residential Energy Efficiency Pilot Project (AREE)

Hans Rosenlund [1], Tareq Emtairah [2], Florentine Visser [3]
[1] *CEC Design, Sweden*
[2] *Lund University, Sweden*
[3] *Architect, Jordan/Egypt*

Abstract

The AREE house was built in 2007/2008 to provide a showcase of a high performance building in Aqaba city in the southern part of Jordan. The total energy performance of the building was achieved through three types of measures grouped into passive design elements, material choices and renewable energy installations. The energy performance and associated costs and benefits for each type were modelled to highlight opportunities for low and high income segments of the residential building market in Jordan.

This paper provides a post construction evaluation of the actual energy performance of the building and the real costs and benefits. The sustainability concept of the building is reviewed, as well as the construction process and the life cycle costing of the energy enhancing measures. The findings show that passive design elements and material choices do improve the energy performance. This is derived from the actual indoor comfort monitoring in comparison with base case simulations. The payback time on the incremental investments needed is less than 3.5 years. At the same time, the monitoring also showed that not all passive design measures for energy performance were effective. This paper reflects on the experience and lessons learned from AREE for potential wider integration of sustainability elements into building projects in Jordan.

Keywords: *Sustainable building design, energy efficiency, water efficiency, computer simulation, thermal performance, life-cycle cost.*

1 Background

Worldwide, the direct and indirect contribution of the built environment (buildings and physical infrastructure) to environmental impacts is estimated to be in the range of 30 to 40 per cent of the total anthropogenic impacts (UNEP DTIE, 2007). The situation in Aqaba, southern Jordan, can be considered more severe than this. The existing urban form is directly contributing to environmental stress in the region. Its design, material composition and spatial layout does not reflect the environmental conditions of the region and locks-in a costly and resource intensive occupancy lifestyle that suits neither the regions' scarcity of resources nor the low income of the majority of the population (Biggs, 2005). Typical construction styles have very poor insulating qualities and do not meet the national code requirements of maximum overall U-values (1.8 W/m^2K for walls and 1.0 $W/^2K$ for roofs). Prevalent building practices within both residential and commercial segments do not even adhere to the national building code with regard to energy performance requirements. Therefore improving the energy performance of buildings has the potential to deliver substantial environmental improvements at the aggregate level (Commision of the European Communities, 2005).

The Aqaba Residence Energy Efficiency (AREE) is a model building for the 9^{th} District in Aqaba city. The aim of the project is to achieve substantial improvements in energy efficiency through integrating passive design elements and material choices without radically departing from the conventional building and cost structures prevailing in the region. A secondary objective is to showcase the potential and the payback time of the application of integrated solar cooling technology in a residential building in southern Jordan.

Aqaba is located at latitude 29°N and longitude 35°E on the Aqaba Gulf of the Red Sea. The meteorological station is 51 meters above sea level. The climate in Aqaba is characterized by very hot summers and mild winters. Average yearly temperature is 24°C, monthly averages range is from 16°C in January to 32°C in July. Daily average maximum is 39°C (July) and average minimum 9°C (January). Prevailing wind direction is from the North.

The project idea was born after the transformation of Aqaba into a special economic zone. Within this new status, the local authorities envisioned a rapid growth in the governorate population from 118,300 inhabitants, year 2006 estimates, to nearly double that in year 2020 (ASEZA, 2007). This rapid growth will put greater demand on the expansion of the built environment, and consequently greater pressure on the already strained energy and water resources.

The AREE project idea was initiated in 2005 following a study by Lund University (Sweden) on the challenges of introducing alternative building practices into the Aqaba built environment. One of the key recommendations of the study was the need for a demonstration project on energy efficient building (Biggs, 2005). The study team from Lund University invited, in collaboration with the Center for the Study of the Built Environment (CSBE), three architectural firms to provide a concept designs for a Green Building on a plot of land purchased for this purpose. In the design brief, the project initiators specified the following requirements for the design: a residential building that;

- showcases design and material elements reflecting Aqaba's dominant socio-economic and landscape features (i.e. sensitivity to landscape features and average socio-economic conditions);
- displays practical 'low-tech' applications of energy, water and material

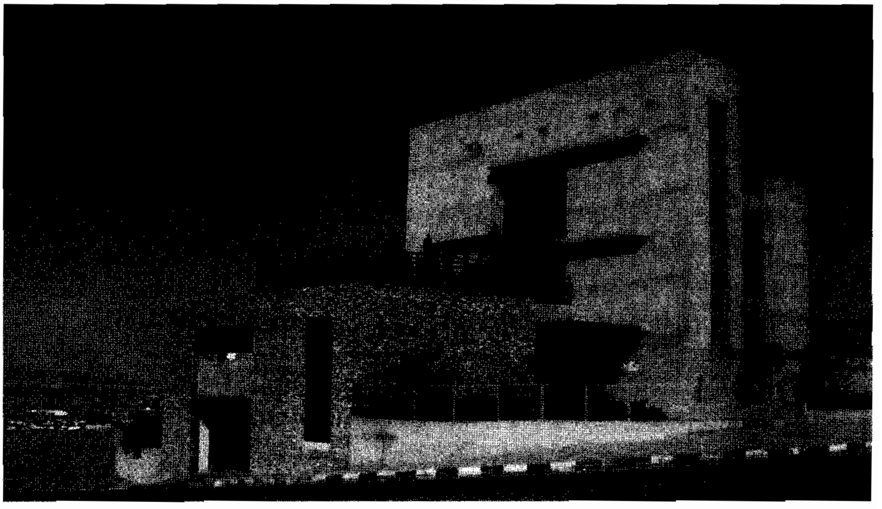


Figure 1: The building seen from south.

efficiency in a functional way; and

- acts to challenge conventional concepts of the accepted residential building style without alienating it – inspiring Aqaba builders, developers and home owners to adopt a similar approach.

From the start the accessibility of design and approach to inspire adoption was emphasized. As the 9th district of Aqaba was a newly established district, part of the planned expansion of the city, the choice of the project location was seen as an opportunity by the project developer to influence the urban development. The local authority, the Aqaba Special Economic Zone Authority (ASEZA) had issued specific building guidelines for this district, including informal town setting, variety in building massing, simple cubical forms, vertical windows, and the use of shadows and earth tones for facades.

The final design for AREE builds on the winning entry by one of the architects to the above mentioned design call. Section 2 of this paper describes in detail the features of the final design, including energy efficiency concepts. In Section 3 the evaluation of the energy performance is presented and compared to modeled performance based on both the actual design and a reference building representative of the conventional local construction. In Section 4 the life-cycle costs are analyzed, and in Section 5 the lessons learnt from the execution of the energy concept are discussed.

2 The Building Concept

The final version of the AREE building concept included the following elements:

Building type: residential; a one family house that can also be converted into three apartments. Additionally the design should provide flexibility for other kinds of use such as guest lodging or office space. Total floor area is 420 m^2.

Architecture: The architectural design is adapted to the local climate and makes use of the following design elements to improve the energy performance: building orientation, compact building mass, floor plan layout (individual rooms on the north side; circulation space as buffer-zone to the south side), shading for windows, facades and roofs, roof garden, improved natural ventilation, recessed windows, evaporative cooling, and thermal mass for heat accumulation and solar gain in the winter.

Perceptions of comfort and energy saving behavior: Outdoor living space is provided by shaded terraces on each floor to encourage outdoor living during the day and to prevent excessive cooling of internal spaces. Furthermore, night-ventilation is promoted to release heat during the night, preventing overheating of the interior space during the day.

Relation to urban quality: Urban quality and community character are important, and required by the local design guidelines. The garden space is optimized to facilitate shading and privacy around the house. This also relates well to the required informal town concept. The garden walls are designed to be planted. Unity in building expression, according to its location, makes the house a land mark on the corner plot. The main building volume is situated perpendicular to the main road, where the entrance is located. The sub-volume along the secondary road is built upon the plot line according to the building regulations and provides parking space.

Cost factors: The rational design in structure and room planning aimed for cost efficiency in the construction. For instance, the bathrooms are situated in the same location on each floor, on top of each other, next to the installation shaft to facilitate economical plumbing infrastructure. The distance to the grey water reservoir was also taken into consideration in the total lay-out design.

2.1 General Sustainability

The sustainable design concept of the building focuses on water and energy efficiency as the two primary concerns for built environment in Aqaba.
The water efficiency strategy aims at reduction of water consumption and reuse of grey-water for garden irrigation. In all bathrooms a dual sewerage system was installed, separating grey and black water. The low-tech grey water filtration and storage system was based on a low-cost design for rural water recycling projects by the Jordan Hashemite Fund for Human Development (JOHUD). The garden design by Matilda Nilsson includes drought resistant plants to minimize water consumption for irrigation (Biotopia).

The energy efficiency concept is further detailed in the next section.

2.2 Energy Efficiency Concept

The energy efficiency concept is based on an integrated approach incorporating measures for energy conservation, rational use of energy and application of renewable energy sources. Since Aqaba is located in a hot-arid zone, the strategy is mainly aimed at reducing end-energy for cooling in the following ways:

- architectural design;
- building materials; and
- installations.

2.2.1 Architectural Design

The building is oriented with bedrooms towards north and east to protect the interior rooms from summer afternoon heat. The zones towards the west side are buffer areas with a short term use; as corridors and bathrooms. Windows are recessed in the thick walls and have Venetian shutters to allow shading and ventilation. The upper communication space has large windows towards south-west for winter heating (Figure 2).

2.2.2 Building Materials

The structure is heavy with high thermal capacity combined with an insulation layer of 50 mm mineral wool in the cavity walls of the envelope. The U-values

for the wall systems range between 0.4–0.5 W/m²K. The windows are made of steady steel frames with good weather stripping and double glazing. Extra effort has been put into high-quality construction detailing and execution to prevent air leakage. Table 1 provides a description of the building envelope and the U-values, compared to common building practice in the region.
The ground floor living area has a green roof, which serves as terrace garden on the first floor. This garden roof also functions as an extra thermal mass, and has a positive effect on the indoor climate of the living room beneath.

2.2.3 Installations

A solar-driven adsorption cooling system is installed on the top roof. The solar hot water matrix delivers domestic hot-water, heating and energy for the adsorption chiller, which delivers cooling at a high efficiency rate. An underground cooling system is incorporated in the floor of the living area, and for evaporative cooling of incoming air a water fountain is installed outside the kitchen window. Energy efficient lighting and appliances are selected based on the best available options in Jordan.

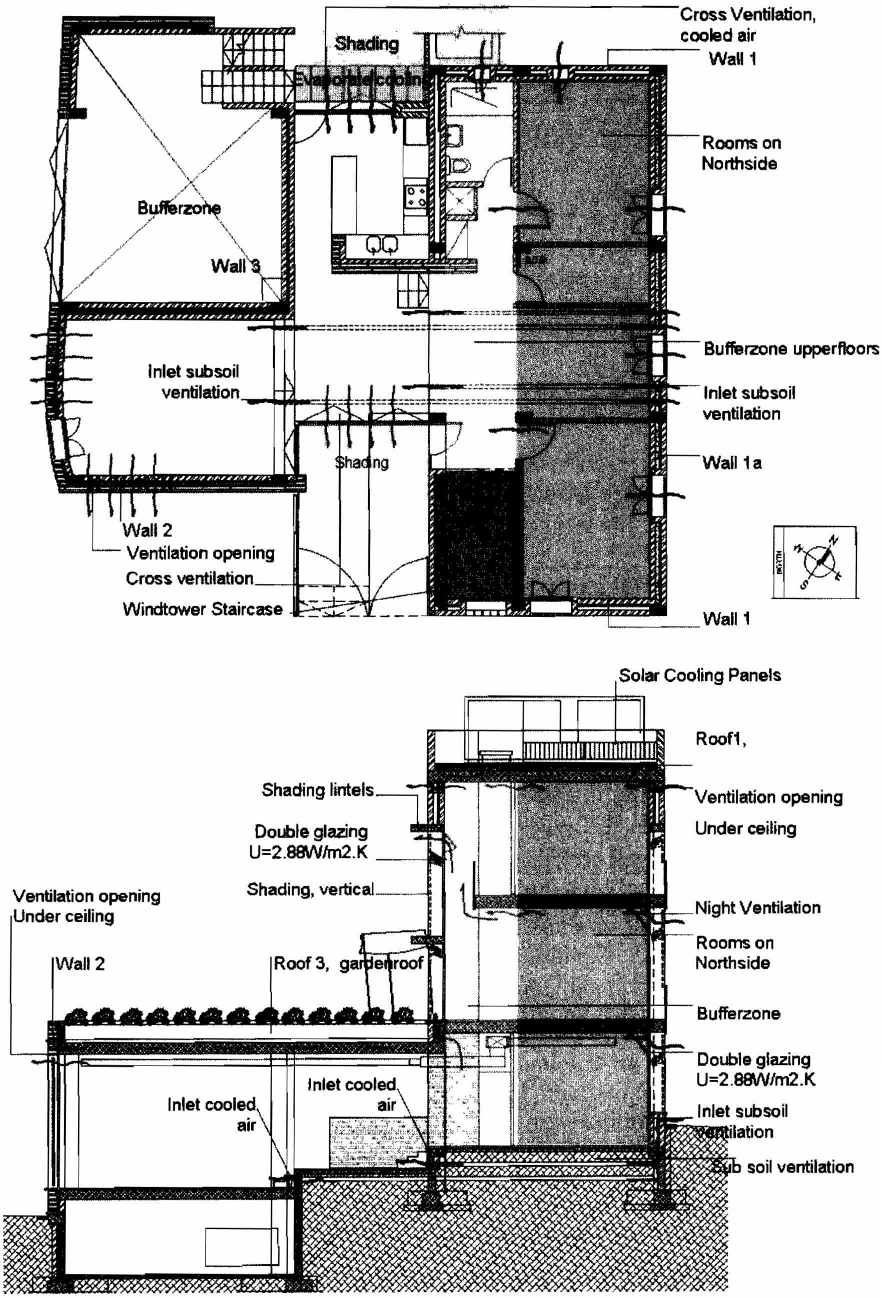


Figure 2: Ground floor plan and section.

Table 1: Building envelope in AREE compared with conventional buildings.

Construction elements	Description	U-Value [W/m²K]
AREE Project		
Wall 1: Double CHB (Concrete Hollow Block) wall with 10 cm cavity, used in main volume.	▪ Cement plaster mixed with straw (20mm) ▪ CHB with perlite aggregate (150 mm) ▪ Insulation layer Rockwool (50 mm) ▪ Air Cavity filled with sand and straw (50 mm) (filling applied to North walls only) ▪ CHB with volcanic aggregate (150 mm) ▪ Cement plaster mixed with straw (20 mm) Total = 44 cm	0.34 - 0.39
Wall 2: Stone cladding wall used in sub-volume	▪ Granite stones (200 mm) ▪ Concrete backfill (50 mm) ▪ Insulation layer Rockwool (50 mm) ▪ CHB with volcanic aggregate (150 mm) ▪ Cement plaster mixed with straw (20 mm) Total = 47 cm	0.50
Glazing	Double glazed windows	2.88
Roof 1: Concrete roof used in main volume	▪ Terrazzo tiles (30 mm) ▪ Cement mortar (30 mm) ▪ Waterproofing layer (4 mm) ▪ Insulation layer of extruded polystyrene (50 mm) ▪ Sand (70 mm) ▪ Reinforced concrete (70 mm) ▪ Concrete rib blocks (240 mm) ▪ Cement plaster mixed with straw (20 mm) Total = 51.4 cm	0.44
Roof2: Concrete roof with garden used in sub-volume	▪ Earth (400 mm) ▪ Stone aggregates (40 mm) ▪ Geo-textile (5 mm) ▪ Waterproofing layer (4mm) ▪ Reinforced concrete (250mm) ▪ Cement plaster mixed with straw (20 mm) Total = 71.9 cm	0.87
Conventional Building		
Wall 1: Cavity HCB	Single layer CHB (stone aggregate), no insulation + 15 mm plastering on both ends	1.62
Wall2: Stone cladding	Stone cladding + concrete backfill + cavity + CHB (stone aggregate) + 15mm cement plastering	1.92
Glazing	Single glazed windows	5.88
Roof	Similar to AREE roof 1 without the insulation layer	2.20

3 Evaluation of the Energy Efficiency Performance

Evaluation of the energy efficiency was made through long-term temperature measurements and validated by computer simulations. Since the solar cooling plant did not come to full operation during this period, any energy use in relation to enhanced indoor comfort could not be monitored. Instead, these estimations were made through the simulations, see Section 3.2.

3.1 Monitoring

The building was monitored by a 16-channel Grant Squirrel SQ2020-1F8 data logger, which recorded hourly air and surface temperatures from May 2008 until November 2009, see Figure 3.

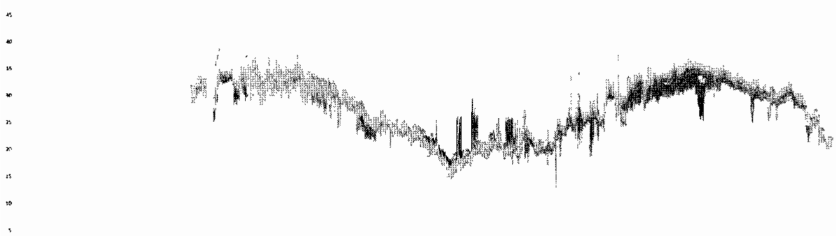


Figure 3: Overview of the monitoring period.
(Occasional spikes due to disturbances.)

Generally, when the building is kept closed the indoor climate is very stable, and shows a considerable time lag which helps to overcome extreme periods of heat or cold. The free-running building produces an excellent winter comfort; however, in the summer passive climatization is not sufficient in Aqaba.

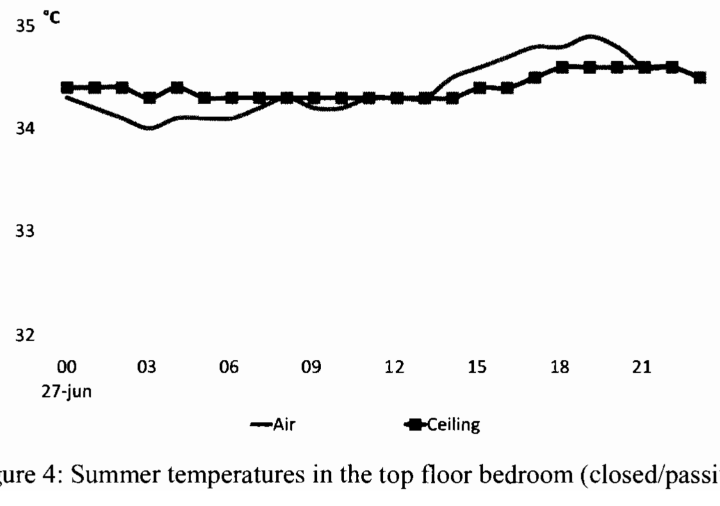


Figure 4: Summer temperatures in the top floor bedroom (closed/passive).

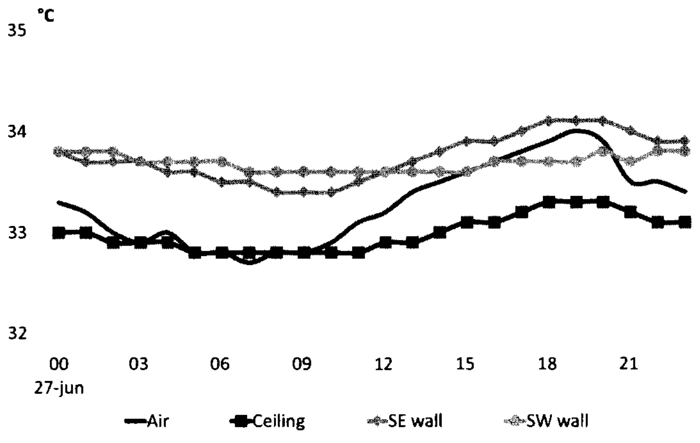


Figure 5: Summer temperatures in the ground floor living room (closed/passive).

3.1.1 Summer performance

The positive effect of roof insulation is seen in 4, where the ceiling temperature remains very stable regardless of heavy solar radiation on the outer surface during the hot period. The green roof has an even better performance; the stable ceiling temperature is at the same level as the minimum indoor air temperature, thus helping to cool the interior of the living room, see Figure 5. However, indoor temperatures are uncomfortably high in both spaces.

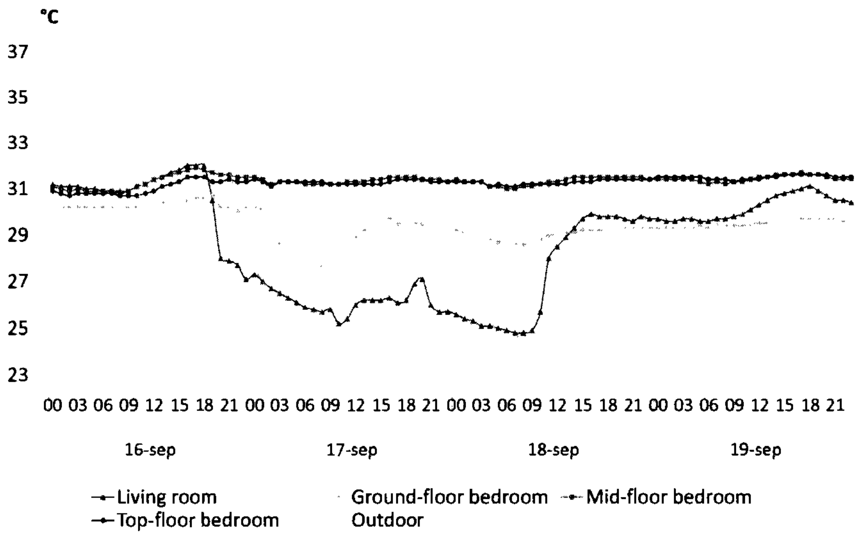


Figure 6: Test of solar cooling plant in the ground floor (closed/passive).

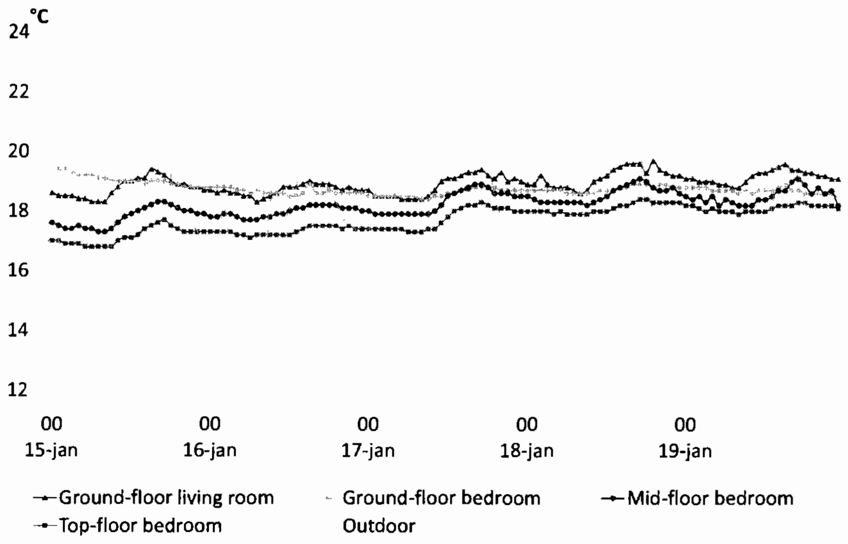


Figure 7: Winter temperatures in selected rooms (closed/passive).

Despite several trials, the adsorption cooling plant did not come to regular operation. Therefore, an evaluation of the energy use in the building could not be made. Figure 6 shows a one-day test run of the ground floor system, where the living room temperatures were brought down to around 26°C, while the bedroom, served by the same air distribution system, did not reach the comfort level.

Because the measurements started before the mounting of the shades on the large south-west windows, the results were very negative for summer comfort – the bedrooms behind the corridor got over-heated through the partition wall.

3.1.2 Winter performance

In January, a cold week was selected for controlled measurements during which the building was kept closed. Figure 7 shows that the larger the envelope area, the lower are indoor temperatures, and that the warmer ground clearly contributes to a better comfort. However, in this case the indoor temperatures are close to comfortable, and, considering that the building is inhabited, a normal occupation of the building would probably raise this level a couple of degrees, especially if daytime ventilation is utilized. Thus, the building performs passively very well in the winter.

3.2 Computer Simulations

Since the adsorption cooling installation was not operational during the measurement period, advanced computer simulations were used to evaluate the energy efficiency of the building. The software DesignBuilder (DesignBuilder

Ltd), which uses the powerful engine EnergyPlus (US Department of Energy), was chosen for these calculations. The building was modeled with high accuracy, including 17 zones whereof nine were conditioned. See Figure 8.

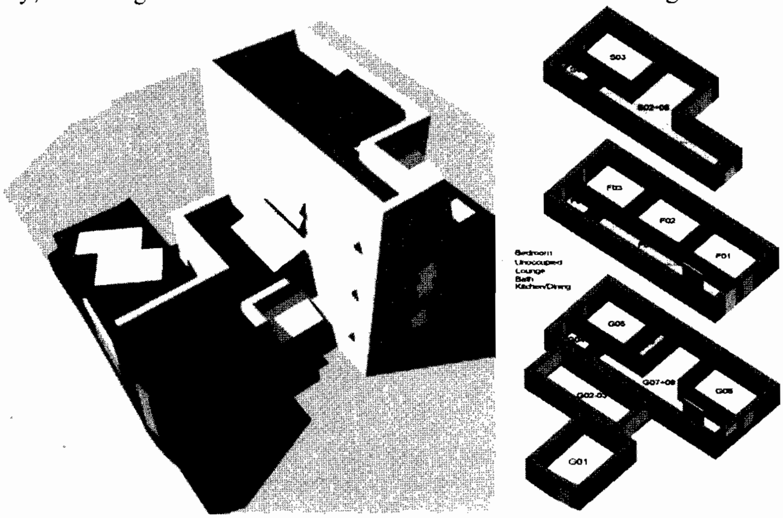


Figure 8: Computer model of the building.

3.2.1 The Actual Building

Simulating the 'as built' project with internal loads and ventilation for normal occupancy and full-time space conditioning (19–24°C), resulted in an annual cooling energy use of 6 MWh, or 19 kWh/m² apartment area (310 m²). Figure 9

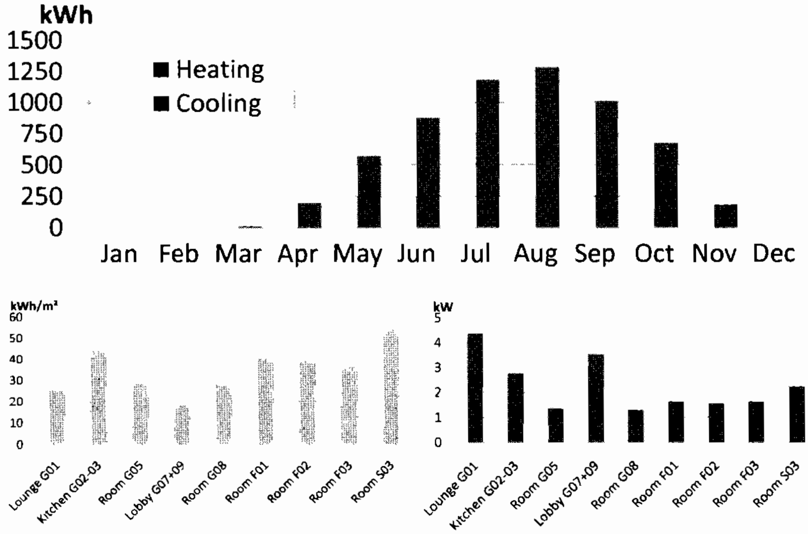


Figure 9: Simulated energy use of the building.
Top: per month. Bottom per room:
Left: per m² net area; right: peak power requirement.

shows that the cooling season is principally from April to November, and heating is not needed at all. The highest specific cooling need is in the top-floor bedroom (S03), followed by the kitchen/dining area with a large window area rate. The requirement for installed cooling effect is 20 kW, where the ground-floor living area accounts for the highest demand, and its central air distribution system adds up to a 13 kW peak load, while requirements for individual units in bedrooms are 1.6–2.2 kW, the top-floor representing the higher level.

It is difficult to find reliable figures on electricity use for residential space cooling in Aqaba, but sources from Department of Statistics (DOS, 2007) and Biggs (2005) indicate that a reasonable average level is about 120 kWh/m². This would mean that the AREE building saves 84% energy compared to 'normal' buildings. There could be several reasons behind this huge difference, which we will see in the next section.

3.2.2 Variations and Improvements

One possibility to compare to a 'standard' building is to replace the actual envelope elements for normal Jordanian building practice, i e with U-values of 1.8 W/m²K for walls and 1.3 W/m²K for roofs. This would increase the annual energy use by 21% to 23 kWh/m², and also the cooling power requirement by 30%. These are still levels far below the assumed 120 kWh/m², which could depend on a clever building design, but also on the 'disciplined' occupant behaviour built into the simulation model. Probably both factors influence, and it is not possible to say how much each of them contributes.

A traditional method of cooling is by increased night ventilation. In Aqaba, however, night temperatures do normally never come down to comfortable levels (<24°C) during June–September. However, in April, May and October there is an opportunity to utilize this nocturnal heat sink. If windows are opened during this time instead of running the air-conditioning ('hybrid ventilation'), a saving of 10% on cooling energy can be obtained.

Another possibility of saving cooling energy is by increasing the envelope insulation. A case with tripled insulation (150 mm mineral wool) was simulated, and also here the saving potential compared to the actual design was 10%.

In hot areas and during hot periods the upper limit of the comfort zone is normally higher than in cooler places and seasons – unless people get used to cooled spaces like shopping malls or offices ('adaptive' comfort model). Assuming an extended AC set-point limit of 18–27°C instead of 19–24°C may result in a considerable energy saving; 38% compared to the baseline case. Furthermore, installed cooling capacity can be reduced by 25% which brings down the investment costs for the cooling installation.

Finally, combining hybrid ventilation, increased insulation and an extended comfort zone, we end up with a saving potential of 52% of the energy use compared to the AREE design and regular operation, and 98% saving compared to the assumed normal level in the residential sector of Aqaba today. It should be

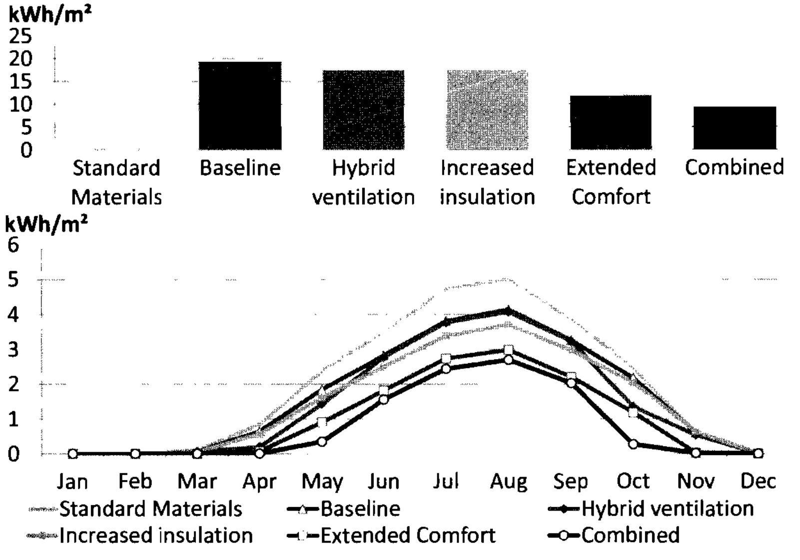


Figure 10: Specific cooling energy for six scenarios.
Top: annual. Bottom: monthly.

kept in mind that only the increased insulation requires an extra investment cost, the other cases provide costless methods of saving energy.

The specific energy use of all the cases discussed above is presented in Figure 10.

4 Life-Cycle Costs

The investment costs for the realized building (standard finishing) amounted to 155 000 Euro. This investment represents an increase of about 48 000 Euro compared to a conventional building (standard materials). Figure 11 presents the life cycle costing and pay-back potential from these additional investments. The payback is described in two scenarios. The first scenario includes the additional costs for all measures including the solar cooling installations: This is called the 'realized project' (Figure 11, top). The second scenario comprises only the additional investments due to design and construction technology. This is called the 'replicable version' for large dissemination (Figure 11, bottom).

What we conclude from these calculations is that investments in passive design elements and improved building materials, alone, yield good pay-back potential over the life time of the project. The incremental costs are around 11 per cent more than the conventional and the pay-back period in this case is about 3.3 years from the energy savings. This compares well with recent trends in high performance buildings across Europe where on average the incremental costs add up to 10% for buildings with less than 45 Kwh/m^{2}a of total primary energy use for space and water heating and electricity (Hastings, 2007). In the case of

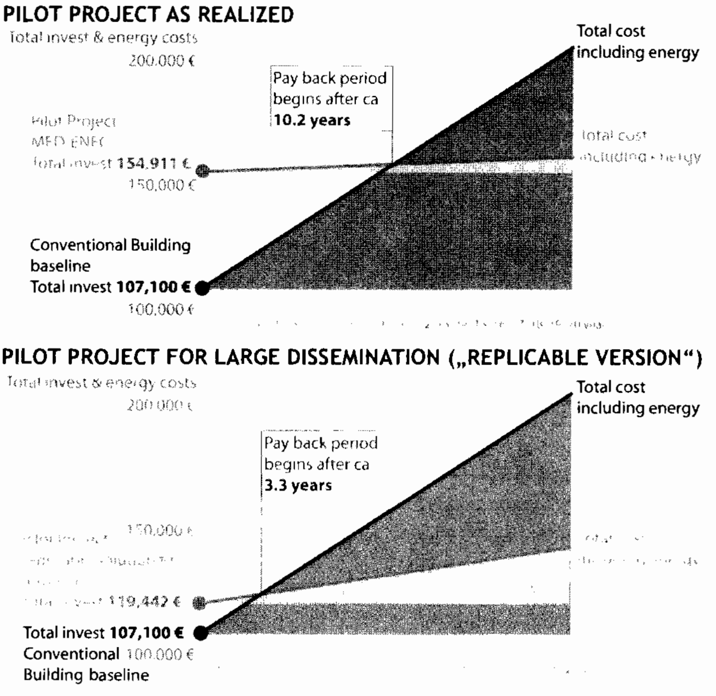


Figure 11: Life cycle costing including total energy costs.
Top: the realized project. Bottom: the 'replicable version'. Source: MED-ENEC

Jordan, however, for a broad dissemination of the realized scenario (with solar cooling installation) building costs and payback have to be further reduced.

The computer simulations point out some possible further improvements. In combination with costless saving options, like hybrid ventilation and extended comfort zone, increased thermal insulation may save running costs and also decrease investment levels for the cooling equipment. However, any detailed cost estimates for these alternatives have not been made.

5 Lessons Learnt from the Construction Process

Our account of the lessons from the construction process is derived from the periodic project management reports to the funding partners as well as direct observations from the authors' team, as two of the authors have been extensively involved in the project management. Here we will focus primarily on observations related to the execution of the energy concept.

During the design phase, several rounds of discussion took place with the local authorities to get approval for the architectural drawings. In the first design proposal, the main building volume had a better climatic orientation; however that had to be adjusted to comply with setback rules for corner plots. Therefore the final orientation of the realized building is not optimal. Another example is the noted efforts needed to work with local engineering consultants and construction contractors to seal thermal bridges, which should have been a simple problem to solve in the view of the architect. For those actors, AREE had more unusual construction detailing, particularly the ones that are related to elimination of thermal bridges. These details were new to the workers, and to great extend also for the engineers involved in the engineering drawings.

This has lead to several errors in execution which increased the delivery time and costs related to the execution of the energy concept. Finally, the project team faced supply chain problems with the choice of materials for AREE such as the alternative wall blocks with a higher thermal resistance than standard ones.

Given the experience from AREE, an optimist might say that building green in Jordan does not have to be neither costly nor technically inaccessible. An alternative reading of the pilot project experience may also suggest that Jordan, and in particular Aqaba city, is locked-into an inefficient built environment and ineffective building value chain. The challenges of introducing alternative building technologies are more systemic than what they appear on the surface.

The experience from the pilot project points to challenges within the overall building system. These challenges can be as far-reaching as zoning rules working against energy efficiency, the local construction industry practices and norms, knowledge and capacity problems among the chain of actors in building projects and supply chain bottlenecks for alternative materials. On the other hand, one could argue that these challenges are not unique to Jordan and more symptoms of characteristics inherent in the construction work. The project-based orientation as opposed to a process orientation, among other factors, has been frequently noted as one of the barriers for the diffusion of new and energy efficient techniques in the literature on innovations and buildings (Shove, 1998; Gann & Salter, 2000; Taylor & Levitt, 2005; Beerepoot, 2007).

6 Conclusions

As demonstrated with this pilot project, there are several low-cost measures that could well improve the energy efficiency of the built environment in Aqaba. Passive design elements such as orientation, appropriate sizing of windows and shading, combined with behavioral elements can reduce net energy demand up to 70% compared to the common practice scenario. With additional investments in improved envelope construction such as the use of insulation, double glazed windows and tighter control over thermal bridges, the payback on energy saving can be less than 3.5 years, which was the case with AREE. At the same time we need to acknowledge that not all passive measures in AREE worked well for the Aqaba climate. Generally with the hot summer conditions in Aqaba, passive climatization measures, similar to the ones used in AREE, alone are not sufficient for creating indoor comfort; additional active cooling is needed. However, occupants' wise 'management' of active and passive climatization systems, and their ability to adapt to extended comfort zones, strongly influence the total energy use for acclimatization of their residence.

To demonstrate the potential of renewable cooling technologies, a solar powered adsorption cooling system was installed. The costs associated with such systems still make them very unattractive for the private residential market. The challenge even goes further in terms of lack of locally based capacity for the installation, maintenance and operation of such systems.

Acknowledgements: The energy saving measures in this project including the monitoring were enabled by a grant from MED-ENEC, an EU-funded project to promote energy efficiency in construction in the Mediterranean. ASEZA provided funding for the realization of water efficiency measures including the garden concept. Energy efficient lighting was granted to the project by Philips.

References

ASEZA. (2007). Aqaba Special Economic Zone Authority Strategic Plan 2007–2010. Retrieved February 18, 2010, from ASEZA: http://www.aqabazone.com/files/bro-eng.pdf

Beerepoot, M. (2007). Public energy performance policy and the effect on diffusion of solar thermal systems in buildings: a Dutch experience. Renewable Energy , 32 (11), 1882–1897.

Biggs, C. (2005). Building What? The Challenge of Introducing Alternative Building Practices into the Aqaba Built Environment. Lund University, International Institute for Industrial Environmental Economics - IIIEE. Lund, Sweden: Lund University.

Biotopia. (n.d.). AREE - The garden. Retrieved February 18, 2010, from Biotopia: http://aree-garden.biotopia.se

Commision of the European Communities. (2005). Green paper on energy efficiency or doing more with less. Brussels.

DesignBuilder Ltd. (n.d.). DesignBuilder. (DesignBuilder Ltd) Retrieved 11 06, 2009, from DesignBuilder: http://designbuilder.co.uk

DOS. (2007). Population and Housing. (Department of Statistics) Retrieved 2009, from The Hashemite Kingdom of Jordan Department of Statistics (DOS): http://www.dos.gov.jo

Gann, D., & Salter, A. (2000). Innovation in project-based, service-enhanced firms: the construction of complex products and systems. Research Policy , 29, 955–972.

Hastings, R. (2007). Introduction. In R. Hastings, & M. Wall, Sustainable Solar Housing 2: Exemplary Buildings and Technologies (1–7). London: Earthscan.

JOHUD. (n.d.). MEDWA project: sustainable water management. Retrieved February 18, 2010, from JOHUD: http://johud.org.jo/MEDWA-water-project.html

Shove, E. (1998). Gaps, barriers and conceptual chasms: theories of technology transfer and energy in buildings. Energy Policy , 26 (15), 1105–1112.

Taylor, J., & Levitt, R. (2005). Inter-organizational knowledge flow and innovation diffusion in project-based industries. System Sciences 2005: Proceedings of the 38th Hawaii Conference, (p. 247c). Hawaii.

UNEP DTIE. (2007). Buildings and climate change: status, challenges and opportunities. Paris: UNEP.

US Department of Energy. (n.d.). EnergyPlus. (US Department of Energy) Retrieved 11 06, 2009, from EnergyPlus: http://apps1.eere.energy.gov/buildings/energyplus/

Integration of Wind Turbines in the Built Form and Environment

Islam Abohela, Neveen Hamza, Steven Dudek
Newcastle University, United Kingdom

Abstract

In response to various international agreements and national initiatives towards tackling climate change researchers, architects and engineers continue to investigate the possibilities of reducing reliance on grid supplied energy to integrate micro-generated power from renewable resources including in-situ integrated wind turbines in buildings. This paper reviews existing research on the integration of wind turbines within the built environment. Three distinct strands of research, which represent the main three stages for integrating wind turbines in the built environment, are identified and reviewed: the first strand reviews types of integrating wind turbines within the built environment, this involves the role of the form of the building in harnessing wind power . The second strand is related to assessing wind flow within the built environment using different tools such as mathematical models, in situ measurements, wind tunnel tests, and CFD simulation software. The third strand assesses the feasibility of integrating wind turbines within the built environment in terms of environmental, economic and social aspects. Research across these strands presents key issues that challenge the design team when considering the integration of wind turbines in the built environment. The potential of integrating wind turbines in the built environment and manipulating building form to harness wind power is a multidisciplinary team work that requires involvement of architects and their consultants at an early stage. However, this paper argues for the need to widen the impact assessment of integrating wind turbines in the built environment to more than its economic, environmental and technical impacts to include their social acceptance.

***Keywords**: Literature Review, Wind, Turbines, Architecture, Urban settings.*

1 Introduction

Austin et al. (2005) noted the increase in the degree of public awareness regarding the impact of climate change on the environment and the harmful effect of dependency on fossil fuels. Stankovic et al. (2009) acknowledged that the increase in awareness has led to actions in many sectors to mitigate climate change such as the integration of renewable sources of energy in buildings. According to the Intergovernmental Panel on Climate Change (IPCC), buildings are responsible for one third of global energy related CO_2 because of their dependency on conventional sources of energy which are the main source of harmful carbon gas emissions (Ürge-Vorsatz, D., 2007). One of the untapped potentials to reduce harmful carbon gas emissions from buildings is the in situ generated electricity through wind turbines. Manipulating building form to augment and enhance the performance of these wind turbines can lead to decreasing reliance on grid supplied electricity (Abohela, 2009; Taylor, 1998). Smith (2003) also added that wind generation is a good choice of renewable energy as it is cheaper in terms of installed cost per kilowatt than photovoltaic cells and therefore it is an attractive proposition as a building integrated power source. In addition, urban wind turbines are gaining acceptance over large scale wind farms because large scale projects are being constructed in isolated locations which require making the infrastructure for transmitting the generated power and distributing it among end users, which is costly and causes power losses during transmission and distribution (DTI, 2006). From an architectural perspective the principal aim of this paper is to review existing research on the methods and tools used to integrate wind turbines in the built environment, focusing on the Building Augmented Wind Turbines (BAWTs) where the form of the building plays a major role in harnessing wind power. Existing literature on the integration of wind turbines in the built environment has been focusing on three main research strands; the first strand is related to assessing wind flow within the built environment. The second strand is related to types of integrating wind turbines within the built environment. The third strand looks into the environmental and socio-economic feasibility of integrating wind turbines within the built environment. These three strands represent the areas of research architects investigate when integrating wind turbines into buildings.

2 Integrating Wind Turbines in the Built Environment

According to Coleman & Preston (2008) the idea of exploiting wind energy in the built environment is attractive because wind energy is considered one of the most reliable clean sources of energy on the planet and wind turbines are likely to be in operation for about 85% of the year, and have a service life of at least 20 years. However, DeMeo & Parsons (2003) warn that wind turbines can't be relied on as the single means of generating electricity due to their intermittent operation and that they have to be backed up by other sources of grid electricity supply and renewable energy generation. Denoon et al. (2008), Eriksson et al. (2008) and Yuen et al. (2004) stated that the results of assessing wind flow in the built environment underpin decisions on the method of integration and kind of wind turbine to be integrated in the built environment. Aguiló et al. (2009) classified three methods of integrating wind turbines into the built environment; the first is the building integrated wind turbines, where a separate wind turbine is located on a free-standing tower away from the building itself; the second is the building mounted wind turbines, where the wind turbine is installed on to the building structure and the third is the building augmented wind turbines where the building form is shaped to concentrate wind flow and is shaped towards the wind turbine.

Dutton et al. (2005) described the building integrated wind turbines as afree standing wind turbines which are capable of working close to buildings and taking advantage of the augmentation in wind flow caused by surrounding buildings, they can be retrofitted into existing urban areas or incorporated in the design of a new urban area where the whole design account for the existence of the wind turbine. Although the building integrated wind turbine may yield more power than the building mounted wind turbines, the cost per kilowatt tends to be relatively high (compared to medium/large scale wind turbines) in part to cover for required foundations, tower and cabling. Example of this type is the small stand alone turbine at the Mile End Ecology Centre in London and the wind turbine at a BP station, Wandsorth, London which is a 6kw turbine with blade diameter 5.5m (Figure 1) (Aguiló et al., 2009).

Figure 1: The building integrated wind turbine in a BP station in London

On the other hand Dutton et al. (2005) and Webb (2007) describ building mounted wind turbines as physically linked to buildings where the building acts as a vertical post for positioning the wind turbine to exploit the desirable wind flow augmentation caused by the building. In addition to its requirement to structurally support the wind turbine; the building should provide reduction in vibrations and noise emissions. Anderson et al., (2008) studied the Green Building in Temple Bar, Dublin, as an earlier attempt for mounting Three small horizontal-axis wind turbines combined with solar hot water and photovoltaic collectors (Figure 2). The application resulted in excessive noise, vibration, and eventual cracking of the turbine blades. The wind turbines were determined to be uneconomical and were eventually replaced by photovoltaic cells. Another example is the Kirklees council building (civic centre 3) in the town centre of Huddersfield, UK was retrofitted to house a large array (143m2) of solar photovoltaic panels and two 6kW wind turbines to generate electricity and a set of solar energy collectors (48m2) to heat the building's water (Figure 2). The Council wanted to demonstrate leadership in reducing its building's carbon footprint by around 8% (15 tonnes of Carbon dioxide/annum) and reduce dependency on grid generated electricity. It is interesting to note that the estimated electricity generated from the photovoltaic array and the wind turbine was estimated at 5% of the total electricity demand. However, similar to the Green building in Temple Bar the wind turbines failed to generate a reliable electricity supply, and were eventually disconnected from the grid and left to promote a demonstration of good intentions. Wind mounted turbines in both cases were seen as an expensive add on. In the case of Kirklees council building £15,000 were spent on preparing the roof to take the structural load, vibration and improve the insulation of the roof. In addition to being the most expensive technical installation and an unplanned aesthetic effect, failing to deliver the expected performance increases public scientism of these systems (Kirklees Environment Unit Report, 2006).

According to the WINEUR project (2005): for building mounted wind turbines to be successful in generating electricity, the average wind speed should not be less than 5.5 m/s . According to Bahaj et al. (2007) and Müller et al. (2009) high-rise buildings have the largest potential for wind turbine integration when compared to low-rise structures. In locating the building wind turbine, the building roof should be approximately 50% higher than its surroundings, and the turbine located near the centre of the roof on the most common wind direction for the location, with the lowest position of the rotor at least 30% of the building height above the roof level. The Warwick Wind Trials Project states that the poor sites for mounting wind turbines are the single story buildings and the good sites are 45m tall exposed flats in isolated settings on hilltops (Encraft, 2009). Figure 2, demonstrates two case studies highlighting the limitations of this integration method.

Figure 2: Left: The Green Building in Temple Bar, Dublin / Right: The Kirklees council building (civic centre 3) in the town centre of Huddersfield, UK

Cace et al. (2007) found that turbine height has a significant effect on capturing higher mean wind speed and power generated, while output varied considerably with wind direction (Mithraratne, 2009).Horizontal axis wind turbines with a yawing system maybe used allow the turbine to change direction facing the prevailing wind. However, if the wind frequently changes direction, this would affect the energy yield of the turbine negatively. A vertical axis wind turbine would be recommended as it is dependent on the wind speed rather than the wind direction and can withstand changing wind direction and turbulent wind flow. Reducing the effect of the changing wind direction could be overcome if the building form is shaped in a way to direct wind towards the installed turbine.

2.1 Building augmented wind turbines (BAWTs)

In this type of integration the form of the building harnesses wind to be driven towards a turbine. In this case the building form acts as a support for the integrated wind turbines and a wind collector. Here the architect plays a major role in sculpting the building to be based on aspects related to aerodynamics. The building design may require some modifications based on wind flow assessment using wind tunnel test or CFD simulations (Dutton et al., 2005). Denoon et al. (2008) illustrated a number of new developments that were based on the principle of aerodynamic building form to enhance the performance of the integrated wind turbines. For example Figure 3 includes the Bahrain World Trade Centre, Pearl River Tower in China, Strata SE1 project in London, all implemented BAWTs (Figure 3) (Peel & Lloyd, 2007; Cochran & Damiani, 2008). However, Müller et al. (2009) noted that it cannot be assumed that such projects will become the norm as urban wind turbines may not always be visually appropriate and hence not be put forward by architects and designers. Therefore, a successful wind turbine design would be integrated to add to the architectural value of the building.

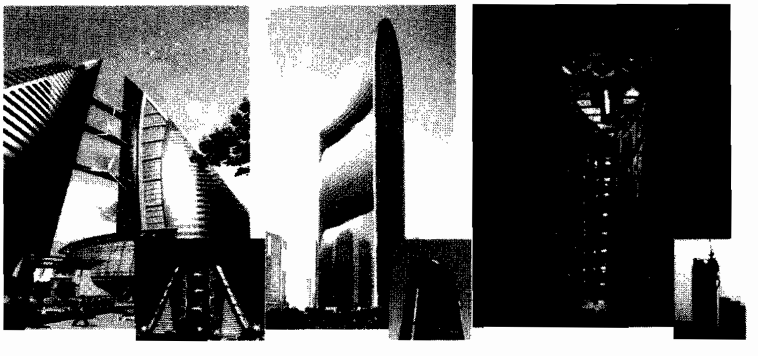


Figure 3: From left to right: Bahrain World Trade Centre, Pearl River Tower in China, Strata SE1 project in London

2.2 Role of building form in harnessing wind power

Capeluto et al. (2003) and Ricciardelli, Polimeno (2006) asserted that wind flow within the built environment depends on the exact geometry of all buildings on site. Malcolm et al. (2007)and Campos-Arriaga (2009) noted in modelling wind flow, that corresponding to the majority of existing buildings, the geometry of most of the modelled forms in the built environment is simplified to simple cubes arrayed perpendicular to each other.

Sharp edged buildings are extensively investigated in research (Kubota & Ahmad, 2005; Lim et al., 2009; Lien et al., 2004; Sun & Huang, 2001; Tutar & Oguz, 2002). Blocken & Carmeliet (2004). Denoon et al. (2008) found that wind speed increases at the edges of the building and wind turbines could be implemented to take advantage of the speeding effect of wind hitting the sharp edges. However, these turbines should be designed to operate within urban areas where air flow is unpredictable. Peter et al. (2008) found that lens and aerofoil building forms can overcome wind loads and minimize their effect on laminar air flow. Two examples of this are the Bahrain World Trade Centre and the Pearl River Tower in China. The Bahrain World Trade Centre Tower is formed to collect and squeeze wind flow between the two towers where the horizontal axis wind turbines are placed. Killa, & Smith (2008) stated that the funnelling of the Bahrain World Trade Centre towers has the effect of amplifying the wind speed at the turbine location of up to 30% which would result in the turbines providing the building with 11% to 15% of the electrical energy needs. The same funnelling effect is implemented in the Pearl River Tower where the building incorporates four large openings, approximately 3 x 4 meters wide. The facades are shaped to decrease the drag forces and optimize the wind velocity passing through the four openings. These openings function as pressure relief valves for the building (Frechette & Gilchrist 2008). However, Peter et al. (2008) argued that wind is often regarded as a burden for high rise buildings since it tends to be the governing lateral load. The main strategies used to reduce wind loads on buildings and advantage the performance of the integrated wind turbines are: softened corners, setbacks, varying cross-section shape, spoilers and porosity of the building body.

Mithraratne (2009) concluded that building form manipulation based on wind flow assessments would play an important role in reducing the turbulence and wind shear around buildings by 10–15% and 15–30%, respectively which are responsible for reducing energy production from building integrated wind turbines. This reduction in energy yield from the expected output of the turbines is one of the main reasons behind a state of uncertainty about the feasibility of integrating wind turbines in the built environment. *In addition to challenges posed to accurately assess wind speeds on site* economic feasibility, environmental and social aspects should also be addressed.

3 Assessing Wind Flow in the Built Environment

According to Mertens (2006) and Paterson & Apelt (1989) the research tools used to understand wind flow within the built environment can be divided into three main groups: Mathematical models, Experimental models (both full scale and scaled models) and Simulation tools or Computational Fluid Dynamics (CFD) calculations and they all have specific advantages and drawbacks. Many researchers (He & Song, 1999; Lei et al., 2006; Leitl et al., 1997; Malcolm et al., 2007) considered mathematical models difficult to use, extremely time consuming and requires a thorough knowledge of fluid dynamics. In addition, CFD modelling is considered the development of the mathematical models as it relies on solving the Navier-Stoke equations which are still the cornerstone of CFD codes applied in practical studies. However, there is currently a considerable effort in research to develop other simulation models to solve the turbulence problem. One of these techniques is the use of Large Eddy simulation (LES) techniques in CFD which successfully simulates wind flow at pedestrian level; another model is the Reynolds-averaged Navier-Stokes (RANS).

As for In situ measurements, Plate (1999) and Syngellakis & Traylor (2007) asserted that this tool is probably the most accurate tool for assessing wind flow on a particular site, especially when considering retrofitting wind turbine into an existing building. However, the major drawback of this tool is the difficultly and expense of even carrying it out once, let alone having to change measurement locations and times. On the other hand, Willemsen & Wisse (2002) carried out different experiments proving that in situ measurements are loaded with errors especially at pedestrian level in the built environment which could reach 20%. However, both CFD and Wind Tunnel Tests have embedded errors.

The second method, the wind tunnel was originally developed for aeronautic and industrial engineering, many researchers (Baskaran & Kashef, 1996; Blocken & Carmeliet, 2004; Jones et al., 2004; Jiang et al., 2008; Malcolm et al., 2007 and Plate, 1999) investigating the reliability of wind tunnel tests in assessing wind flow in the built environment. Collectively they concur that the data obtained from these tests are reliable if the wind tunnel used is an atmospheric boundary layer tunnel and the model is accurately constructed with all surrounding elements affecting wind flow and in many cases the results agree well with CFD simulation. On the other hand, Denoon et al. (2008) found it difficult to accurately model the effect of turbulence in a wind tunnel because the wind tunnel is limited by its size, this is why a complete accurate simulation of wind flow is not yet possible, which means that the results obtained from wind tunnel testing will have errors that should be taken into account. Another drawback of Wind Tunnel Tests which Campos-Arriaga, (2009) highlighted is that wind tunnels are expensive in terms of construction, highly technical in terms of operation and maintenance which render them unviable for testing design iterations. This problem can be mitigated by validating results by other measurement methods such as the CFD simulations.

Currently CFD is used in modelling the potential of introducing natural ventilation in high rise buildings. This could be taken a step further to look into account enhancing the building form to improve wind power generation. Swiss Re building by Fosters and Partners was extensively modelled to capture natural ventilation in its atriums throughout the building height and assess reducing the wind turbulences on pedestrians (Figure 4) (Kitson, M., & Moran, H., 2006). Clifford et al. (1997) and Jones & Whittle (1992) predicted that due to the ever-increasing computational power, CFD will gain acceptance as a tool for assessing wind flow within the built environment. Augenbroe (2004) and Jones et al. (2004) asserted that the main advantages of CFD simulation which encourage architects and engineers to broadly use it is the speeding up in the design process giving the designer the opportunity to assess and compare the impact of design modifications on wind flow scenarios around buildings.

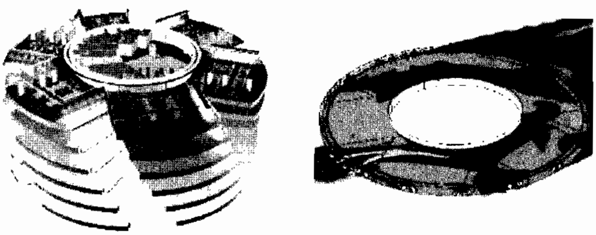


Figure 4: A CAD model of several floors in the Swiss Re building (left) and a CFD simulation showing airflow through one of the floors (right)

On the other hand, Denoon et al. (2008) warn that the current computational power renders CFD simulation incapable of accurately modelling turbulent wind flow in very dense urban environments. Malcolm et al. (2007) and Chen & Zhai (2004) conclude that CFD simulation results for wind assessment in the built environment should be treated an approximation. It is also noted that CFD is reliable when assessing wind flow upstream of an obstacle but downstream there will be a degree of error using the K- ε turbulence model which is a model based on solving equations representing turbulent properties of the flow by determining the scale of the turbulence (ε) and the energy in the turbulence (K), but broadly giving reliable flow predictions around the obstacle away from the ground.

Based on the literature review (Table:1) summarizes the wind assessment tools in the built environment in terms of accuracy, usage as a visualisation tool, preference of usage for existing and future planed developments, cost, required time for assessment and availability to architects. It explains why existing research in this area (Campos-Arriaga, 2009; Chen, 2004; He & Song, 1999; Mochida et al., 1997; Murakami et al., 1999) favours Wind Tunnel test and CFD modelling over Mathematical models and in Situ Measurements.

Table 1: Comparison between urban wind assessment tools

	Tools arranged in descending order
High Accuracy	In Situ Measurements – Wind Tunnel – CFD – Mathematical Models
High Visualization	CFD - Wind Tunnel - In Situ Measurements - Mathematical Models
Assessing wind flow in existing urban areas	In Situ Measurements – CFD – Wind Tunnel – Mathematical Models
Assessing wind flow for future planned urban areas	CFD – Wind Tunnel – In Situ Measurements – Mathematical Models
Lowest cost	Mathematical Models - CFD – Wind Tunnel – In Situ Measurements
Less time consumed	CFD – Wind Tunnel – Mathematical Models - In Situ Measurements
Availability to architects	CFD – Wind Tunnel – In Situ Measurements – Mathematical Models

4 Holistic Evaluation of Integrating Wind Turbines in the Built Environment

Wind turbines as seen in the previous case studies have been promoted as means to reduce the building carbon footprint. However, Mithraratne (2009) argued that it is important to include in the assessment the CO2 emitted due to manufacturing the turbine, transport to site, installation on site, operation and maintenance, decommissioning, disposal and recycling of waste. Stankovic et al. (2009) claimed that the idea of 'tonnes of CO_2 saved' by using any form of renewable energy is simply a means to present something tangible to inspire action.

Webb (2007) linked the economic feasibility of wind turbines to wind speed because energy yield is directly proportional to the cube of wind speed. But in order to accurately assess the cost of installing a wind turbine in the built environment, the assessment should include basic turbine cost, mains inverter and/or power converter cost, structural installation costs and cabling costs. In addition, costs of the assessment of wind flow for estimating energy yield before installing the wind turbine should be included in the costs as well. Malcolm et al. (2007) also added that the cost of the assessment might not be economically feasible when comparing it with the cost of the domestic wind turbine which may be worth only £1000–£2000. In addition, currently, micro-scale wind turbines are already being sold alongside performance claims that cannot be justified, which may lead to loss of public confidence and resentment of these systems.

Cace (2007), Dayan (2006) and Stankovic et al. (2009) acknowledged that ,similar to large scale wind farms, urban forms of integrated wind turbines also has to battle with public acceptance and confidence in the technology. The main public concerns are the visual impact of the wind turbines, noise, safety in the proximity of a wind turbine, shadow flicker, blade-reflected light, electromagnetic interference, and their adverse effects on biodiversity and birds flying into blades, and last but not least the effect on property values and house prices. On the other hand, Anderson et al. (2008) pointed out that there is a concern that environmentally conscious homeowners, businesses, local government bodies and other organizations will install rooftop wind systems as a signal of their support for sustainability, but may do so without adequate consideration of safety, structural building integrity or turbine performance. The potential consequence of such projects could be the failure of the project due to issues such as underperforming turbines, noise, and vibration (e.g. The Green Building in Dublin) and this would lead to the development of a negative reputation for wind energy and the renewable energy industry which has high potentials in replacing conventional sources of energy.

5 Conclusion

It can be concluded that of all the types of integrating wind turbines in the built environment, it's the BAWTs that gives architects the opportunity to express their concerns about climate change and reflect it in environmentally friendly iconic designs where the form of the building plays a significant role in harnessing wind power. However, in order to ensure the success and feasibility of such designs, a complete assessment of wind flow characteristics in the proposed site should be carried out. Of all the tools used for assessing wind flow in the built environment, architects favour CFD simulation over other available tools because of its potentials in comparing design alternatives, its high visualisation representation and its comparative ease of use when compared with other assessment tools. On the other hand, it should be noted that CFD simulation is not an accurate tool and should be validated by other available tools which is the same case for all wind assessment tools because they are all embedded with errors. Calculating these errors and taking account of them is very important when assessing the feasibility of integrating wind turbines into buildings.

Existing research is this area focused on the environmental and economic feasibility which were directly linked to reduction in carbon footprint and energy yield respectively. As for the economic feasibility, it can be concluded that economics of urban wind turbines is not yet competitive due to the high initial cost and long payback period which would be overcome by more understanding of the performance of, and integration of, wind turbines in the built form. On the other hand, social feasibility needs to be given the same weight in research as the economical and environmental feasibility and researchers should address public's concern about the integration of wind turbines in the built environment.

As the Building Augmented Wind Turbines offers the greatest potential in terms of producing energy, a new way of thinking about the augmentation is required: a new methodology needs to be developed to enable successful integration of wind energy integration into the buildings we design and use. This is not only about sculpting the building form to channel the wind through the turbines, it is a holistic approach, integrating form, structure, fabric, services, space usage and wind energy generation into one design. As the Green Building in Dublin and Kirklees Civic Centre demonstrated without even elemental integration, the energy potential of wind turbines is doomed to failure and will just become a green flag. The Bahrain World Trade Centre, the Pearl River Tower and the Strata SE1 building are the first steps in augmenting the building form to enhance wind generation, but these are just the first steps, we need to integrate not only energy generation into the design but the whole function of the building.

These existing BAWT buildings are the first stages of the development of this methodology, these are not the complete solution, we need to learn from these designs; what were their successes and failures. Again this needs to be reviewed in a wider context, not just the amount of energy or CO2 saved. Technology and the integration of technologies and system thinking develops rapidly, what is current today will be obsolete in five years time. So we will never get 'a solution' but we need to get closer to a solution.

Acknowledgements

This work is supported by the School of Architecture, Planning and Landscape in Newcastle University, UK.

References

Abohela, I. (2009). *The Integration of Wind Turbines in Architectural Design.* Paper presented at the Third Ain Shams University International Conference on Environmental Engineering.

Aguiló, A., Taylor, D., Quinn, A., & Wiltshire, D. R. (2009). Computational Fluid Dynamic Modelling of wind speed enhancement through a buildingaugmented wind concentration system. Retrieved 20-01-2010, 2010, from http://www.2004ewec.info/files/23_1400_derektaylor_01.pdf

Anderson, D. C., Whale, J., Livingston, P. O., & Chan, D. (2008). Rooftop Wind Resource Assessment using a Three-Dimensional Ultrasonic Anemometer. Retrieved 20-01-2010, 2010, from http://www.ontario-sea.org/Storage/26/1798_A_Wind_Resource_Assessment_on_a_Rooftop_Using__3D_Ultrasonic_Anemometer.pdf

Augenbroe, G. (2004). Trends in building simulation. In A. M. Malkawi & G. Augenbroe (Eds.), *Advanced Building Simulation*. Oxfordshire: Spon Press.

Austin, M., Bateman, C., Roberts, T., & Takayama, M. (2005). *Urban Wind Turbine Senior Design Project*. Boise State: Boise State University Mechanical Engineering Department.

Bahaj, A. S., Myers, L., & James, P. A. B. (2007). Urban energy generation: Influence of micro-wind turbine output on electricity consumption in buildings. *Energy and Buildings, 39*(2), 154-165.

Baskaran, A., & Kashef, A. (1996). Investigation of air flow around buildings using computational fluid dynamics techniques. *Engineering Structures, 18*(11), 861-873.

Blocken, B., & Carmeliet, J. (2004). Pedestrian Wind Environment around Buildings: Literature Review and Practical Examples. *Journal of Thermal Envelope and Building Science, 28*(2), 107-159.

Cace, J. (2007). Socio-economic issues related to the installation of small wind turbines in the built environment. Utrecht: The European Commission.

Cace, J., Horst, E. t., Syngellakis, K., Niel, M., Clement, P., Heppener, R., et al. (2007). Urban Wind Turbines, Guide Lines for Small Wind Turbines in the Built Environment. Retrieved 25 January 2010, 2010, from http://www.urbanwind.net/pdf/SMALL_WIND_TURBINES_GUIDE_final.pdf

Campos-Arriaga, L. (2009). Wind energy in the built environment: a design analysis using CFD and wind tunnel modelling approach. Unpublished PhD, University of Nottingham.

Capeluto, I. G., Yezioro, A., & Shaviv, E. (2003). Climatic aspects in urban design--a case study. *Building and Environment, 38*(6), 827-835.

Chen, Q. (2004). Using computational tools to factor wind into architectural environment design. *Energy and Buildings, 36*(12), 1197-1209.

Chen, Q., & Zhai, Z. (2004). The use of Computational Fluid Dynamics tools for indoor environmental design. In A. M. Malkawi & G. Augenbroe (Eds.), *Advanced Building Simulation*. Oxfordshire: Spon Press.

Clifford, M. J., Everitt, P. J., Clarke, R., & Riffat, S. B. (1997). Using computational fluid dynamics as a design tool for naturally ventilated buildings. *Building and Environment, 32*(4), 305-312.

Cochran, B., & Damiani, R. (2008). Integrating Wind Energy into the Design of Tall Buildings – A Case Study of the Houston Discovery Tower. Retrieved 27 January 2010, 2010, from http://www.cppwind.com/support/papers/papers/windenergy/Building-Integrated_Turbines.pdf

Coleman, B., & Preston, I. (2008). Revolutionary power. Retrieved 29 January 2010, 2010, from http://www.worldarchitecturenews.com/index.php?fuseaction=wanappln.commentview&comment_id=60

Dayan, E. (2006). Wind energy in buildings: Power generation from wind in the urban environment - where it is needed most. *Refocus, 7*(2), 33-38.

DeMeo, E., & Parsons, B. (2003). *Some Common Misconceptions about Wind Power*. Texas: All States Wind Summit.

Denoon, R., Cochran, B., Banks, D., & Wood, G. (2008). Harvesting Wind Power from Tall Buildings. Retrieved 20-01-2010, 2010, from http://www.ctbuh.org/Portals/0/Repository/T8_DenoonWood.357b6d8b-96e3-4988-b1d6-240cbafe12e3.pdf

DTI. (2006). Our Energy Challenge: Power from the People, Department of Trade andIndustry, UK. Retrieved 20-01-2010, 2010, from http://www.dti.gov.uk/files/file27575.pdf

Dutton, A. G., Halliday, J. A., & Blanch, M. J. (2005). *The Feasibility of Building Mounted/Integrated Wind Turbines (BUWTs): Achieving their Potential for Carbon Emission Reductions.*: Energy Research Unit, Rutherford Appleton Laboratory, Science & Technology Facilities Council.

Encraft. (2009). Encraft Warwick Wind Trials Project.

Eriksson, S., Bernhoff, H., & Leijon, M. (2008). Evaluation of different turbine concepts for wind power. *Renewable and Sustainable Energy Reviews, 12*(5), 1419-1434.

Frechette, R., & Gilchrist, R. (2008). *Towards Zero Energy, A Case Study of the Pearl River Tower, Guangzhou, China*. Paper presented at the CTBUH 8th World Congress.

He, J., & Song, C. C. S. (1999). Evaluation of pedestrian winds in urban area by numerical approach. *Journal of Wind Engineering and Industrial Aerodynamics, 81*(1-3), 295-309.

Jiang, Y., Liu, H., Zhang, B., Zhu, F., Liang, B., & Sang, J. (2008). Wind flow and wind loads on the surface of a tower shaped building: Numerical simulations and wind tunnel experiment. *Science in China Series D: Earth Sciences, 51*(1), 103-113.

Jones, P. J., Alexander, D., & Burnett, J. (2004). Pedestrian Wind Environment Around High-Rise Residential Buildings in Hong Kong. *Indoor and Built Environment, 13*(4), 259-269.

Jones, P. J., & Whittle, G. E. (1992). Computational fluid dynamics for building air flow prediction--current status and capabilities. *Building and Environment, 27*(3), 321-338.

Killa, S., & Smith, R. F. (2008). *Harnessing Energy in Tall Buildings: Bahrain World Trade Center and Beyond.* Paper presented at the CTBUH 8th World Congress.

Kirklees Environment Unit Report (2006). Detailed technical information: Civic Centre 3 – Energy from the Sun and the Wind. Retrieved 18 February 2010, 2010, from http://www.kirklees.gov.uk/community/environment/renewable/CivicCentre3casestudy.pdf

Kitson, M., & Moran, H. (2006). Taking the Built Environment to New Heights. Retrieved 16 February 2010, 2010, from http://www.fluent.com/about/news/newsletters/06v15i2/a5.pdf

Kubota, T., & Ahmad, S. (2005). Analysis of Wind Flow in Residential Areas of Johor Bahru City. *Journal of Asian Architecture and Building Engineering, 4*(1), 209-216.

Lei, L., Fei, H., Xue-Ling, C., Jin-Hua, J., & Xiao-Guang, M. (2006). Numerical simulation of the flow within and over an intersection model with Reynolds-averaged Navier–Stokes method. *Chinese Physics, 15*(1), 149-155.

Leitl, B. M., Kastner-Klein, P., Rau, M., & Meroney, R. N. (1997). Concentration and flow distributions in the vicinity of U-shaped buildings: Wind-tunnel and computational data. *Journal of Wind Engineering and Industrial Aerodynamics, 67-68*, 745-755.

Lien, F. S., Yee, E., & Cheng, Y. (2004). Simulation of mean flow and turbulence over a 2D building array using high-resolution CFD and a distributed drag force approach. [Article]. *Journal of Wind Engineering and Industrial Aerodynamics, 92*(2), 117-158.

Lim, H. C., Thomas, T. G., & Castro, I. P. (2009). Flow around a cube in a turbulent boundary layer: LES and experiment. [Article]. *Journal of Wind Engineering and Industrial Aerodynamics, 97*(2), 96-109.

Malcolm, A. H., John, D. W., & Simon, J. W. (2007). Estimating the potential yield of small building-mounted wind turbines. *Wind Energy, 10*(3), 271-287.

Mertens, S. (2006). Wind energy in the built environment : concentrator effects of buildings. Essex: Multi-Science.

Mithraratne, N. (2009). Roof-top wind turbines for microgeneration in urban houses in New Zealand. *Energy and Buildings, 41*(10), 1013-1018.

Mochida, A., Murakami, S., Ojima, T., Kim, S., Ooka, R., & Sugiyama, H. (1997). CFD analysis of mesoscale climate in the Greater Tokyo area. *Journal of Wind Engineering and Industrial Aerodynamics, 67-68*, 459-477.

Müller, G., Jentsch, M. F., & Stoddart, E. (2009). Vertical axis resistance type wind turbines for use in buildings. *Renewable Energy, 34*(5), 1407-1412.

Murakami, S., Zeng, J., & Hayashi, T. (1999). CFD analysis of wind environment around a human body. *Journal of Wind Engineering and Industrial Aerodynamics, 83*(1-3), 393-408.

Paterson, D. A., & Apelt, C. J. (1989). Simulation of wind flow around three-dimensional buildings. *Building and Environment, 24*(1), 39-50.

Peel, D., & Lloyd, M. G. (2007). Positive Planning for Wind-Turbines in an Urban Context. *Local Environment: The International Journal of Justice and Sustainability, 12*(4), 343 - 354.

Peter, I., John, K., Jamieson, R., & Andrea, F. (2008). Wind and tall buildings: negatives and positives. *The Structural Design of Tall and Special Buildings, 17*(5), 915-928.

Plate, E. J. (1999). Methods of investigating urban wind fields--physical models. *Atmospheric Environment, 33*(24-25), 3981-3989.

Ricciardelli, F., & Polimeno, S. (2006). Some characteristics of the wind flow in the lower Urban Boundary Layer. *Journal of Wind Engineering and Industrial Aerodynamics, 94*(11), 815-832.

Smith, P. F. (2003). Sustainability at the cutting edge : emerging technologies for low energy buildings. Oxford: Architectural Press.

Sun, H., & Huang, S. (2001). Simulation of Wind Flow Around a Building with a k –ε Model. *Theoretical and Computational Fluid Dynamics, 14*(4), 283-292.

Stankovic, S., Campbell, N., & Harries, A. (2009). *Urban wind energy*. London: Earthscan.

Syngellakis, K., & Traylor, H. (2007). Urban Wind Resource Assessment in the UK, An introduction to wind resource assessment in the urban environment. Chineham: European Commission's Intelligent Energy Europe Agency.

Ürge-Vorsatz, D. (2007). Climate change mitigation in the buildings sector: the findings of the 4th Assessment Report of the IPCC. Retrieved 15 February 2010, 2010, from http://www.ipcc.ch/pdf/presentations/poznan-COP-14/diane-urge-vorsatz.pdf

Taylor, D. (1998). Using buildings to harvest wind energy. *Building Research & Information, 26*(3), 199-202.

Tutar, M., & Oguz, G. (2002). Large eddy simulation of wind flow around parallel buildings with varying configurations. *Fluid Dynamics Research, 31*(5-6), 289-315.

Webb, A. (2007). *The Viability of Domestic Wind Turbines for Urban Melbourne*. Melbourne: Alternative Technology Association.

Willemsen, E., & Wisse, J. A. (2002). Accuracy of assessment of wind speed in the built environment. *Journal of Wind Engineering and Industrial Aerodynamics, 90*(10), 1183-1190.

WINEUR. (2005). Wind energy integration in the urban environment,Technology inventory report: European Commission.

Yuen, C., Zanchetta, M., & Battle, G. (2004). *Performance of a Building Integrated Wind Farm*. Paper presented at the The 21st Conference on Passive and Low Energy Architecture (Plea). Retrieved 28 January 2010, from http://alexandria.tue.nl/openaccess/635611/p0563final.pdf

Vernacular Architecture and Sustainability

The latest achievements of research into human induced climate change have led specialists to the conclusion that the World needs a fundamental reboot and major measures are still needed in all sectors to avoid global catastrophes. Although much has been done already to reduce the environmental impact of the built environment in the last twenty years, there is still a huge scope and a great need for further improvement in this field. Newly emerging technologies as well as a deeper insight into the metabolism of buildings and urban settlements are the keys to a wider use of sustainable principles and a drastic reduction of buildings' dependence on fossil fuels.

Vernacular architecture, a term used to categorize methods of construction which use locally available resources and traditions to address local needs, has often been highlighted as not only playing an important role in current design but forming the fundamental basis for current sustainable architecture with respect to taking local climate, environment, materials, and culture as a starting point for good design. Vernacular architecture tends to evolve over time to reflect the environmental, cultural and historical context in which it exists and thus presents a whole set of local knowledge remaining from times when buildings and cities had to function without the heavy reliance on fossil fuels. We have to learn from vernacular architecture, translate and incorporate local knowledge into today's building concepts and design tools – vernacular architecture should be our inspiration.

Thus it was a very interesting and timely occasion to focus on sustainable vernacular architecture and to present many good examples that exist and that can be used to learn from for future building and city design that draws from the rich experience of local traditional architecture. In this chapter we find a paper that examines examples of troglodyte architecture that aims to re-introduce the concept of earth-sheltered architecture while two papers have a closer look at traditional passive cooling devices and analyze their role as environmental mediators, creating thermally pleasant living conditions. One work is extending the research to traditional neighborhood pattern and trying to find a sustainable morphological order, another work deals with climate analysis and thermal comfort measurements of traditional houses, while yet another work looks at vernacular architecture as a planning and management strategy. This chapter illustrates how we can learn from vernacular architecture and how it can guide all of us towards a sustainable built environment with minimal impacts from our work as building and city designers. It is essential for our common future.

Matthias Haas
Norwegian University of Science and Technology

Analyzing a Traditional Neighbourhood Pattern of Old Dhaka: A Case of Tantibazaar

Tanima Tabassum
State University of Bangladesh. Bangladesh

Abstract

Dhaka is like a treasure house where layers of different ages of the city over the last 400 years remain juxtaposed. These layers contains a hidden morphological order of the different urban settlements of Dhaka and shows an indigenous archetype which formed spontaneously and created an organic pattern of settlement. The residential neighborhoods of old Dhaka, locally known as 'Mohallas', were considered as the morphological archetype of historic Dhaka. The spatial hierarchies within this neighborhoods form the fabric of the city that reflects the indigenous settlement character of Bengal. Tantibazaar is such a significant neighborhood that reflects the organic settlement pattern of historic Dhaka with a unique morphological identity of compact and linear buildings with a narrow frontage along a spinal axis. Moreover, this morphology contains a combination of spatial and social cohesiveness that is a sustainable living pattern for Dhaka's socio economic context. Due to rapid urbanization, changing economic opportunities and higher cost of urban land, insufficient legislative framework, inadequate financial support, lack of awareness and resources, absence of development control regulations, the historic urban fabric of these 'mohallas' is facing extermination. Though in this paper the urban settlement patterns of the neighborhoods present in Old Dhaka's urban fabric and their tangible and intangible quality is attempted to be identified.

***Keywords**: Old Dhaka, Traditional mohalla, urban pattern, Morphological Order, Indigenous neighbourhood Pattern.*

1 Preamble

1.1 The Context of Old Dhaka

Dhaka, the capital city of Bangladesh, has grown from a small treading center to a metropolis while its antiquity can be traced back to the 7th century A.D (Birt, 1975). Dhaka's existence as a small town of some importance is proved by the discovery of two mosque inscriptions and remains, traditions and literary evidence (Dani, 1962). N.K Bhattashali (1936) has reconstructed the extent of the city of Dhaka of pre-Mughal (old Dhaka) and Islam khan's city (new Dhaka) from the pages of Mirza Nathans Baharistan-i-Ghaibi. These two distinct part as old and new Dhaka has developed through different historical phases and possessed various development patterns like indigenous, formal and informal. Within the spatial pattern, both old and new Dhaka has experienced the verity of phase developments. Hence, among the spatial structures within this it has been observed that there are two distinct phases, Old Dhaka and New Dhaka exists side by side. One in the historic core and the other in the extemporaneous settlement of recent years – the former is called the 'indigenous' and the later is labeled as 'informal' development (Siddiqui, et al, 1991). The historical core of 'old Dhaka' retains the traditional features of the urban settlement that it has inherited from the past. The natural endowment of its organic morphology is valued for its 'indigenous' urban pattern (Nilufar, 2004). The residential neighborhoods of old Dhaka, locally known as 'mohallas', were the enclaves of caste or craft groups are considered as the morphological archetype of the old part. Most of these 'mohallas' (neighborhoods) were developed as Hindu trader's settlement and named after the specialized trades and crafts for which they are engaged such as TantiBazaar, ShakhariBazaar, Bangla Bazaar, Lakhsmi Bazaar, Kamar Nagar, Sutar Nagar, Goala Nagar etc (Imamuddin, et al, 1989). These neighborhoods mainly indicate the predominance of the Hindu artisan and professionals among the population of Pre Mughal Dhaka's urban center that had flourished with their craftsmanship during the Mughal period.

Apparently, the labyrinthine growth of the old Dhaka's localities does not express any order of settlements but distinct geographical areas have morphological character. This character constitutes an indigenous historic structure of the urban fabric. However, James Taylor (1840) found no order in the historic urban form of Dhaka. The organic character of these densely built areas expresses the aspiration of demand of the inhabitants. It is a complex pattern of connecting street network with densely built houses. There were narrow streets forming the boundaries of different neighborhoods creating a web of interlinked connections and deep cul-de-sac forming sharp turns in the urban blocks. These types of pattern are the common phenomenon in most of the localities of old part. However, a few long lines passed through the residential areas, which give rise to another type of urban pattern, eg. Shakhari Bazar Road, TantiBazar Road. These were mainly the commertial interface of the city; and such areas have no no lanes and by lanes as the access are from single bazaar streets. These streets are defined by closely spaced buildings in contrast to the former pattern where buildings are loosely spaced. Thus, two distinct urban patterns exist in the old city (Khan, 1982). Tantibazar is a unique example of the later pattern which posses at least 300 years urban settlement morphology. It was known for the craft 'tant shilpo' (weaving) especially the 'Dhakaiya muslin' which was the hallmark for the economic development of Bengal that time. For the last 300 years, this 'mohalla' retains its spatial as well as social identity. However, with the passage of time the special trading for which it was known, had changed but still carrying the name Tantibazaar and the unique settlement pattern of its kind (Fig: 1).

In the present urban context of old Dhaka, Tantibazaar holds a significant position through a development pattern and morphological change both in their trading and settlement pattern. Now the inhabitants of Tantibazaar are mostly goldsmith (Sharnaker).

A recent observation of Tantibazar shows a contrasting picture of the decaying past with the present due to uncontrolled growth, densification and poor maintenance.

Figure: 1, Dhaka in 1859, showing the densely pattern bazaar street of Tantibazaar (Source: Renell's map no-14).

1.2 Objective

Cities grow upon themselves with time mostly following the natural laws. The material form of the city is the intrinsic to its sociological, cultural and psychological reality (Rossi, 1982). Thus, the organic cities are autonomous and each part of its pattern develop according to its own law. However, this paper analyzed the organic settlement pattern of a traditional neighborhood, which retains one of the hidden orders of indigenous settlement pattern of old Dhaka until this date. Identifying the traditional pattern and analyzing the tangible and intangible aspects of the residential neighborhoods of historic Dhaka in the form of physical pattern, morphological development, building fabric, street facade building-space relationship and their responsiveness are the parameters for the study. It is believed that harmonious relationship of these factors make the settlement sustainable. The spatial pattern of these neighborhoods was sustainable as grew out of the community need.

This paper also focuses on the spatial pattern of a specialized neighborhood (TantiBazaar) which reflects the character of traditional settlement pattern of Dhaka to develop it as a cultural heritage and a symbol of a socio-spatial sustainability. As in Alexander's (1977) words, "A pattern is a discovery in the sense that it is a discovery of a relationship between context, forces and relationships in space, which holds absolutely".

1.3 The Urban Setting of TantiBazaar

Tantibazaar is located in the southern part of old Dhaka(in Ward-72, presently named as Prosonno Podder lane).It has grown along a narrow road of 12-15 feet wide and started from the junction point of the English road and North South road and connected to Shakharibazar through Panitola (Rakhal Chandra Sen Podder Street) . It is 1000 feet in length with rows of densely built houses. The settlement shows both closely spaced buildings and sometimes a few large plots also. The area is mainly a commercial hub with the residential quarters at the back of the shops. These are mainly the shop houses, a traditional form of mixed-use buildings where the street fronts are used as gold jewellery shops while the rear parts of the ground and upper floors are used for residential purpose. these residential house forms shows a dilapidated image of the past several era as the settlement of Tantibazar has gone through a long historical journey.

1.4 Historical Background of TantiBazaar

The pre-Mughal Dhaka acquired the name of "Bayanno Bazaar and Teppun Gali"(Birt, 1906). The main settlement lay between the river Buriganga and Dulai khal(present English Road) with its center near BanglaBazar. The town consisted of few important local market centers like lakhsmi Bazaar, Bangla Bazaar, Shakhari Bazaar(conch shell market), Tanti Bazaar(weaver market) and few other localities of other (Khan & Islam, 1964). The same occupational groups used to live in groups and in most cases the same house used for the factory as well as the residence (Bhattacharya, 1954). Dhaka had a glorious past at that time of pre-Mughal Muslim rules. In 1608 dhaka became the capital of Mughal Bengal. During 17^{th} centaury (1608-1610), Mughal Subedar Islam Khan Chisti gave privileges like tax rebate were given to these people of different professions to settle the new capital of Dhaka (Ahsan, 1991). These settlers were mainly the manufacturers and professional groups.

Tanti Bazaar was originally the place of the weavers. The area was developed with shop-house settlement and reputed for the muslin factories. The trade of 'Tantshilpo' specially the Dhakaiya Moslin and the finest cotton were produced here, which was craved by the elites and the ruling class. Tantibazar, Nawabpur and Islampur were the hub of this cotton trade. The trade flourished for few centuries. During 1757, an urban revival took place in dhakadue to the advent of English colonizers. With the shifting of capital from Dhaka to Kolkata and introduction of 'mule twist', Dhaka's commercial prosperity received its severe shock. In 1817, muslin factory was closed and weavers deserted Dhaka to seek employment in agriculture (Ahsan, 1991). Gradually Bengal became the consumer from the producer in weaving sector. The area again lost its grandeur because of the migration of the rich inhabitants specially the Hindu businessperson to India after the partition in 1947. After that, a different trade started to flourished here. And Tanti Bazaar became a place for the Goldsmith, which was practiced there since Mughal period in a small scale.

2 The Growth Pattern of Tantibazaar

2.1 Morphological development

The settlement of Tantibazar express a strong morphological identity mostly with compact and linear buildings with a narrow frontage along the spinal axis and this was distinct from the loosely spaced buildings and large plots in surrounding areas except the settlement at Shakharibazar.

Most of the settlement's pattern is linear in nature at a wider scale and circular at homestead scale (Muktadir & Hasan, 1995), being along the river or some sort of water bodies as main source of services and communication lines. As such, Dhaka has grown from a small settlement within the confines of Buriganga and Dulai Khal to a sprawling metropolis. Dependence of indigenous settlements on natural services of water is clearly reflected in their evolutionary trend (Mowla, 1997). The indigenous urban fabric reflects the rural pattern of life, which had to adopt and transform to fit in the more competitive tighter urban spatial environment (Fig: 2). The study area reflects clearly that adaptation of urban texture through its morphological development and also expresses a strong sociocultural identity of its people.

The maps of previous era contain the morphological development of the spatial pattern of the area as a strong spine of communication holding the plots on either side (Fig: 3). A chronological observation through mapping, gives the

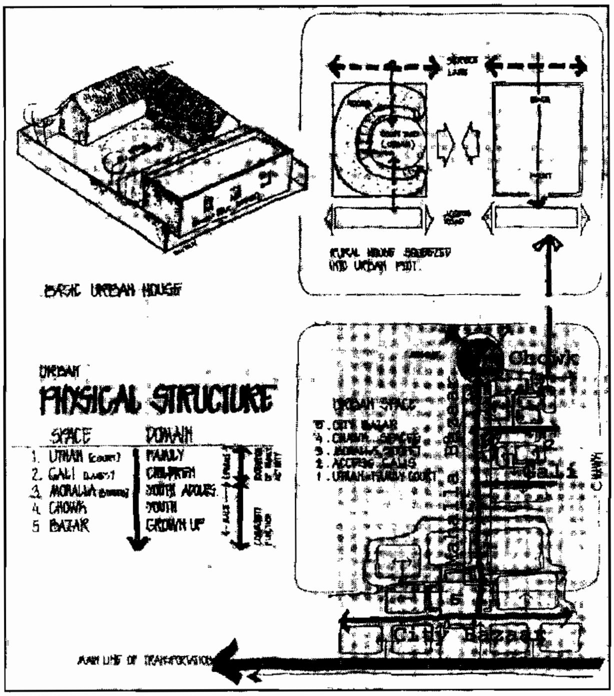


Figure: 2. Spatial manifestation of social structure: evolution of urban space in indigenous Dhaka (source: Mowla, 1997).

total picture of the evolutionary process of the urban texture of the area. At micro level, it shows the transformation of rural house form with a source of water and service along with it. Almost every house contains water well for drinking water and an artificial canal was thought to have existed for the purpose of service at the rear side. It is thought that the southern part connected to ShakhariBazaar is developed at first then gradually the northern part of the street streched and extended up to Dholai Khal presently the English Road. Therefore, when each single land has to be subdivided to provide multiple families of the next generations, each plot to get street frontage and back service provision become linear and narrow. The plots were divided by mutual agreement between inheritors. Therefore, access and service line worked as a guiding factor for linear plot divisions. With the establishment of the piped services, the houses were no longer dependent on the location of the services, which led to the more elongated development of built form. In some cases, the plots are divided into two divisions with a narrow passage at the side of the front plot, which results into horizontal consolidation. Now it is growing vertically which is destroying the indigenous settlement character and the flavor of traditional pattern.

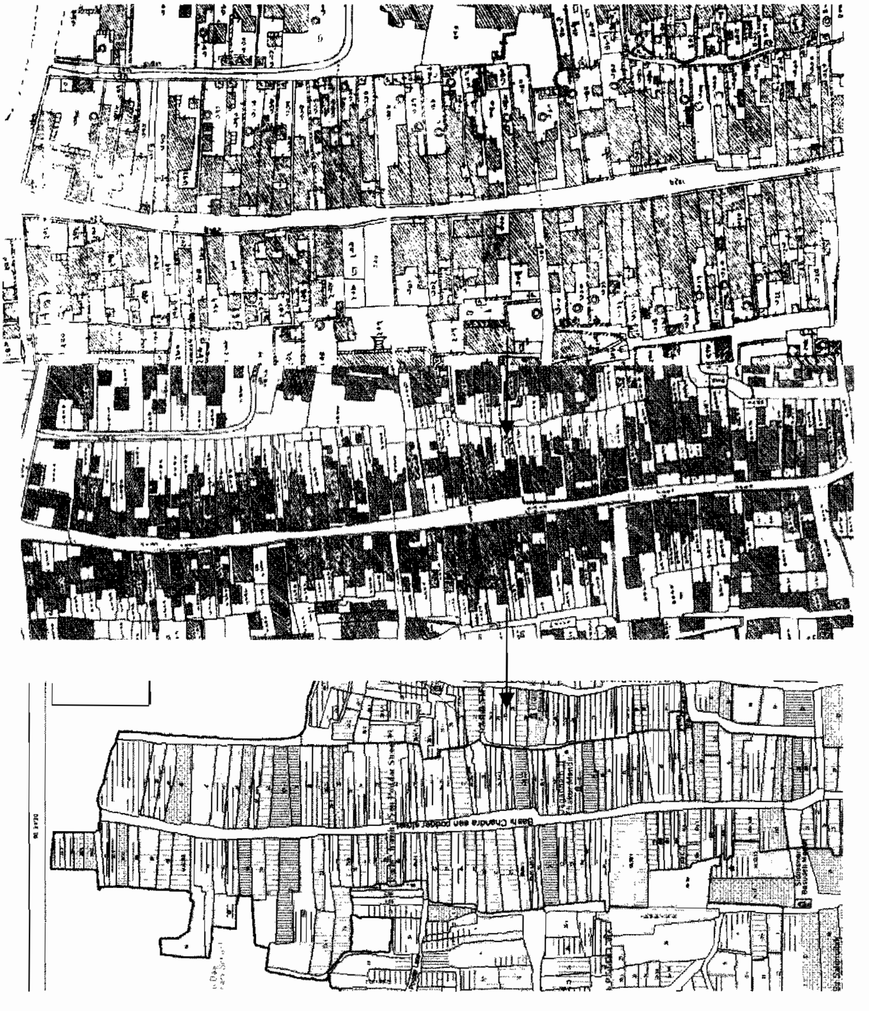


Figure: 3, Chronological development of Tantibazaar showing through the CS map of 1915, RS map 1952-55 and Base map 2002 (source: DCC).

2.2 Analyzing the settlement patter

The fundamental characteristics of the indigenous pattern are winding, intricate streets, where walls defining the boundary (Khan, 1982). Historically a group of these boundaries forms the traditional neighborhoods. Neighborhood is primarily a social phenomenon arising from cohabitation in a physical area, locally known as 'mohalla' or 'tola' (Nilufar, 2004). In the old part of Dhaka, the mohallas were created with a few houses, mostly arranged along the access road, sometimes along the urban space of bazaar street. Tanti bazaar, the Hindu trader's and weaver's settlement developed as such a local mohalla. The religion and socioeconomic status had a deep impact on its physical character. The urban fabric of the mohalla has a strong spatial quality of indigenous character. The settlement developed from a central axial spine of communication and bazaar street and the plots were arranged along the spine. The road is very narrow (12-15 feet) and intimate in nature. Through physical evidences, it is observed that the settlement developed through a hierarchy of spaces and hierarchy of social relationship, which was manifested by a particular type of spaces. Here the urban fabric developed as a sequence of Uthan,Galis, Mohalla, Morh, Chawk, Bazar. In which the narrow roads and galis (lanes/streets) have a human scale. Galis, common walls, inward facing houses, the commercial/civic morh (corner, roundabout or bent in a path) or chowk (square) areas, the mahalla etc. are some of the elements of its urban fabric. At micro level, it shows a transformation of village house pattern in to an urban extended family house (Mawla, 1997). And the mohalla is created with these houses. This is the oldest pattern identified at various locations of indigenous Dhaka also identified in the settlement of Tantibazar.

Here the mohalla was composed of shop houses, having shops at the road frontage then the residential unit is provided around the uthans. The Galis are present in form of a circulation towards the community street and the natural bending of the circulation spine created the morh, a place of interaction. The main access possessed the quality of both the character of the chawk and bazaar in a overlapping manner and contains the nature of traditional bazaar street.

2.2.1 The hierarchy of private house forms

Most of the buildings of Tantibazar exhibit a common character. The plots are elongated and sometimes an extreme configuration of 10feet x 100 feet can also be seen. The land is almost filled with built-up areas and the building height varies from 2-3 stories.

A house form according to Rapoport (1977), is the consequence of a whole range of socio-cultural factors seen in their broadest terms. A traditional rural 'Bengali House' in its basic form is a cluster small 'shelters' of huts around a central yard, locally called the uthan (Muktadir & Hasan, 1985). Influence of this rural traditional house form is also observed in traditional neighborhoods of urban areas. The settlement of TantiBazaar also exhibits this traditional form of house pattern. The early house form of tantibazaar was observed as a thatched hut, from the picture of D'oyly, titled as 'a Tantee or Indian Weaver of Dacca (Fig: 4). In the later development, the houses are mainly divided into three segments: the commercial part facing the street also provide a sense of privacy from the roadside, the residential area in the middle and the service area, consisting of toilets and washing areas in the open courts at the rear. Mainly two broader types of courtyard houses are identified here. **Typology 1** showing a shop frontage then sequentially comes the uthan of U shaped around which the residential rooms are arranged and at the back there is the service court having a well (most buildings of TantiBazaar) (Figure 2). Typology 2 shows a comparative loose pattern having a vast open courtyard with an out house in front and two inner courtyards in a sequence as private and service court, sometimes having a gateway façade(house no 32, 74/2 resembles the affluent group of TantiBazaar) (Figure 3). There is another pattern of the first type of house form **Typology 3,** which contains a Mandir (Hindu worship place) in front of the house of type 1 category having a narrow passage beside to go to the rear residential part with an L shaped courtyard. Sometimes the Mandir is placed behind the shops (house no 106) or beside the main courtyard house (house no 17), which was mainly the personal temple of the house but now used by all.

2.2.2 The spatial pattern of community spaces

In this settlement, the narrow road plays a significant role in the social relationship of the community and works as a magnet of the settlement. Traditionally the people of Bengal have a habit of socialization in outdoor spaces. This habit led to the formation of Uthan, Galis, Mohalla, Morh, Chawk and Bazar etc., the traditional outdoor civic spaces, as the cornucopias of myriad events and different human activities (Mowla, 1997). This form of community relationship is also visible in the area of Tantibazar. Face–to-face relationship of the mohalla residents is another contributing factor to the sense of community. The natural bent of the path and the overlapping point of Tantibazar and Panitola became the mohalla morh and became the main socialization point. The frontage of the series of shops also provides a place for interaction (figure-7 & 8). Another place of gathering is the religious structure. So the civic facilities are incorporated at the human scale that develops the interactions of the inhabitants. The sense of stronger community also encourages maintaining many cultural rituals and increases the bonding.

The mohalla or indigenous neighborhoods are semi autonomous socio spatial units, with a very little control from any higher level of administration. In Tantibazar, four autonomous bodies are present to provide administrative control, one is the Mohalla Panchayet and other three bodies of gold traders' like- Bangladesh Poddar Samity, Swarnashilpi Sramik Sangha and Bangladesh Pathar Samity are present for trading administration. These have maintained the communal bondage and the spatial quality of the area.

The medieval artifact of old Dhaka is an expression of indigenous urban form. It is claimed that the organic cities reflect the 'community spirit'; and truly, the spatial structure partly reflects and partly determines the social

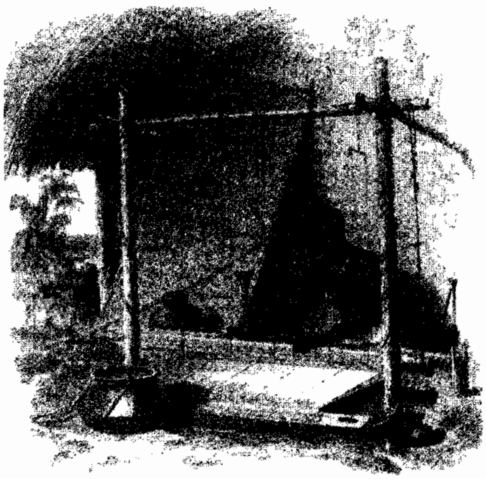


Figure 4. A Tantee or Indian Weaver of Dacca (Source-)

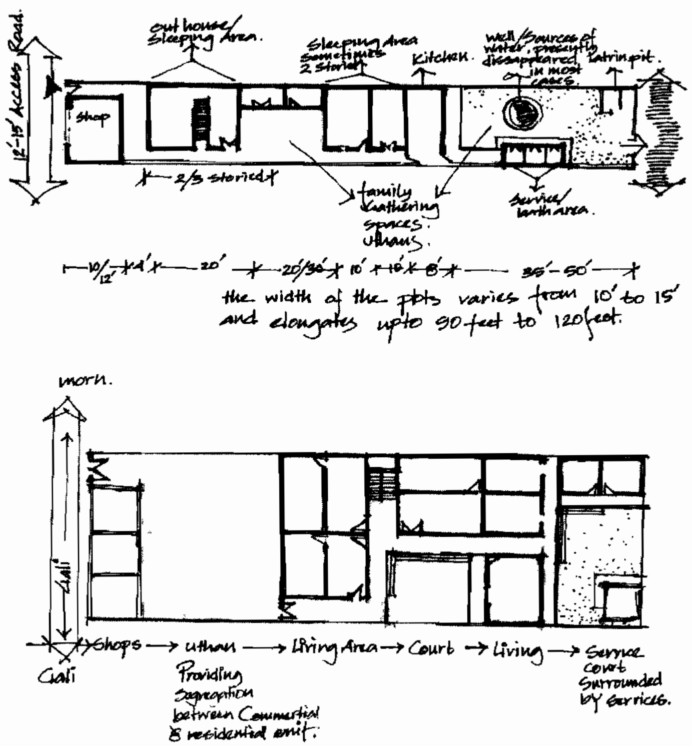


Figure : 5 & 6. Chronologically showing the house Typology 1 & 2 (Source- Author).

structure (Pahl, 1970). Tantibazaar as a neighborhood of old Dhaka also bearing this community spirit which is totally absent in modernized urban society.

3 Building and Space Relationship

Tantibazaar settlement maintains a vibrant character through its spatial development. Here both the spatial character of the individual houses and the face-to-face relationship of the houses create an intimate and human character.

The most important physical quality of a space is enclosure that creates sense of place. Street bounded by adjacent buildings gives a feeling of three-dimensional space. The street of Tantibazaar having a width of 12 to 15 ft, creates a good sense of enclosure and the quality of intimate urban space. This intimate space enhances the community and cultural activities at outdoor urban environment, which is also sustainable for community spirit. According to Alexander, interesting and lively spaces have nodes of activity at a maximum distance of 300 m along their length (Alexander et al, 1987). In Tantibazaar, that lively space is observed throughout the linear road especially at the shop frontages and natural bents and it serve as a main gathering space. The spaces in between and in front of the buildingsare vibrant and provide many closed and short vistas, which make the streets, galis and other public space comfortable, satisfying and secure for assorted activities and to walk through (Mowla, 2002).

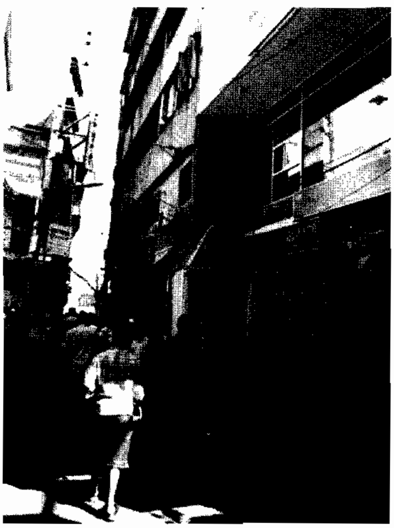
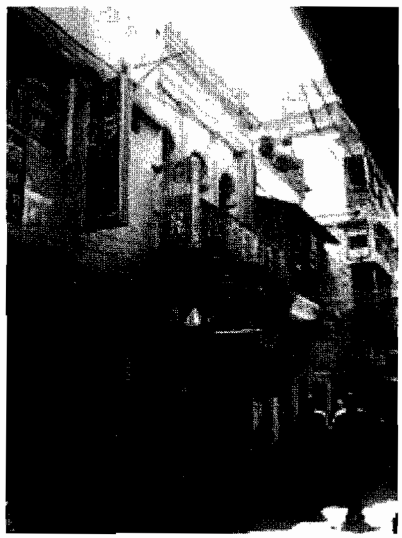



Figure: 7 & 8. The places of socialization at the linear road (Source: Author).

At the micro level, the courtyard is the most vibrant place for geo climatic reason and for social aspect of interaction (Figure 9). It is the breathing space for the dwellers. The houses with Courtyard along with a mandir create activities for the neighborhood to perform religious rituals that also act as a form of urban space. The façade articulation around the courtyard also encourages outdoor active ties thus improve social ties among buildings through the semi open verandahs. The water well is another element present at the back courtyard that acts as a place of socialization (Figure 10). The courtyards present in this neighborhood is mostly U shaped in the inner part and L shaped at the rear side and the other side is provided with a thick high wall which provides security among the neighbors and enclosure.

The building facades also imply a harmonious relationship through balconies and windows with the street level. In most cases, the street connects with the building units through the commercial unit. The settlement possessed a street façade proportion of about 1:1 to 1:2 which is now totally lost due to newer development above the old structures (Figure 11 & 12),. In many portion of the road, the original character of the neighborhood has changed due to new construction of tall buildings, which gives a completely contrasting character to the spatial relationship of the area. Still now, the inherent quality of the community fillings is present in the space (Figure 13) but the environmental aspect is effected due to over saturation of people.

Figure 9 & 10: Showing the building space relationship through courtyard and service court at the inner house level (Source: Author).

Figure 11 & 12: Showing the contrast between the intimate space of the traditional character and imposed scenario of some modern intervention (Source: Author).

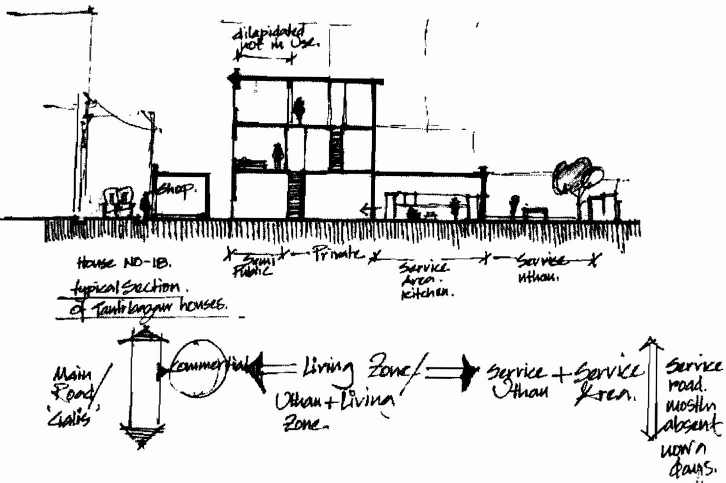


Figure: 9 The inherent quality of communal feelings through the sequence of spaces at TantiBazaar (Source: Author).

4 Findings for the sustainability in urban space

At a glimpse, the settlement texture of Tantibazar may look chaotic and absence of order in the pattern. But behind the chaos, there exist a order which occurred due to usability of people. But due to rapid urbanization, haphazard development is occurring in this indigenous pattern. Most of which is not respecting any contextual basis of Tantibazar settlement inspite of the presence of the old buildings. The buildings character, specially the uniformity and continuity expresses the evidences of the previous era also symbolizes the unity in the social life of the neighbourhood. The overcrowding situation is even creating an unhygienic environment for living. The uncontrolled and fast changing character of the urban pattern is thus disruptive to the community structure.

The overall observation of the spatial pattern of the area may be summarized as follows:

- The actual socialization revealed through neighborliness and theoretically, neighborhoods are characterized by social homogeneity and tightly knit pattern of primary relationship (Nilufar, 1997). Thus, the linear mahalla represents strong sense of neighborly relation due to the same occupation, ethnicity and caste and creates social cohesiveness within the members..
- The bazaar street at an intimate scale works as a place of community.
- Face to face, relation among the streetscape makes the street vibrant and acts as a catalyst to increase the social bondage.
- The neighborhoods having an intimate territory works better.
- Pedestrian relationship at the tertiary road level like in the Galis(Lane) makes the street level more vibrant with overlapping activities such as communication, social gatherings. It also makes the neighbourhood environment friendly.
- Courtyard house pattern is geo climatically and socio culturally efficient for the living pattern and contextual base of this region.
- Hierarchy of spaces from the public domain to private domain creates a sequence of socialization space and sense of controlling which is sustainable in the context of this region where it provides seclusion to the women from the male visitors.
- Enormous number of voids in build form helps to interact to urban spaces. Elements like courtyards, verandahs, windows are the key elements to enhance the indoor out door relationship.
- The street façade height to width of the road ratio have a impact on the intimate scale of living as analyzing the neighbourhood of Tantibazaar it is assumed to be of 1:2 to 1:3.
- Mixed land-use pattern as working place along with living spaces also increases the belongingness among the inhabitants of the area which also enhances the social interaction.

- The narrow road pattern creates a chaos within the area so it should be converted as a pedestrian way to give people a chance to enjoy the flavor of the past.

All these are the basic characteristics to develop social, cultural and commercial activities within the neighborhood boundary. And these will promote one step towards a sustainable neighborhood.

5 Conclusion

It is believed that beneath the strangest twist of a lane or alley, behind the most fitfully bounded public space in organic cities, lays an order derived from long established cultural tradition and historical layering of the social contract and the result of a string of compromises between individual rights and the common will (Kostof, 1991). This hidden orders need to be identified and analyzed to understand the essence of context and tradition. For a centuries Tantibazar has a long history as a traders neighborhood, started as a place for the 'Tantis' and then developed as a neighborhood of the gold smiths. The type of trading changed over time due to political reasons but the essence of the indigenous neighborhood settlement is still present through the social character and the physical identity of the buildings. The settlement texture developed through the cultural demand of rural context and took a form of urban pattern with changing nature of the social and commercial development.

The overall development gives a picture of harmony and continuity but in a fragmented way due to the modern interventions of recent times. Towards a sustainable living pattern, these types of settlements should be revived for the social and cultural identity of Dhaka. With the course of time, Dhaka is facing the treat of cultural identity and neighborhoods formed with heterogeneous groups at a large scale minimizing the scope of social stability. This indicates the need for protecting the character of the neighborhood and controls the chaos. And it need to be reminded that old Dhaka is a perennial source of tangible cultural heritage; as we lost most of the unique resources of this heritage, the rest should be protected.

References

Alexander, Christopher. (1966). A city is not a tree, in Design no. 206, 47-55.

Alexander, C., Neis, H., Anninou, A and King, I (1987). A new theory of Urban design, Oxford: Oxford University press in Moughtin, 1999.

Ahsan, Majid. Rosie. (1991). Dhaka: Past Present Future, chap-Changing Pattern of the Commercial Area of Dhaka City, Ed. Sharifuddin Ahmed, 432-437.

Birt, F., B., Bradly. (1906). Romance of An Eastern Capital, London, 75.

Bhattacharya, S. N. (1935). Dhaka University Studies, 1(1), November.

Bhattashali, N. K. (1936). Bengal Past and Present, XXXIII, 27-29.

Dani, Ahmed. Hasan. (1956). Dacca: A Record of its Changing Fortune. Dhaka: Asiatic Press. 21-22.

D'oyley, Sir. Charles. (1991). Translation of the Antiquities of Dacca. Translated by, Shah Mohammad Nazrul Alam, Academy Publisher, Dhaka.

Immamuddin, Abu. H., Hassan, S. A. , Alam, W. (1989). Shakharipatti: A Unique Old City Settlement. Dhaka. Aga khan Architectural Design for Conservation. 1.

Khan, F. Karim. , Islam, Nazrul. (1964). High class residebcial areas in Dacca city. In the Oriental Geographer, VIII(1), 1-41.

Khan, I. M. (1982). Alternative Approach to the Redevelopment of old Dacca. Unpublished Doctoral Dissertation, Katholic Universiteit Leuven.

Kostof, Spiro. (1991). The City Shaped; urban patterns and meaning through history, London: Thames & Hudson.

Mowla, Q. A. (1997). Settlement Texture:Study of Mohalla in Dhaka. Journal of Urban Design. 2(3). U.K. 259-275.

Mowla, Q. A. (2002). Emergence of Civic Space in Dhaka. Plan Plus. 1(1). 98-116.

Muktadir, Mohammad. A. , Hasan, Dewan. M. (1985). Traditional house Form in Rural Bangladesh-A case study for Regionalism in Architecture.

Nilufer, Farida. (2004). Hidden Morphological Order in an Organic City .Journal of Protibesh. 10. 33-40.

Nilufer, Farida. (1997). The spatial and social structuring of local area in Dhaka city- A Morphological study of the urban grid with reference to neighbourhood character within naturally grown areas, Unpublished doctoral thesis, Unit fir Advance Architectural Studies, The Bartlet school of graduate studies, university Collage London, University of London.

Pahl, R. E. (1970). Patterns of Urban Life. London : Longmans.

Rapppoport, A. (1977). Human Aspects of Urban form-Towards a Man Environment Approach to Urban Form and Design. Oxford: Pergamon Press.

Rossi, Aldo. (1982). The Architecture of the City. Cambridge (Mass): MIT Press.

Siddique, Kamal. et. Al. (1991). Social Formation in Dhaka city.-A study in the third world urban society, Dhaka University press limited.

Taylor, James. (1840). A Sketch of the Topography and Statistics of Dacca.

Passive Cooling in Traditional Construction: Case of Domestic Architecture in Egypt

Loredana Ficarelli
ICAR Department, Politecnico di Bari;Italy.

Abstract

This research, dealing with environmental protection, defence and the reuse of the traditional constructive techniques, finds appropriate answers in the study of the forms, technique and features of Mediterranean cities. Starting from a urban scale analysis and a traditional town planning, you arrive at the study of its architecture and its extrinsic systems: court house, the takhtabush, the loggias, courtyards, covers, the mashrabiya, the claustrum, the wind-escaper, the malqaf, the badgir, the qà'a, the salsabil, the landscape. These cities, subject to extreme climatic situations, since the past, have given simple and efficient architectural and technical answers. For example, the relative humidity and the temperature were both controlled through stone and raw brick construction. This condition, combined with a control operation of cooling systems and their use in a hot-dry climate, exploits the high thermal mass of stone or cooked or raw brick masonry. This process can slow down the passage of heat inside and maintain low temperatures during the hottest hours.

Keywords: *environmental protection, extrinsic system in Mediterranean architecture, cooling system.*

1 Form and technique in domestic architecture of Cairo.

The research comes from the study of singular places within the Mediterranean basin, which, in the past, gave architectural and technical answers, both efficient and practical considering the extreme climatic conditions.

The complex relationship between architecture and climate is the origin of this is The complex relationship between architecture and climate is the origin of this discussion, up to the achievement of wealth and comfort, dealing with the climatic problem in architecture through physics.

Egypt has a climate distinctly desert, characterised by sultry heat and drought, owing to the geographical position of the country in a north African large desert tropical strip. The extreme shortage of water affects the landscape. Vegetations and agriculture are possible only near rare humid climatic zones.

Cairo, placed at latitude 30° north and longitude 31° east, has the typical features of the northern Egypt desert climate, an extremely dry climate, characterised by rare rainfall in winter semester and only for a few days.

The traditional architecture in Cairo converts the extreme climatic conditions into a sophisticated local construction culture that anticipates the modern bioclimatic approach to design.

The climatic conditions of these areas, in fact, have determined the inclusion of specific techniques of passive climate control, which, in the past, favoured a better thermal comfort inside houses. The urban structure is organized so that spaces are controlled, regular, introverted, thus providing, on the one hand, for the environmental wealth, ensuring light and ventilation, on the other hand it becomes an expression of urban culture.

"Les Maison du Caire" is among the most complete examples of architecture in harmony with the ecosystem. These houses are considered case studies strongly explanatory of this research and tools of methodological definition.

2 The Formal and Constructive Parties of the Cairota House.

The domestic architecture in Cairo has a very different style from that of other African places from Mamelouk period (thirteenth-sixteenth century) onwards. Whether the Mamelouk houses are built within the Fatimid walls, on the banks of the Nile, or near the Citadel, they generally overlook the street or a private courtyard. They are strongly influenced by the place and have a well-organized structure.

On the ground floor there are usually kitchens, storages for food or stalls, rooms for housework and reception that represent the organizing and administrative heart of the most private part related to everyday household.

The upper floor with its bedrooms, living rooms or service rooms, is almost entirely closed, to protect from the heat and outsiders. This part of the house combines two important aspects of everyday life, joining in an antithetical, but at the same time symbiotic way, the public and private sphere of family. The rooms are divided into women's rooms and men's rooms. These spaces are characterised by lack of large openings, which reflect the unique character of the Cairo house, and where tranquillity and privacy are guaranteed by the complex architecture.

Among the most important elements of houses in Cairo there is the court: on the ground floor, just like on the upper floor, all the rooms and spaces are organized around the court, that is the heart of the house, but it can be also considered one of the most important elements for natural ventilation of the all domestic architecture. The court-system is useful for natural air-cooling.

The court may also take the role of staging area for the reception of merchants passing along the caravanned way on which most of the houses overlook. To enter this area it is necessary to cross the bayonet entrance and the following maq'ad.

From the court you reach the most emblematic space of the house in Cairo: the qa'a. This space, depending on the circumstances, devoted to family meetings, receptions or parties, is the representative part of the house, the place where to stay, live, receive and relate to others. This place is the founding element of the house and, as evidenced by the literature, the house itself was named after it: the qa'a house, which knows its decline only in the late Ottoman era.

The need for a reception and representation room is transformed over the centuries and becomes more and more important. In the fifteenth century there is indeed a new reception room reserved for men, called maq'ad.

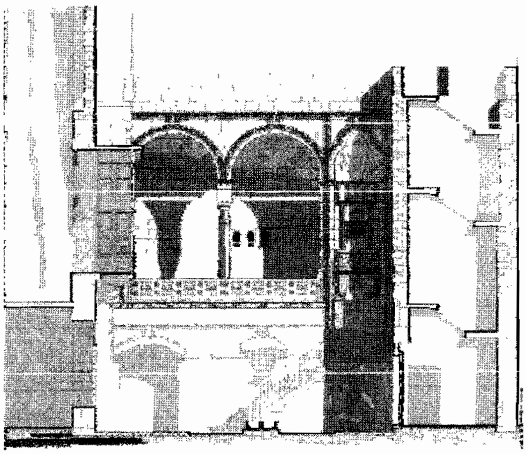


Figure 1. Drawing section of a Maq'ad (Qa'a Zaynab Kathun).

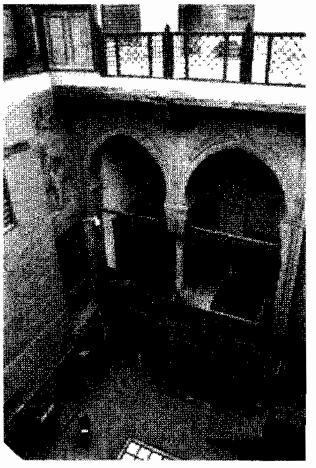


Figure 2. Qa'a Zaynab Kathun Maq'ad.

It opposes, in its architectural design, the qa'a, that was usually closed and not very bright, almost dark, with large balcony that overlooks widely on the court or the garden, across two or more arches, ensuring a moment of openness and breathing more than the ever-present qa'a, which does not escape the foundational role that sets it apart.

In the seventeenth century, as witness to this constant and relentless path, it is added to the ancient loggia above the maq'ad, a new place of rest and reception, a sort of porch, or takhtabush, that is related and organized within the court or the garden.

The takhtabush is a place reserved to men; it is just a place like a portico, on the ground floor, that appeared in XVI – XVII century. Takhtabusch is usually covered by a wooden ceiling supported by stone columns. This place, near the entrance of the house, is opened on the south side of the court, but natural ventilation is also ensured by mushrabiye. It is a space of shadow and light breeze, it plays an important role in the Cairo house, because of its technical and aesthetic function. The court, with its distribution value, has a semi-public vocation.

Figure 3. Constructive detail of the maq'ad.

The house then undergoes significant and important changes that will lead to find the most mature form of the Cairo house, reaching its highest expression in the Ottoman era.

2.1 The Qa'a

The Qa'a is the main room of the all house and, being formal and constituent part of the Cairo house, it is made up of two strongly hierarchic_elements: the central Durqa'a and two or four Iwan, which are lengthwise or widthways located.

The durqa'a is generally a square or rectangular space, with a double-height slightly lowered, compared with the iwan side, from which stands out a lantern, the Marmaq, ensuring the ventilation and lighting of qa'a. On the heart of durqa'a often takes place a fountain has aesthetic role, and that collaborates with refreshment of the room by mixing air and water for increasing the humidity . In fact, the durqa'a with its lantern, while being one of the most important space of domestic architecture, is also an important element to leave convective motions of the air.

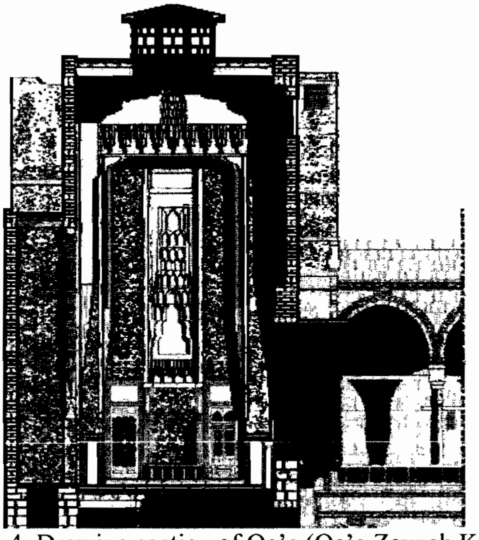


Figure 4. Drawing section of Qa'a (Qa'a Zaynab Kathun).

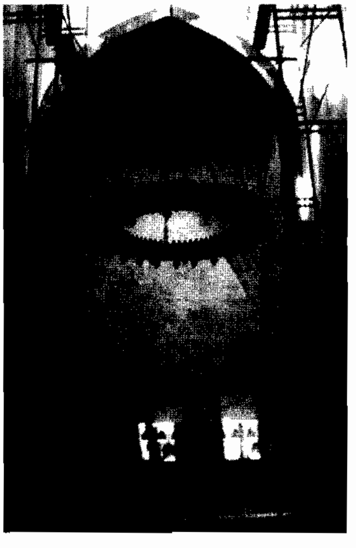


Figure 5. Qa'a al Dardir iwan.

Iwans' side assume the role of relax spaces where you can comfortably attend events organized by the owner of the house.

It is usually located on the ground floor, but it can also be found upstairs, but in this case it is specifically a mu'al-laqa.

The qa'a also has secondary spaces all around: a vestibule, lavatories, a khurustan, some windows (taqat) and it usually has a higher room, called tabaqa.

The mandara is a specialization of qa'a, usually placed on the ground floor, exclusively devoted to men. The presence of mandara carries qa'a to the upstairs. When you find a mandara in domestic architecture, it is often possible to find a qa'a, on the upper floor, for women. Several rooms are attached to the mandara as rest rooms, used by households.

The qa'a generally is illuminated and takes air through a sophisticated wall and a ceiling system. In the central elevated area is placed a skylight roof.

By the end of the Mamelouk period and the biginnig of the Ottoman one, there is an increase of Mandara and qa'a within a single household group, as for example in Bayt Al Suhaymi. This type of house, sumptuously decorated, is emblematic of the complex house in Cairo.

The Maq'ad, or porch, appears in the fifteenth century and represents a new reception room devoted exclusively to men and placed at the ground level of the house. The porch overlooks the courtyard of the house. Its specific function is that of living room or reception room and it is the preferential area of the house, richly furnished with cushions and carpets. This space opens on the garden, through windows and doors with grilles, mashrabiya.

Element of mediation between the road and the house, the maq'ad is the place to wait for guests before accessing the private space of representation of the house: the qa'a.

3 Structure and Systems of the Cairota House and Tectonic Sequences

The systems that allow a balanced relationship between the city and home, between the house and collection devices in the Cairo house, are defined and structured. The skifa, an entry bayonet that allows the opening on the road and especially proper ventilation, however keeping the visual privacy of the same and the court are systems, which contribute together with the malqaf to produce the passive cooling.

In winter blows the harmattan, a north-west aliseo, that blows from the Sahara carrying a large amount of red-dish dust; the cloud of dust, travelling, has a vertical structure that can reach 5000 m in height. In the spring blows khamsin, a warm and dry wind, that comes from the south-east. This is not a monsoon, as it does not blow constantly for long periods of time, but intermittently, it is active during the period between late winter and the start of the summer. The name derives from Arabian khamsun or hamsin, which means fifty, which is the approximate number of days during which it blows, carrying with him sand storms. Less frequently, the khamsin may also blows in winter, as the wind, relatively cold, always carries sand and dust. The orientation of the urban fabric is historically determined by a complex set of cultural religious and functional factors, but we cannot overlook the role of climatic factors.

The environmental and morphological characteristics of the site determine the shape and orientation of buildings. The structural, distributive and formal of the house are influenced by materials and by wooden grids, which protect the intimacy of the house from the outside world and ant the same characterize them aesthetically. By shielding the window, it is possible to reduce the glare of the sun and to regulate humidity of the breeze passing through it.

These techniques of guidance of the main direction of the winds, of shading, of thermal mass and convection currents, set up a consolidated system in the traditional construction of ancient residences, but at the same time would be useful in modern buildings.

Such techniques are also present in the texture of roads drawn from the Fatimid for the foundation of the ancient city, a grid, designed so that only the large Al-Muizz street could have north-south orientation, squarely with the evolution of the sun to get the shade during most of the day. The secondary roads branch off the main one in a east-west direction, remaining constantly in shade, due to their very small section and thanks to the upper floors of the houses, that protrude from both sides above them. The only area exposed to direct sunlight is the intersection of routes with the main artery.

These elements represent a complex architecture and a urban system in which the form follows the technique and technology declines its materials.

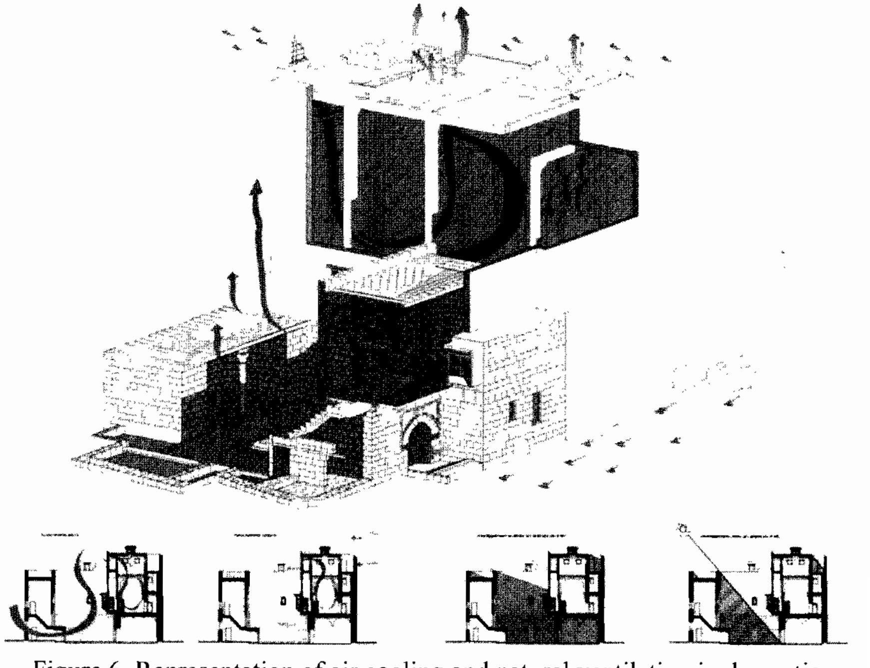


Figure 6. Representation of air cooling and natural ventilation in domestic architecture.

Through proposed architectural solutions, it is possible to ensure flows and currents of natural air in desert areas, using some physics principles.

By tapping wind through badahaug and malqaf, there is an architectural response to the problem of high temperatures in a desert climate. In these areas, therefore, this device has had a great development and it is still a characterizing element of the local architecture

Among the factors that better explain this phenomenon is the northern malqaf channeled the north cool breeze and brings in the qa'a result of pressure from the air, caused by the wind at the entrance.

The Bernoulli-Venturi effect is fundamental to understanding how the differential pressure generated by cur-rents can produce air flow.

In fact, the difference in speed produces a differential pressure that causes a blast from areas with most pressure to those of least pressure; the air heats up inside the qa'a, rises and gets in touch with fresh introduced by malqaf, the wind comes into iwan, rises to the top of dur-qa'a, accelerates by form and escaping from musharahbye.

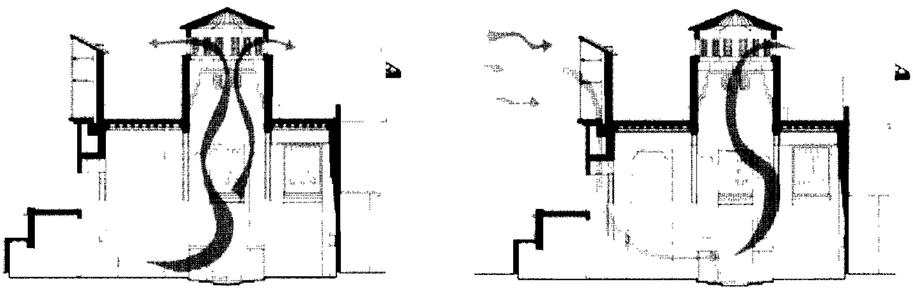


Figure 7. Diagram of operation of Malqaf.

The final product is once again a perfect balance between human needs and qualitative and morphological characteristics of the soil.

3.1 Tha Malqaf System

Malqaf, then, are wind towers, with the opening facing north, devices that can capture the dominant breezes and avoid direct solar radiation penetrates courtyards or the covered premises.

This architectural device directs the wind inside the house, with the aim of providing controlled natural ventilation, which is essential for the comfort of the inhabitants of the house.

The main feature of this device is the structure that stands out from the top of the roof, designed precisely to capture the wind.

For the proper functioning of this component, it is necessary it has a system to close and filter.

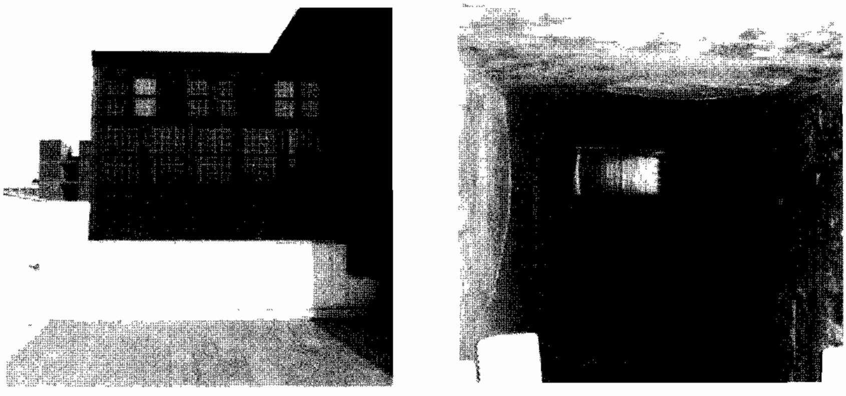


Figure 8 - 9. The Malqaf System.

The malqaf channels inside the prevailing current of air from the north, and then adjusts the flow and access in qa'a, through a series of different openings within it. The air, directed towards the central part of qa'a, is further cooled by a fountain on the floor of durqa'a; when the air becomes warmer it tends to rise upward, it comes out through the high central tower of the room, the shuksheika, which is a hexagonal or octagonal or circular lantern, and fitted with openings on the sides, then it expedites the flow of air masses up and facilitates the expulsion of hot from the tower to the outside.

Finally, the dome of high tower durqa'a, that is a light wood building, allows it to warm up and increase even higher convective cycle, creating air currents inside even when the air is completely stopped.

The malqaf is characterized by:

- a projecting roof, which is a very lightweight wood building. The system, which is absolutely essential in the process of tapping wind, is characterized by two vertical supports on which rests a horizontal beam. This simple element, which supports part of the cover, also defines the main opening towards the north which is the central part of the structure;

- an internal or external masonry conduit that passes through the various levels of construction and that serves to channel and redistribute the wind inside the building. These conduits have shapes and sizes, which vary widely;

- a draft system: the fresh wind cannot penetrate the collector to arrive then in the room unless it is related to a series of openings that allow air, already present in the room and overheated now, exiting through a large and soaring opening, the skylight or mamraq;

A system of monitoring and closing of the wind collector. There may be windows, wooden grates, grills, shutters of wooden doors, depending on the type of collector;

A filtering system: it can be found inside the masonry and outside conduit, a series of small wooden shelves, often staggered, used to purify the wind from insects and sand that characterize the Cairo hot desert wind. They represent real filtering systems.

3.2 The Mashrabiya

In the seventeenth century the opening becomes the window in the wall, but it is screened by a flat or rounded wood carved grate, which will be literally called mashrabiya.

The term "mashrabiya" literally means "place used to store drinks" and it is a small projection in a dim light, that served for support of small jars that needed to stay cool; exposed to light, this kind of balcony is composed of small carved wooden items that are then assembled to create a grid. Over the centuries the term has been extended and large wooden panels, made with this technique, have the same name: mashrabiya.

The mashrabiya is a window element that automatically activates a convective cycle that moves air masses from the zone of high pressure to that of low pressure.

This ventilation phenomenon gives also comfort to the small streets naturally. In the afternoon hours, when the court begins to warm up, the malqaf system returns the air in court as far as the secondary roads, until the evening, thus creating a perfect balance between the different areas of the house.

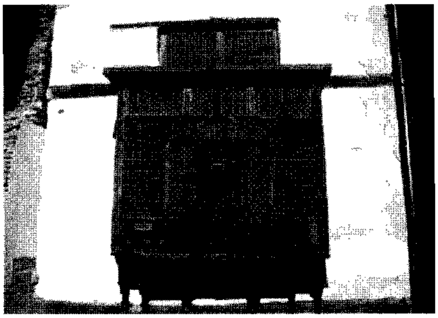
In the Arab system of the house three functions are entrusted to openings: ensure the lighting of the room without the glare effect; ensure ventilation of the room through humidity and impurities filtering system, given by a more or less dense mesh, and allow people, who are in the room, to have a look on road without sacrificing privacy.

The grid can have a large or small mesh depending on the function of the room:

- the larger mesh allows air and light to penetrate; it ranks at the top of the opening, closer to the ceiling of the room;

- the smaller mesh ranks in the lower openings of the complex system, thereby protecting the privacy of women of harem, preventing any kind of indiscreet glance from the outside, but at the same time ensuring a safe and fair view of city life.

The entrance is a real filter between the macrocosm of town and the microcosm of the house, between public and private, a sacred and symbolic ritual joining and separating two worlds that keep a strong antithetical relationship.



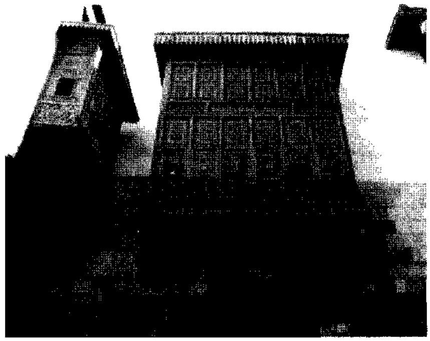


Figure 9. Qa'a al Dardid mashrabiya

Figure 10. Qa'a Zaynab Kathun mashrabiya.

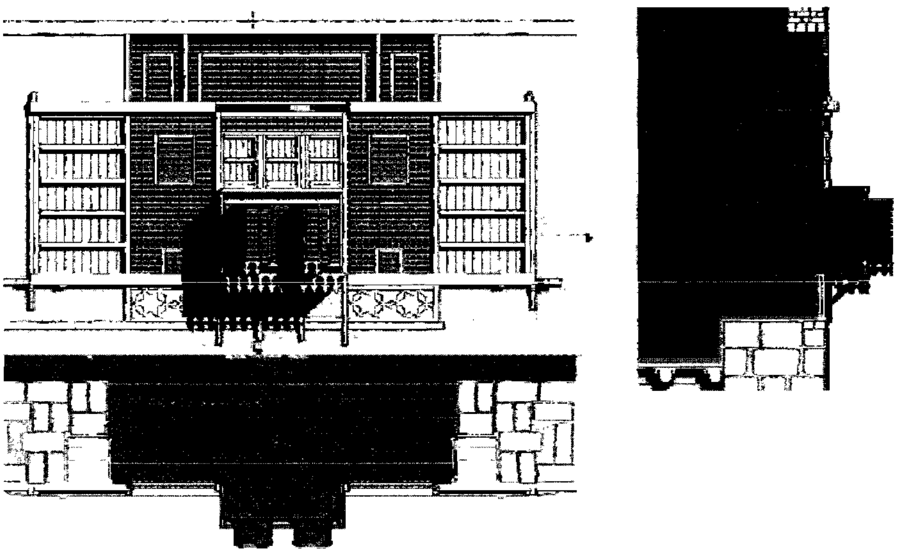


Figure 11. Drawing plant, section and façade of Qa'a al Dardir mashrabyia.

4 Conclusions

The compilation of a manual of good practice is based on the traditional construction, with particular reference to experiences of the History.

The close analysis of the morphological genesis of places and their close dependence on climatic phenomena, have confirmed the need to use again these construction techniques, without changing the distinctive features of the place.

Architecture has its own "natural" order, which is not influenced by history or styles; it is the order of physical function. Styles update, languages change, but the physical principles of behaviour of buildings remain. The perfect functioning corresponds to a right link between the technical possibilities and the ability to read the external environmental conditions.

In architecture it is essential to understand the vocation of a place. This means to study and analyze the traditional architecture and to propose updated morphological and typological solutions, considering the geographical potential and the emergence of new needs.

The environmental issue requires a radical departure from the indiscriminate use of energy.

The project must make choices and then direct them towards the use of local, climatic and materials resources, thus opening new eco-efficiency scenarios. A planning, which takes great care over energy conservation and sustainability, must pay attention to the technical and cultural features of its own environment.

To make an environmental control means to ensure a climatic comfort. Such a control can be made by constructing buildings with thick and solid walls characterized by high thermal mass, so to oppose external conditions to a conservative behaviour of the internal environment, thus causing the thermal inertia.

Another form of environmental control is determined by the correct employment of the building elements: doors, windows, screens. These elements facilitate ventilation and prevent overheating.

These intervention models are based on passive methods, on the one hand isolating the building from the outside by using a high thermal mass construction, thus securing the day heat all through the night, in winter, and the night cool during the day, in summer; on the other hand using openings with special shielding. These openings are sophisticated devices, which enable to create gentle breezes and to maintain the coolness of the rooms. They are always made of wood, a material that does not become red-hot even if it is exposed to sunlight for a long time, therefore the air itself, passing through it (the mashrabiya), does not warm up.

In conclusion I believe that the contemporary design must be able to reinterpret the local building knowledge. To design in Mediterranean contexts today, means to understand the reasons related to the climate, the natural resources and materials of the places.

This does not mean a slavish imitation of the forms of traditional architecture, but rather an innovative and critical reinterpretation of the reasons that for centuries have guided the construction.

References

A.A.V.V., (1991). L'habitat traditionnel dans les pays musulmans autour de la mediterranéè. Annales Islamologiques I.F.A.O.

Badawi, A., (1948). Le dessin architectural chez les anciennes Egyptiens. Le Caire.

Behrens-Abouseif, D., (1989). Islamic Architecture in Cairo: an introduction. The American University in Cairo Press.

Blair, S., Bioom, J. M.: The Art and Architecture of Islam. Yale University Press: Pelican History of Art, Foundising Editor.

Cuneo, P., (1986). Storia dell'Urbanistica. Il mondo islamico, Bari, Laterza.

Fanfoni, G., (2001). Historical and Architectural aspects of the Cairo Mawlawiya. C.I.E.R.A.

Fathy, H.: The qa'a of the Cairene Arabe house, its development and some new Usages for its design concept. Colloque international sur l'histoire du Caire, DDR.

Gawed, A. A.: Enter in Peace: The Doorways of Cairo homes. Annales Islamologiques I.F.A.O.

Givoni, B. GIVONI, (1969). Man, climate and architecture. Elsevier Publishing Company Limited.

Goitein, S., (1983) A mediterranean society, The Jewish Communities of the Arab World as Portrayed in the Documents of Cairo Geniza, Daily Life. Berkeley: University of California Press.

Hanna, N., (1991). Habitat au Caire aux XVII et XVIII siècles. Annales Islamologiques I.F.A.O.

Jaubert, O., (1995). Capteurs de vents d'Egypte. Essai de typologie. Annales Islamologiques I.F.A.O.

Lezine, A. Persistace des traditions pre-islamiques dans l'architecture domestique de L'Egypte musulmane.

Marcais, G., (1965). L'art Fatimide. Enciclopédie de l'Islam, II.

Maury, B. ; Revault, J. : Palais et Maisons du Caire du XIV au XVIII siècle, vol. II.

Olgyay, V., (1981). Progettare con il clima: un approccio bioclimatico al regionalismo architettonico, Muzio.

Pauty, E., (1932). Les Palais et les Maisons d'epoque musulmans au Caire, Memoires publié par les membres de l' Institut Francais d' Archeologie Orientale au Caire. Cairo.

Petruccioli, A., (1984) Tecnology from tradition to innovation in Environmental Design. Roma.

Regette, F., (2003). Traditional Domestic Architecture of The Arab Region. Sharja.

Scnalon, G., (1973). Fustat expedition preliminary report. Back to Fustat. Annales Islamologiques I.F.A.O.

Steel, J., (1988). Hassan Fathy. Academy Editions, St. Martin's Press.

Traditional Ways of Dealing with Climate in Egypt

Mady A. A. Mohamed
Zagazig Department of Architecture, Zagzizig University, Egypt

Abstract

Egypt is occupied in the hot dry/arid climatic zone of the world and part of the great desert (Sahara) of North Africa except for the narrow valley extending linearly around the Nile River across the country (Mostafa, 2001). This climatic zone is characterized by arid climatic conditions with extremely high temperatures and almost no rain and a very high diurnal difference throughout the year (Givoni, 1998). Egyptian people have tried from ancient times to reduce heat impacts and provide shade by several ways (traditional passive cooling devices) in order to have the feel of thermal comfort.

The passive devices such as; Courtyard, Malkaf, Mushrabiya, Salsabil, Shuksheika, Taktaboosh, are marked by perfect responsiveness to the climatologically pressures they endure. During a field trip in Egypt, a number of existing traditional buildings around the country have been visited. In exploring these precedents, it became evident the use of passive cooling devices as natural environmental controls was effective. Moreover, the richness of the architecture had evolved as a result of their application. This paper demonstrates the importance of these passive cooling devices as environmental mediators, creating thermally pleasant living conditions. This is done through reviewing, classifying and analyzing their design characteristics.

Keywords: *Passive Cooling, Traditional Measures, Low Energy Architecture, Thermal Comfort, Hot Arid Zone*

1 Introduction and Research Problem

The architectural designer should attempt to perform the control task by passive controls (i.e. by the building itself), and resort to active controls (i.e. by energy-based heating or cooling systems), only when the passive controls cannot ensure comfort. This approach is suggested for three main reasons (Hui, 1997):

• **Economic** - the installation of mechanical equipment means a capital cost and also the recurrent cost of energy consumed and system maintenance;

• **Ecological/environmental** - passive buildings impose the least load on the ecosystem, consume less energy and should produce less waste; and

• **Aesthetic** - passive buildings are more likely to be in harmony with their environment.

People have tried from ancient times to adapt their buildings with the harsh climate in the hot-dry zone through reducing heat impacts and providing shade. In a previous work (Mohamed, Osman, & Gado, In review), found that traditional ways of dealing with climate such as earth Architecture began to decline in Egypt with the introduction of concrete construction. Conversely, in Europe and America there have been a number of new developments in earth Architecture technology. This in turn has lead to an increase in its popularity as a more sustainable alternative to accepted mass construction techniques. Also, during the subjective assessment of this work, the authors found that the majority of people in Egypt do not have the knowledge and the know-how of these intelligent ways. The current work tries to present these ways, their characteristics, and how they can provide occupants with comfort.

2 Research Objectives

The current research mainly aims to review, classify and analyse the passive cooling devices as environmental mediators. This is achieved through the following objectives;

Review the previous work and the literature review;

Find and develop an appropriate classification to the environmental mediators;

Analyse and set out simple guidelines on using these mediators.

3 Context

According to Koppen's climatic classification (Encyclopaedia Britannica (UK) Ltd, 2002), Egypt is located in the hot-dry zone between 23° and 32° latitude. Where, most of the tropical, true desert climates of the Earth occur between 15° and 30° latitude. According to Givoni (Givoni, 1998), this zone is characterised with aridity and clear sky which promote solar heating during the day and radiant loss during night (Horizontal global radiation reaches 1000 W/m^2). Temperatures are high, with monthly means in the range of 21°C –32 °C. (Encyclopaedia Britannica (UK) Ltd, 2002) where, actual surface temperatures may reach 82 °C on dry sand under intense sunshine. Also, diurnal differences in temperatures are extreme and could reach 35 °C. In most low- latitude deserts, cloud cover is uncommon (fewer than 30 days per year have clouds in some areas). Precipitation amounts are mostly in the range of 0–25 centimetres (Encyclopaedia Britannica (UK) Ltd, 2002). In addition that, dust storms are a common feature in the hot dry regions and particularly during the afternoon. All the above weather characteristics lead to a very harsh environment that needs a very cautious and professional ways of dealing with it.

4 Previous Work

Many attempts have been made aiming to look into traditional ways of dealing with climate in the hot dry zone. Oliver (Oliver, 1997) (Oliver, 2003) presented and discussed the main features of traditional buildings in Egypt in terms of structure, materials and styles. He also mentioned some passive ways that have been adopted by the Egyptians in their buildings such as; the mashrabiya, hosh, durqa'ah, and the courtyard. Fathy (Fathy, 1986), discussed the principles and presented examples of natural energy and vernacular architecture in hot arid climate. He categorized the passive techniques in three main categories based on three main strategies; passive solar, natural ventilation, and evaporative cooling. The environmental performance of Government primary schools in Egypt was investigated and found very poor (Mohamed, Gado, & Unwin, 2005). In a following study (Mohamed, 2009), Mohamed confirmed that using some appropriate passive strategies and measures within the façade skin could enhance the thermal performance of the case studies by 13 %. Mohamed et al. looked into the technical and social factors that led to the decline of earth Architecture in the Sahara desert (Mohamed et al., In review). The results suggested a strong possibility of reusing earth Architecture from the environmental point of view. However, a number of limitations were identified, including; durability, buildability and the attractiveness of the mud architecture to the locals. Filippi, F. (Filippi, 2006) analysed the main characteristics of the urban pattern and buildings' typologies of the traditional earth architecture in two settlements of El Dakhla oasis. Iscandar (Iscandar, 2006) presented some neo-vernacular case studies of Michael Graves, Hassan Fathy and Ramses Wissa Wassef. Iscandar suggested that those examples show respect to the site, the natural environment, the climate and was successful in mixing traditional techniques with contemporary requirements.

5 Methodology

Two types of studies were employed in the current research. The analytical study based on literature review and previous work, and the field study based on two scientific trips. These trips covered wide areas of the country such as the capital city of Egypt "Cairo", representing the semi desert region", and four oasis of the western desert "Al-Baharia, Al-Farafra, Al-Dakhla, and Al-Kharga, representing the desert climatic region". It was not possible to monitor all the cooling devices in this work. However, some measurements in traditional and contemporary buildings were conducted to investigate the performance of the mud material against concrete, and the performance of traditional design of houses.

Figure 2: The author during measuring the air temperature inside AL-Souhimi house

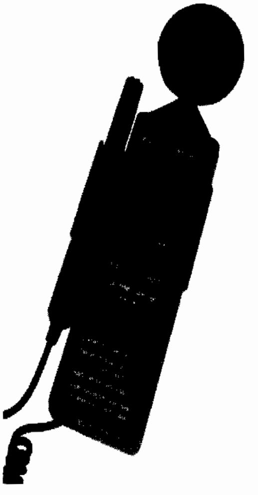


Figure 1: The 4 in 1 instrument

In order to assess the cases studies objectively - in terms of air temperature, Humidity, sound and lighting -, the 4 in 1 digital instrument was used (Figure 1). In this paper, only the air temperature measurements are employed and analyzed for the comparison purpose. Three case studies are located in the same area of Al-Farafra oasis – western desert of Egypt- and one case study is located in Cairo City were under investigation.

6 Achieving Thermal Comfort in Hot Arid Zone

There are several factors that control human comfort and make up what is known as the 'human thermal environment'. Mohamed (Mohamed, 2009) conducted a wide review on these factors and found that they can be divided into two main categories; factors related to the individual and other factors related to the environment. The human factors include; clothing level and activity level. While Environmental factors "which could be lie partially under the architect control" include; air temperature, Mean Radiant Temperature (MRT), relative humidity, and air velocity (McMullan & Seeley, 2007). According to Givoni (Givoni, 1998), there are several design details that affect the thermal performance of buildings in hot-dry zone which in turn affect the human thermal comfort. These are; i) Internal and attached open spaces, ii) Orientation of main spaces and windows, iii) Window size, location, and details, iv) The layout of the building's plan, v) Shading devices, vi) The colour of the building's envelope, vii) Building's materials, viii) Vegetation around and inside the buildings. Also, Ventilation devices, roof construction, and humidification strategies can be added to the above list (Mohamed, 2009). The passive cooling devices that can enhance the state of thermal comfort inside buildings are (Fathy, 1986; Givoni, 1998; Oliver, 1997, 2003):

Sahn /hosh: The Courtyard

Malkaf: A wind catcher.

Nafora: The Fountain

Shesh: The Venetian blinds

Taktaboosh: A covered outdoor sitting area at ground level.

Mushrabiya: open wooded lattice screens.

Rasha/taka: A small opening at an upper level of a wall

Salsabil: A water-fed cooling plate

Shuksheika: The vented or fenestrated lantern over the main hall.

The current work classifies the traditional passive techniques based on Fathy's classification and Givoni's affecting factors on thermal performance of buildings. This helps to devise an integrated classification system for the traditional passive ways of dealing with climate in Egypt. Although some of these measures have an impact on more than one factor that affect the thermal performance of buildings, this study classifies each one of them with regard to one factor which has the greatest impact on it. Figure 3 illustrates this classification.

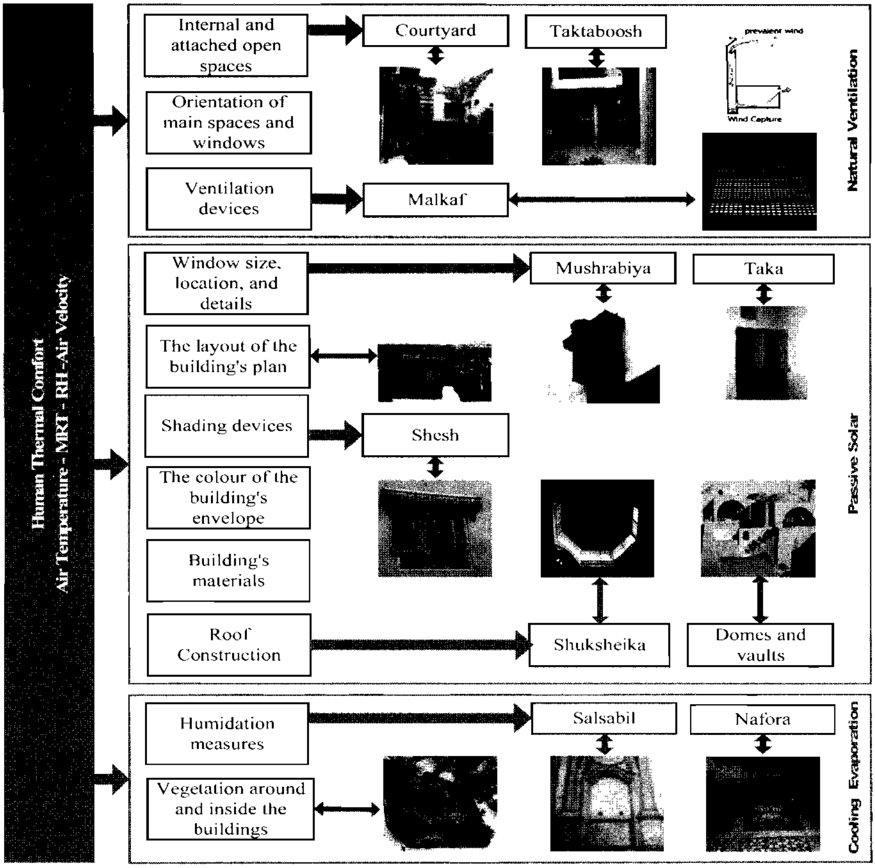


Figure 3: The integration between the traditional passive measures/factors affecting thermal performance of buildings/factors affecting Human thermal comfort, by the author

7 Passive Cooling Devices

7.1. Internal and attached open spaces

Shaded open spaces are very preferable in the hot dry zones. They can reduce the daytime air and radiant temperatures at the occupied space.

7.1.1 The Courtyard

People used to open their houses onto a private internal open space that visually and acoustically separated from the outside called Sahn "The courtyard" (Figure 4) (Afify, 2002). The courtyard helps in maintaining cooled indoor temperatures. With some modifications to the courtyard such as using water and vegetation in its landscape, the benefits can be maximized and particularly the benefits of the thermal performance.

The phenomenon of the stack effect is employed in the courtyard to enhance thermal comfort by producing cool breezes (Wazeri, 2002). In the evening, the warm air of the courtyard, that was heated directly by the sun and indirectly by the warm buildings, rises and is gradually replaced by the cooled night air from above. This cooled air accumulates in the courtyard in layers and leaks into the surrounding rooms cooling them (Oliver, 1997). In the morning, the air of the courtyard, which is shaded by its four walls, is heated slowly and remain cool until late in the day when the solar radiations penetrate the courtyard (Fathy, 1986). There are three factors affect the capability of the courtyard (Figure 5) (Wazeri, 2002).

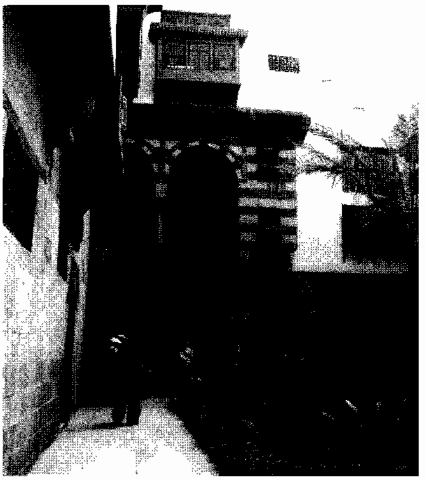


Figure 4: Courtyard of al-Souhimi house, Cairo

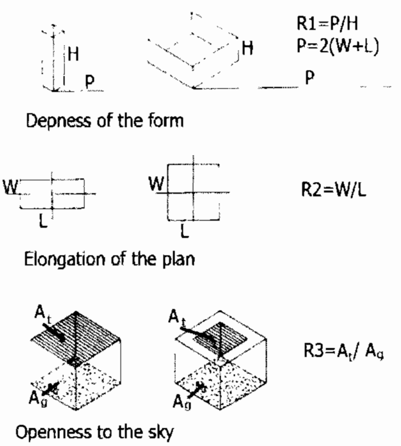


Figure 5: The geometric dimensions of the courtyard (Wazeri, 2002)

The deepness of the form (R1), which is the ratio between the courtyard's perimeters to the height. (R1 should not be less than 3)

The elongation of the plan, which is the ratio between the length to the width of the courtyard. The rectangular shape of the courtyard's plane is better than the square one. He also recommended that the ratio between the length, width and the height must be not less than 1:2:1.4.

The openness to the sky, which is the ratio between the area of the top to the area of the bottom of the courtyard.

He added that the best orientation to the courtyard is by orienting the long side to the east west. A recent study (BMT Fluid Mechanics, 2007), concerned by the effects of surface openings on the air flow caused by wind in courtyard buildings, suggested that openings should be in the upwind and downwind surfaces to achieve the max air velocity. It added that the larger the upwind surface openings, the more the velocity increases significantly.

7.1.2 The Takhtabush

To ensure the air flow, a covered area at the ground level (The takhtabush) was introduced to the traditional house (Figure 6). It is located between the courtyard and the back garden, opening completely onto the courtyard and through a mashrabiya onto the back garden which ensure a steady flow of air by convection (Fathy, 1986). Since the back garden is larger and thus less shaded than the courtyard, air heats up more than in the courtyard. The heated air rising in the back garden draws cool air from the courtyard through the takhtabush, creating a steady cool breeze. (Fathy, 1986)

Figure 6: The Takhtabush in al-Souhimi house, Cairo

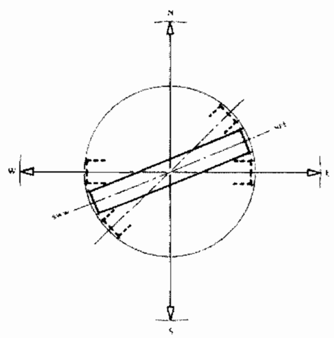


Figure 7: The optimal orientation with regard to the sun and the prevailing winds (Fathy, 1986)

7.2 Orientation of main spaces and windows

In such climate, the sun is the major source of heat and hence the position of the sun regarding any site is very important. The main criterion of choosing the appropriate orientation is to minimize the penetration of the sun radiation in the summer and maximize it in the winter. However, the prevailing winds can not be denied, especially in the hot season, but it could come as a second criterion (Givoni, 1998). Previous studies (Fathy, 1986), (Givoni, 1998) found that, in Egypt, the best orientation with regard to the sun factor is the east west, While, it is the north to south with regard to the prevailing winds. Fathy (Fathy, 1986) solved this problem by bisecting the angle between the two optimal orientations (Figure 7). He added that by using other ways to ventilate the building e.g. the malqaf or wind catcher, the designer can concentrate on orienting the building with respect to the sun factor.

7.3 Ventilation devices

The Malqaf is one of passive ways to catch the desirable wind, which means wind catcher. According to Fathy (Fathy, 1986), it is rising higher than the building with an opening facing the prevailing wind. It captures the cooler and stronger wind from upper boundary layers. Under the pressure difference effect, it blows the air down inside the building. The malqaf is also useful in reducing the sand and dust because the captured wind from above the building contains less solid material than the wind at lower heights. Moreover, much of these solid materials, if any, are dumped at the bottom of the malqaf. It is also very useful in the dense cities, where the wind velocity at the level of the windows is very slow. It can also work as a wind escape; if its opening faced the opposite direction of the prevalent wind (Figure 8) (El-Wakeel, 1989).

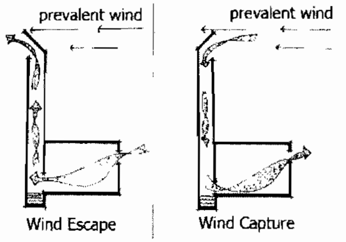


Figure 8: The Malqaf can work as a wind escape or wind capture according to its direction (El-Wakeel, 1989)

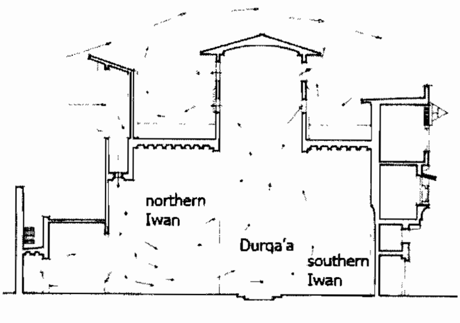


Figure 9: Section through the Qa'a of Muhib AlDin (Fathy, 1986)

The excellent example of the Qa'a of Muhib AdDin in Cairo "the main hall of a house or building, comprising a dorqa'a "central hall" and two iwans "side halls"", (Figure 9) demonstrates the operation of the malqaf as a part of a complete ventilation system. According to Fathy (Fathy, 1986), the malqaf is placed in the northern iwan to catch the desirable air and channels it down. The system of acclimatization was developed depends primarily on air movement by pressure differential and convection. The ceiling of the dur-qa'a rises above the ceilings of the iwan and includes windows in its upper structure. In addition, to provide the space with diffused and agreeable lighting, these openings provide the required air escape. By increasing the size of the malqaf and suspending wetted matting in its interior, the airflow rate can be increased while providing effective cooling. Air can be directed over a Salsabil, a fountain or a basin of still water, to increase air humidity.

7.4 Window size, location, and details

Reviewing vernacular architecture in hot dry climate suggested small windows with total area of about five to ten percent of the floor area (Givoni, 1998). However, large windows can be provided with special design details. Insulated controllable shutters and screens to prevent insects in certain periods could be added to the windows. Figure 10 shows two types of modifications on windows. The first is a wooden lattice screen as an external layer of the windows and the second is an aluminium mesh screen fitted on the glazing "the internal layer"

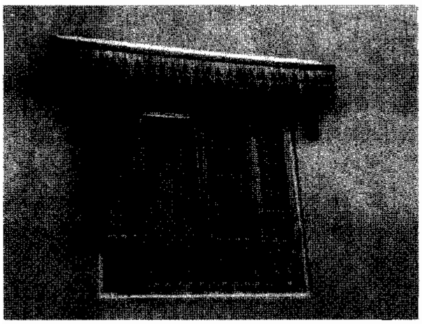


Figure 10: Modifications for windows, Ramsis Wesa Nassef Centre, Giza, Egypt

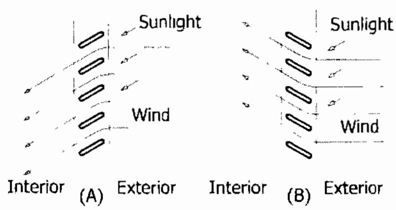


Figure 11: The movable Venetian Blind (Fathy, 1986)

7.4.1 Shesh

The shesh can be added directly to the window. The blind is made of small slats, about 4-5 cm wide, closely set in a wooden frame. The slats are often movable so its angle can be changed. This feature of adjustability is very useful in regulating solar radiation and wind flow into spaces. The sun's rays can be blocked out without obstructing the breeze. When the blinds are drawn, they completely obstruct the view to the outside as well as considerably dim the light reaching the interior .

7.4.2 Mashrabia

The name of mashrabiya is derived from the Arabic word "drink" and originally meant "a drink place" (Figure 12). According to Fathy (Fathy, 1986), this is a cantilevered space with a lattice opening, where small water were placed to be cooled by the evaporation effect as air moved through the opening. The mashrabiya can do five functions according to its design. These functions are to control the passage of the light, to control the air follow, to reduce the temperature of the air current, to increase the humidity of the air current and to ensure privacy (Wazeri, 2002).

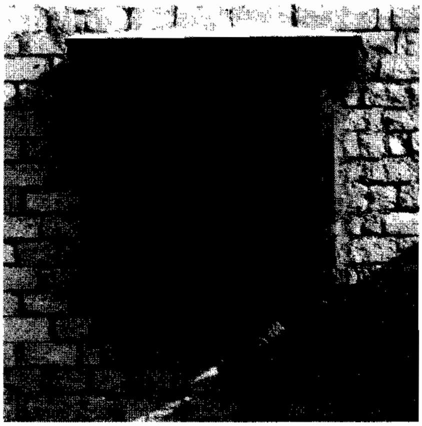


Figure 12: Exterior view of a mashrabiya, Hassan Rashed house, Egypt (Steele, 1988)

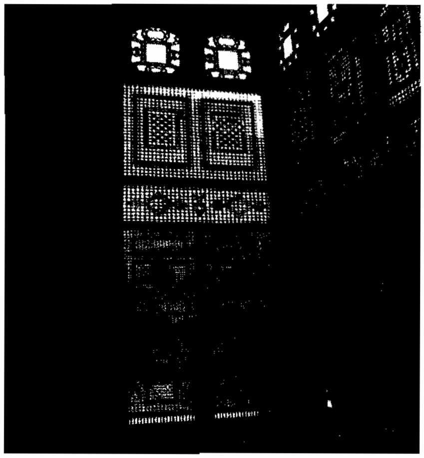


Figure 13: Internal view of a mashrabiya in al-Souhimi house, Cairo

The sizes of the interstices and the balusters of the mashrabiya are adjusted to intercept direct solar radiation using a lattice with small interstices and to allow air flow using a lattice with large interstices (Fathy, 1986). Therefore, large-interstice pattern is used in the upper part of the mashrabiya to allow the air flow while small interstices is used in the lower part of the mashrabiya to prevent the direct sunrays (Wazeri, 2002) (Figure 13). Also, the dimensions of the mashrabiya can be increased to cover any size of opening, even to the point of filling up the entire facade of a room (Steele, 1988).

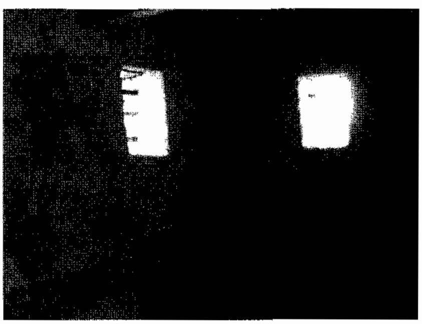


Figure 14: The taka under the roof level, in Al-Qasr house, Al-Dakhla Oasis

Figure 15: The compact urban design in the old areas, Al-Dakhla Oasis

7.4.3 The Taka

Old houses in Egypt included “Rusha” or “Taka” which is higher than the window and facing it. This causes different speed in the air movement and in turn causes the cross ventilation. Thus, the air will be sucked down across the occupants (Figure 14).

7.5 The layout of the building’s plan

The surface area of the external envelope of the buildings should be small as much as possible to minimize the heat flow into the building during the daytime. This could be achieved in a compact urban design (Figure 15). According to Givoni (Givoni, 1998), the ventilation rate, during the day, must be kept to the minimum required for health (about 0.5 air change per hour) in order to minimize heating up the internal spaces by the hotter outdoor air. He added that, during the night times when the outside cool air becomes desirable, higher ventilation rate will be required. This could be achieved through employing some techniques such as using terraces with shutters and openable glazing along the lines of the external walls.

7.6 Shading devices

Internal devices such as Venetian blinds, roller blinds, and curtains, are not preferable in such climate since they intercept the solar radiation after transmission through the glazing and heat up the space (Fathy, 1986). Therefore, the outer shading devices become essential. The size and the position of the shading devices are placed to block the solar radiation in the summer session and to allow the solar radiation in the winter session (Figure 16).

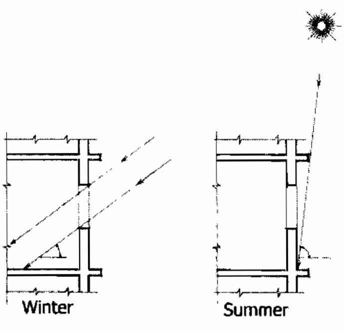


Figure 16: Small overhang shading device on the southern façade (Fathy, 1986)

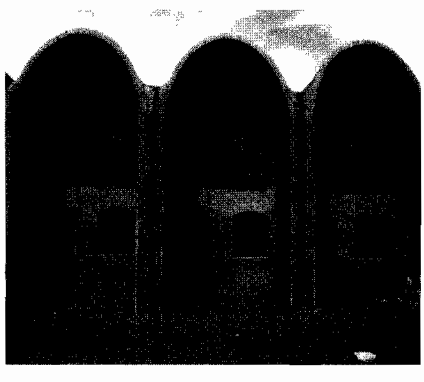


Figure 17: Frame shading device, Hassan Fathy palace of art “paris”, Egypt

Shading devices could be in the form of; fixed and movable devices. Fixed shading devices could be in the form of horizontal overhang, vertical fins, and a combination of the overhang and the fins "frame". Horizontal overhang could be used on the southern windows extending on both sides of the windows. Vertical fins are more effective than horizontal overhangs on the eastern and western windows (Fathy, 1986). Figure 17 shows an example of a frame shading device. Movable external shading devices are more effective than the fixed ones, since it can be employed to prevent or admit solar rays according to the weather conditions but it is too much expensive in comparison with the fixed devices.

7.7 The colour of the building's envelop

Light colours of envelop can reduce the heat gain significantly in comparison with the dark colours. However, in desert regions of the hot dry climate with the light colour and the lack of vegetation, the problem of the glare becomes very common (Givoni, 1998). To solve this dilemma, a required careful design of some building projections and a selective choice of colours with adding landscape vegetation as mush as possible is essential. Figure 18 shows different types of projections with darker colours on the eastern façade of an old house in Cairo. By this ways, these projection elements can reduce the glare as they are the most exposed elements to the outside. The building surfaces behind them can be kept in light colours as they in direct contact with interiors.

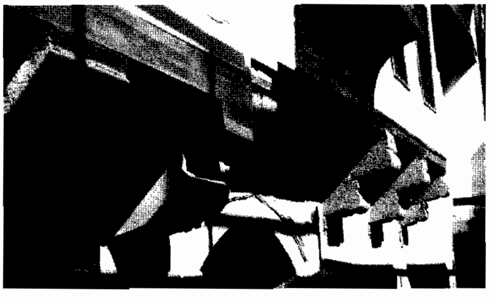


Figure 18: Different types of projection elements, Cairo

7.8 The choice of building's materials

In the hot dry climate, high resistance and high heat capacity of the envelope elements is necessary. High resistance minimize the conductive heat flow into the building mass during the daytime (Givoni, 1998). Actually, this can also reduce the rate of cooling the building mass during night time, but it could be overcome by admit night-purge ventilation strategy. High thermal mass has been achieved traditionally by thick walls that made of heavy materials such as stone, bricks, adobe, and mud. Today the availability of modern insulating materials make it possible to achieved indoor thermal comfort with thinner walls than in the past.

7.9 Roof Construction

The roof surface is always exposed to the sun. Therefore, the outer surface of the roof is heated up by absorbing solar radiation (Givoni, 1998). The roof then transmits this heat to the inner surface, where it raises the temperature of the air in contact with it by conduction. Consequently, the shape of the outer surface of the roof and the thermal resistivity of its materials are very important.

7.10The Shuksheika

People used to shade the roof more naturally by arranged the roof into open galleries and lightweight roof covers (Fathy, 1986). These open areas and roof have the double function of shading the roof and providing cool air. Hot air can escape from the lower floors during the day and cool air descends during the night. This method was developed to be the Lantern (Figure 19) (Wazeri, 2003), which is an opening in the roof covered by a combined of wood and glasses.

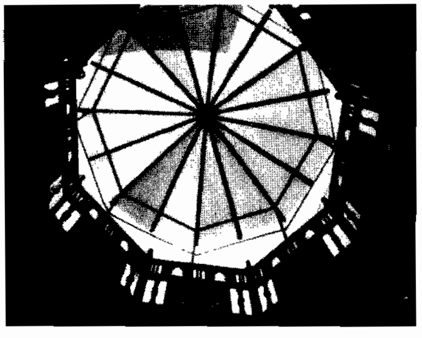


Figure 19: The lantern of a house in Rasheed City, Egypt (Wazeri, 2003)

Figure 20: Dome and vault in Halawa House, Elagami, Egypt (Wazeri, 2003)

7.11Domes and Vaults

One of the most useful ways to adapt with the hot climate is pitching or arching the roof. This is well known in the traditional architecture by domes (the form of a hemisphere) and vaults (the form of a half-cylinder) (Figure 20) (Fathy, 1986). These roof shapes have many advantages. Firstly, the height of the space is increased, and thus sending the warm air that rises or is transmitted through the roof far above the heads of the inhabitants. Secondly, for most of the day, part of the roof is shaded from the sun (El-Wakeel, 1989). At which time it can act as a radiator, absorbing heat from the sunlit part of the roof and the internal air, and transmitting it to the cooler outside air in the roof's shade.

7.12 Humidification measures

In the hot arid zones, providing buildings with water is very important strategy that increases the humidity to promote the thermal comfort. Therefore, the people in Egypt tried to remain in contact with it as long as possible during the hot season.

7.12.1 The Fountain

The fountain plays a role equivalent to the fireplace in the temperate zones, although one is used for cooling and the other for heating. It is an architectural feature occupying a privileged place in the house plan (Fathy, 1986). It is placed in the middle of the courtyard with the living spaces opened onto it. It always has a symbolic form, square in shape, with the inner basin in the form of an octagon or a decagon (Figure 21) (Abdel Karem, 2002). The fountain display its water and mixing it with air to increase the humidity.

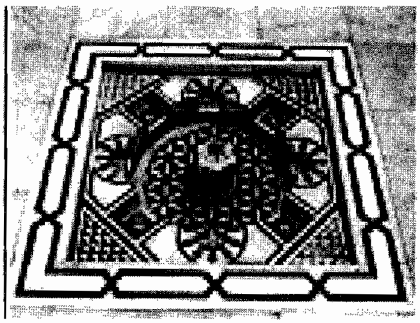


Figure 21: The fountain in Shahera house, Egypt (Abdel Karem, 2002)

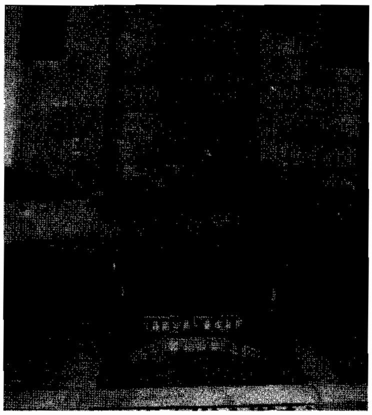


Figure 22: The Salsabil in Al-Souhimi house, Cairo

7.12.2 The Salsabil

In places, where there was not enough pressure to permit the water to spout out of the fountainhead, architects replaced the fountain with the salsabil (Fathy, 1986). The salsabil is a marble plate placed at an angle to allow the water to drop over the surface, thus facilitating evaporation and increasing the humidity of the surrounding air. The water then flows into a marble channel until it reaches the fountain in the middle of the courtyard. (Figure 22).

7.13 Vegetation around the buildings

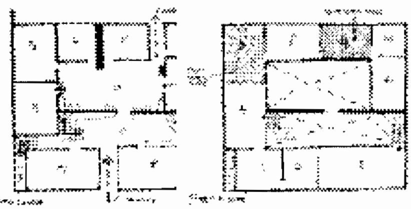
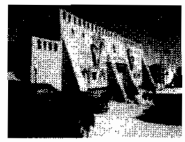
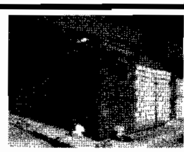
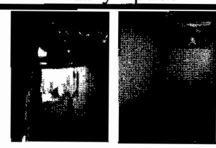
Maximizing the amount of vegetation inside and outside buildings affects positively the thermal performance of buildings. Since vegetation can do the followings; shading of the external surfaces of the building, shading the opened spaces, reducing and filtering the dust in the air, and elevating the humidity level (Givoni, 1998). Specific types of trees and locations should be selected to suit the climatic context. Suitable trees that can be planted around the buildings in order to decrease wind speed from the south that always comes with dust and sand such as Casuarina, Eucalyptus, Abizia, Acacia Fanesiana, and acacia Arabica (Institute of Environmental Researches and Studies (IERS), 1992).

8 Field Measurements

Two field studies were conducted. The one was conducted for three buildings represent the three different trends of construction in the western oases; a concrete house "concrete skeleton and blocks wall", an old mud house in the old area of Farafra and a new mud house built in the new area of Farafra. The concrete house is a normal skeleton concrete with white lime bricks/burned clay bricks. The two mud houses are constructed from the local materials. The bearing walls are the structure system of the buildings with clay bricks. The roofs were constructed from the palm trunks as the main bearing elements and then they were covered by rows of palm leaves followed by a layer of mud bricks then finished it by paste of clay. One of them (the new mud house) Badr's art & sculpture museum is one of the few contemporary vernacular architectural buildings in Egypt. His owner is a sculpture artist called Badr Abdel Moghny. The building consists of two stories including mainly exhibition large spaces, two central courtyards, services spaces, and open terraces in the first floor. The height of the building is relatively high. The four sides of the museum are free with small openings in the facades. The other one (the old mud house) consists of one floor plan with a relatively low height and small spaces. Only one side is free with one small courtyard. All the measurements were conducted between 12.0 pm to 1.0 pm on the 18th of October. Table 1 presents the measurements of the air temperature and their location inside the three buildings in addition to some pictures of them.

On analysing the temperature measurements of the three houses, it is obvious that the performance of the new mud house is the best while the old mud one is the worst. Unexpectedly, the concrete house is better than the old mud house. This is could be because the new mud house employs efficiently the passive strategies and measures (natural ventilation, night purge ventilation, thermal mass, ...etc) while the old mud house does not apply them effectively. This is confirmed that the mud as a building material is not performed as well as we may think.

Table 1: Field measurements inside the first three cases in Farfra oasis

Building/ Place	Monitored space	Temperature °c	Plans/pictures
Badr's Art & Sculpture Museum	GA - Exhibition	30.7	
	GB - Exhibition	30.1	
	GC - Courtyard	31.2	
	GD - Courtyard	29.6	
	GH - Shop	29.6	
	GI - Exhibition	29.1	
	GJ - Exhibition	28.8	 
	FD - Exhibition	31.3	
	FE - Exhibition	30.5	
	Average	**30.10**	The courtyard Main Elevation
House 1 - Concrete construction	Family Space	31.7	 
	Bedroom/Living	31.6	
	Courtyard	30.7	
	Toilet	32.4	
	Kitchen	33.2	
	Average	**31.92**	Corner Elvation Family Space
House 2 - Old Adobe construction	Kitchen	33.1	 
	Bedroom	32.7	
	Living	30.8	
	Hall	31.7	
	Average	**32.075**	Elevation courtyard / bedroom

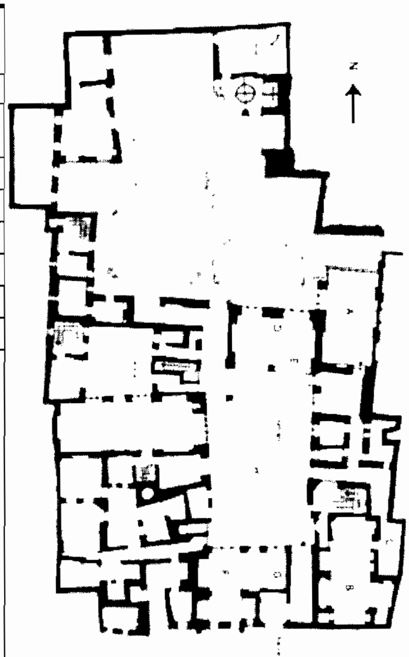
The second field study was conducted inside Al-Souhimi house in Cairo. It is considered one of the few witnesses on the intelligence of the traditional architecture in the east in general and in Egypt in particular. The real ingenuity of their designs lies in the structural modifications that were introduced into traditional spaces (like the qa'a, maq'ad, takhtabush, etc.) to produce independent spatial units adapted to climatic conditions [24] (Table 2). This house contains many of traditional passive measures, if not all known ones, such as the thermal mass, malqaf, the mashrabiya, the courtyard, the takhtabush, the fountains, and the lantern. The bearing stone walls are the structure system for this house. The roofs were constructed from the temper beams followed by temper sheets with additional layers of floor finishing with few spaces covered by lantern.

Table 2: Field measurements inside Al-Souhimi house

Building/ Place name	Monitored space	Temperature °c
Al-Souhimi House	A - Qa'a	29.1
	B - Guest Space	30
	C-Intermediate	30.3
	D - Maqiad	29.7
	E - courtyard	25.7
	F -	27
	G -	27.4
	H - Courtyard	28

A view from the Takhtaboush to the Courtyard

The courtyard



Ground floor of Al-Souhimi house

On analysing the temperature measurements of the different spaces inside Al-Souhimi house, it is obvious that the performances of the surrounded spaces to the courtyard are better than the outer spaces. Also, it could be asserted that the Takhtaboush (D and E) is playing an important and essential role in cooling the building since the temperatures inside it are the lowest. This confirms the importance of accompanying the two passive measures (The courtyard and the Takhtaboush) when be employed in the passive design of buildings.

9 Conclusions

This paper was concerned with traditional ways that modern building should adopt to respond to the hot dray climate. The paper presented the main characteristics of the hot dry zone and climatic considerations to achieve thermal comfort inside buildings. Traditional ways of dealing with climate in Egypt were presented. The main outputs of this work could be summarized in the following points:

The main thermal consideration for such climate should achieve; slow rate of indoor heating during summer daytime, fast rate of indoor cooling in summer evenings, minimizing dust penetration, good ventilation in the summer evenings, and higher indoor temperature relative to the outdoors in winter;

Important design details that architect should consider are; building's materials, orientation, shading devices, building's external envelope, and openings, the internal and attached open spaces, water and vegetation around and inside the buildings;

Traditional ways of dealing with climate in Egypt can be categorized into eleven different factors that affect thermal performance of buildings under three main strategies (natural ventilation, passive solar, and evaporative cooling)

The mud as a traditional material is not performed as well as we may think all the time. While it is more important to use the local materials in combination with the appropriate passive design strategies and measures;

The courtyard is an efficient device in cooling the buildings. However, it could work more efficient if accompanied with the Takhtaboush.

10 Further Work

The outputs of this paper will inform the choosing of the appropriate measures to be investigated and modified in the future work. This will be done through conducting detailed physical environmental measurements and in deep computational analysis. These processes will aid the research to design/develop contemporary, environmentally responsive measures to be employed afterwards to enhance the thermal performance of specific case studies.

References:

Abdel Karem, N. (2002, 2-4 February). The architectural elements in the architecture of Hassan Fathi, an approach for desert development. Paper presented at the Urban development in the desert and its building problems, Alriad, Saudi Arabia.

Afify, H. (2002, 2-4 February). Courtyard house as a prototype in desert environments. Paper presented at the Urban development in the desert and its building problems, Alriad, Saudi Arabia.

BMT Fluid Mechanics. (2007). Large boundary layer wind tunnel. Retrieved 18th January, 2008, from http://www.bmtfm.com/?/335/219/123

El-Wakeel, S. a. S. M. (1989). The climate and the hot zones architecture. Cairo: Alam Alkoteb.

Encyclopaedia Britannica (UK) Ltd (Ed.) (2002) (Deluxe eddition CD-ROM ed.). Encyclopædia Britannica, Inc.

Fathy, H. (1986). Natural energy and vernacular architecture: Principles and examples with reference to hot arid climates. London: University of Chicago Press

Filippi, F. D. (2006). Traditional architecture in the Dakhleh Oasis, Egypt: space, form and building systems. Paper presented at the PLEA2006 - The 23rd Conference on Passive and Low Energy Architecture.

Givoni, B. (1998). Climate consideration in building and urban design. New York - USA: Van Nostrand Reinhold.

Hui, S. C. M. (1997, 23 Mar 2000). Passive design in hot climates. Climatic design of buildings - An overview Retrieved 26/08/2008, 2008, from http://www.arch.hku.hk/~cmhui/teach/65156-7g.htm

Institute of Environmental Researches and Studies (IERS). (1992). Basics Environmental design of fundamental schools guide: Hot dry region. Retrieved. from.

Iscandar, M. F. (2006). Neo-Vernacular architecture in Egypt. Paper presented at the 3rd international conference ArchCairo 2006.

McMullan, R., & Seeley, I. H. (2007). Environmental science in building (6th ed. ed.). Basingstoke: Palgrave Macmillan.

Mohamed, M. (2009). Investigating the environmental performance of Government primary schools in Egypt: with particular concern to thermal comfort. Unpublished PhD thesis, Dundee University, Dundee.

Mohamed, M., Gado, T., & Unwin, S. (2005). The environmental performance of classrooms in Egypt: a case study from El-Minya governorate. Paper presented at the The Second Scottish Conference for Postgraduate Researchers of the Built & Natural Environment (PRoBE 2005). from

Mohamed, M., Osman, M., & Gado, T. (In review). Investigating the revitalisation of the Intelligent Earth Architecture of the Sahara: A case study from the western desert of Egypt. IBI.

Mostafa, A. (2001). Climatic evaluation of Semi-attached residential units. Unpublished unpublished report. Lund University.

Oliver, P. (1997). Encyclopaedia of vernacular architecture of the world (Vol. 2). Cambridge: Cambridge University Press.

Oliver, P. (2003). Dwellings. New York: Phaidon Press Limited.

Steele, J. (1988). Hassan Fathy. London: Academy editions.

Wazeri, U. (2002). Practices on environmental architecture - the sunny design for the interior court - Studies on Cairo and Toshki. Cairo: Madboli.

Wazeri, U. (2003). Friendly architectural design to the environment - towards green architecture. Cairo: Madboli.

Thermal Comfort in the Vernacular Structures of the Traditional Settlements of Pelion-Greece

Eleni Alexandrou,
National Technical University of Athens NTUA, Greece

Abstract

The traditional settlements in Pelion have been studied many times through the years due to the rich architectural and cultural heritage that sustains through the centuries in a beautiful and diverse natural environment. Most of these studies focused on the form and the structure of the buildings in the context of tradition, socio-political and economic and historic conditions as well as the prevailing building techniques in the time they developed. The major findings of my previous research at UCLA in 1997 on "The revitalization of the traditional settlements in Pelion, Greece. Strategies for economic and tourism development in the context of preservation of the natural and human environment", indicated that the villages possess a great diversity of cultural and natural resources and potential that will help them revitalize culturally, socially and economically without compromising future changes. My conclusions of this study led me to continue further my research and examine the issue of thermal comfort, in the traditional houses of the classical era (1750-1850) which represent the prevailing and most recognizable architectural form of the houses in Pelion that derive from the model houses of the broad Balkan area during the Ottoman occupancy. Special attributes of these structures are the climatic elements of these that make them viable even after the centuries that passed. My research included on site temperature measurements on specific buildings for 3 full years.

During the recent years the great area of Pelion experienced fervent construction activity which focused mainly in restoring and remodelling the old building fabric. For that reason I strongly believe that knowing the bioclimatic elements and attributes that the buildings possess is critical for the preservation of the existing as well as the new buildings of the area.

Keywords: *Sustainability, Thermal comfort, vernacular architecture,*

1 The settlements at Pelion

The traditional settlements in the mountain of Pelion in Greece have been admired through the centuries for their impressive setting and architecture. They developed and flourished economically and culturally under the Ottoman Empire during the "Greek Enlightenment". With the advent of the industrial revolution the villages failed to compete with the fast developing urban centers. Therefore their economies started to decline. Economic depression and depopulation were the main characteristics of the region for a long period of time. Dereliction has led to the degradation and partly the distraction of the rich architectural heritage.

Figure 1: Map of the area

However the villages possessed a great diversity of cultural and natural resources and potential that helped them sustain and revitalize in the recent years. This is probably due to the fact that the traditional settlements of Pelion were initially formed and evolved with many sustainable attributes. The settlers chose wisely the location based on good orientation, protection from the weather and enemies and availability of natural resources such as water and prosperous land for family production. Self sufficiency and local autonomy were the most important factors that led to a strong economy which grew beyond family production. The respect for the environment is among the many important attributes that the villages had to show. The settlers understood the importance and their dependence on it and therefore, tried to protect and nourish it. The villages were established in a beautiful and rich landscape and yet did not harm it. On the contrary they enhanced it with harmonious structures built with indigenous materials.

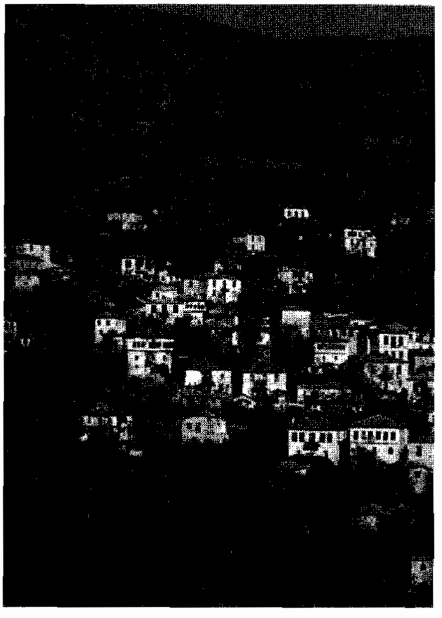


Image 1: The village of Pinakates

My research focuses on the way the traditional settlements developed with consideration and sensitivity to the climate and the natural environment. Furthermore, the effort of the local builders and the inhabitants to comprehend and respond to the local weather conditions, in order to protect or benefit from them and create an agreeable microclimate inside and around the house.

The climatic elements in the vernacular buildings can be enlightening since these structures yield valuable lessons to the designer and builder, on how one can design with and not against the forces of nature focusing on the thermal comfort of the inhabitants.

The settlements of Pelion were formed dynamically with the successive migrations that occurred in the period between the 17^{th} and 19^{th} century. The buildings under study belong to the middle period (1750-1850) and they comprise the classical Pelion architecture (Kizis 1994). This is the period of the socioeconomic flourish and prosperity and these structures that constitute the known Architecture of Pelion have many similarities with the architecture of the broader region of the Balkans and Asia Minor under the Ottoman Empire. (Stylianou, 1987, Kizis, 1994).

2 Climatic Elements of the Vernacular Buildings at Pelion

2.1 Climate analysis

The region of Pelion generally belongs to the 'Mediterranean mountainous" climate, which is characterized by fairly cold winters with strong NE winds, rains and rainstorms, and very often snow. The temperature is often around or below the freezing point (0° C). The summers are hot with temperatures around 30°C (86° F) and in hot spells can rise above 35°C (95°F).

The significance of micro-climate should always be taken under consideration. In the specific area, climatic conditions differentiate slightly between the East and the West sides. The East side faces immediately the sea and thus is more vulnerable to cold winds and air. Some villages (facing south east) benefit less from the low western sun in winter time because of the slope of the mountain. Humidity is much higher than from the West side and the breezes in the summer are cooler. In the West side the climate follows the same patterns but it is more temperate and humidity is much lower.

2.1.1 Community planning and outdoor comfort

Even though the form and structure of the vernacular dwellings in Pelion was determined by many factors, (cultural, topography, socioeconomic, functional, tradition, availability of materials etc.) climate was not disregarded. Many climatic characteristics can be distinguished in community scale as well as in the individual houses.

The planning articulation of the communities was not the outcome of any specific plan. However its structure is not coincidental. It is evident that circulation, orientation, adjacency to the cultivable and grazing land and distribution of natural elements (air, water and light) were taken under consideration. (Makris, 1976)

Usually the setting of the villages is oriented towards the south, southwest on slopes. The morphology of the landscape is a defining factor in the configuration of the villages. The steep slopes in most of them result in an amphitheatrical arrangement that allows for views in most of the structures. The dwellings are not clustered due to an "unwritten" law that required that all structures should be separated by approximately 1m to allow the rain-water to pass. This configuration enhances ventilation, and better solar access in all the facades, during the different times of the day throughout the year. The rich vegetation provided satisfactory shading in the outdoors spaces (yards, plazas, roads). (F. 2)

The deviations of the landscape presented different problems that depended on the intuition and invention of the residents for solutions. These peculiarities of the settlements led to a great variety and diversity among the villages and even though they all followed common guidelines, each and every one of them appear unique in its own interesting features and environment.

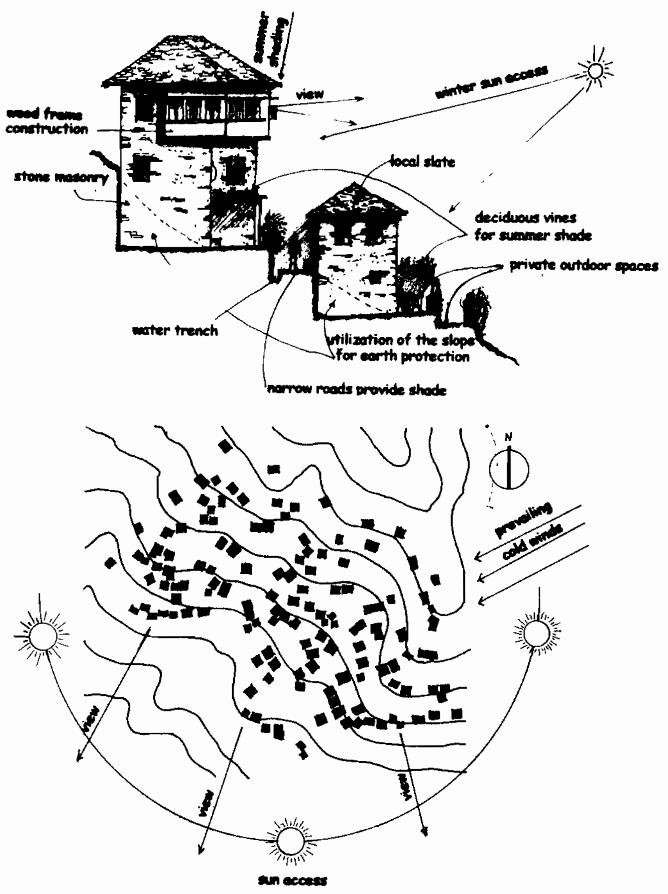


Figure 2: Climatic elements of the community

Outdoor activities are a very important part of the life in the villages, especially during the warm months of the year. Therefore, outdoor comfort becomes very essential for the life and well being of inhabitants. Careful landscaping with trees and many plants can modify dramatically the micro-climate and create agreeable conditions around the house.

In community scale, the narrow winding flagstone trails can be pleasant when adequately shaded by either the surrounding structures, or vegetation and trees. The shade, in combination with running waters in the ditch at the side of the road, enhances the moisture of the air and the cooling effect. The plazas accommodate many people throughout the day, all year round, especially in the high tourist seasons. The huge old plane - tree shades most of the area of the plaza providing great comfort even in the hottest days while it loses all its leaves in the winter when sun is needed.

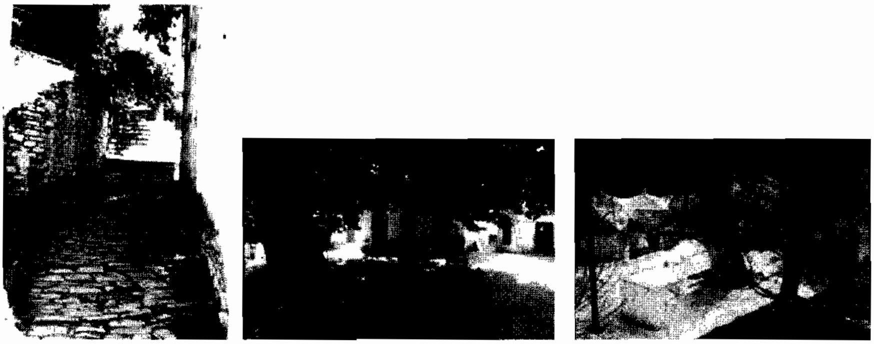


Image 2: Outdoor spaces and the plaza

2.1.2 The house

The houses were fortified, tower like buildings, concentrated on safety. They usually consisted of three floors made of stone and were characterized by the daring wooden cantilevered projections of the last floor. All the levels were divided in two zones the front and the back by a thick structural wall. This division helped accommodate the different functions of the household. The back zone or the inner house (Kizis, 1994) was used for the storage of the goods on the ground floor and for the private rooms on the rest. The front zone or the outer house accommodated the social and join activities of the family as well as domestic and manufacturing activities.

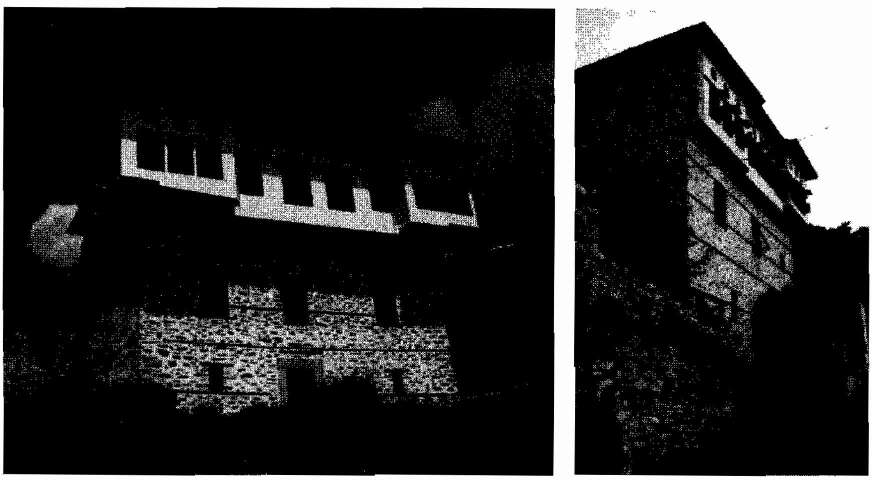


Image 3: Houses of the classical period

The first two floors were made of stone and had only very few openings (for safety reasons). The last floor appears much different with a projecting wooden structure perforated by many openings. In earlier examples these projections included open spaces where the family production took place during the hot months of the summer.

The inhabitants of the villages in Pelion migrated seasonally either between villages (from the highest elevations in the summer to the lower in the winter) or between the different parts of the house.

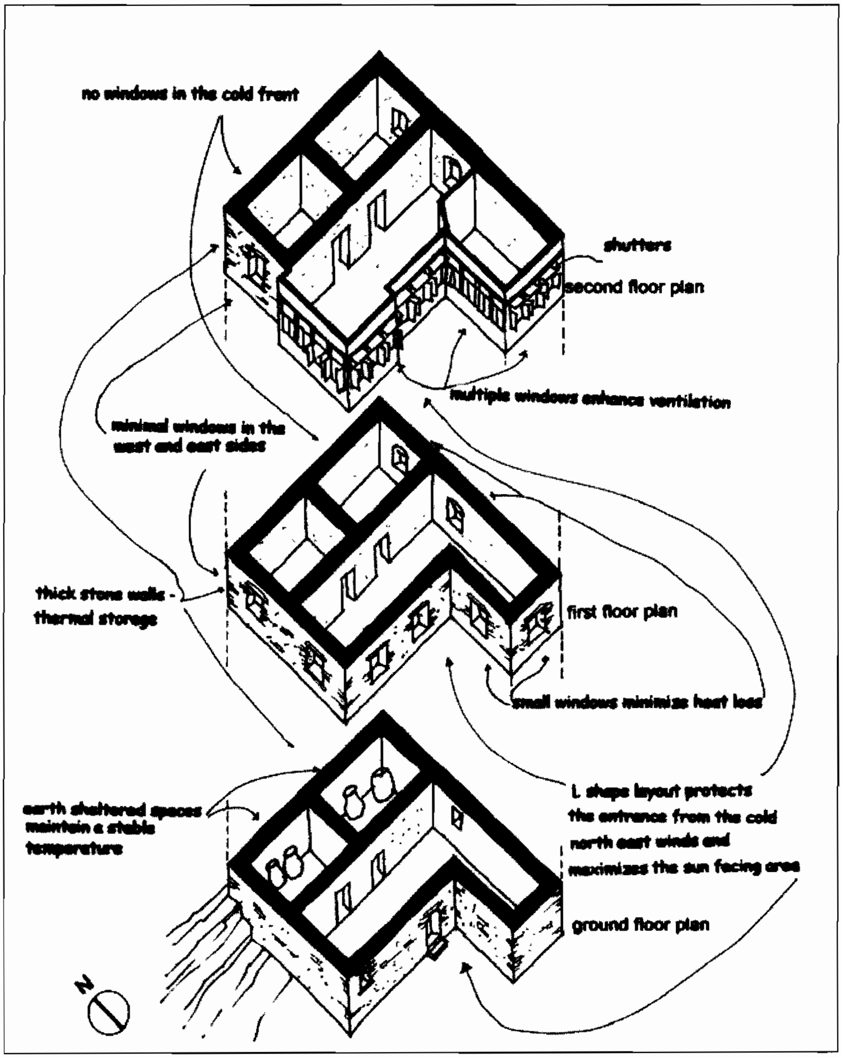


Figure 3: Climatic elements of the structures

The winter house was usually in the middle or lower level with very small height and had the bedrooms in the back zone (which was usually facing the north). The north wall had no windows to minimize the impact of the cold front and the only window in the room was usually facing east or west.In most of the examples these rooms were heated from the fireplace, usually located in the middle of the back wall. The front zone accommodated the family and also had minimal windows facing south, east and west in order to take advantage of the sun. The small number of windows as well as the small height and the floor above minimized the heat losses in this floor, assured more comfortable temperatures and protected the residents from the extreme weather.

The summer house was always located in the top floor and followed the same pattern. The main difference here was the gallery in the front zone with the wood structure projecting in the south, southwest and southeast. This wall was penetrated by an array of openings. These windows helped a lot in the ventilation, especially cross ventilation and had always shutters on the outside. In the north side the thick masonry walls continued all the way to the roof, with only a few openings, and the great mass helped minimize heat gain. During the summer these rooms maintained a fairly cool temperature that made them ideal for sleeping.

The ground floor and especially the back zone usually penetrated the slope of the mountain and took benefit of the insulating characteristics of the earth. In addition the levels above helped this zone maintain a permanent temperature and thus be ideal for food storage. (Fig. 3)

The outdoor activities constituted an important part in the life of the inhabitants. For this reason, the yard was an indispensable piece of every household. During the warm months the local inhabitants spent most of the time outside, protected from direct sun by trellises, covered with the foliage of the deciduous vines. The shading devices also shaded the building itself and helped minimize overheating. In many houses the yards were surrounding the building and were therefore used in different time of the day. Vegetation and planting of the surrounding area provide significant shade to the outside walls. Deciduous trees are preferable since they lose their leaves in the winter when shade is not desired.

2.1.3 The materials

The main materials used in construction in the area of Pelion were stone and wood which the rich mountain possessed in abundance. The stone walls were constructed very thick (usually 80cm or more), mainly for structural reasons. The stones were laid on earth mortar with timber ties at intervals of approximately 1-1.5m to reinforce the structure. The stone walls had no insulation except from the lime mortar and the first layer of the exterior plaster (where applicable) that consisted of tiny bits of flax. This great mass constitutes an important thermal element that could store the heat from the sun and dissipate it in the interior of the house in the later hours of the day when temperature drops. In hot summer days the mass of the walls prevents the penetration of the heat in the interior. At night when the ambient temperature is cooler the retained heat could be flushed out by conduction with ventilation.

At the southern sides of the structures the masonry stopped before the last floor where wooden jetties were constructed. These cantilevered structures sometimes projected as much as 2m especially in the early examples in order to maximize the floor area. (Kizis, 1994) The jetties were constructed by either corbelled timber beams or oblique braces and sometimes by a combination of these techniques. (Kizis, 1994) The wooden walls of the last floor consisted of a system of horizontal and vertical members that formed a frame which was then filled with wattle and daub. Rubble was also used as infill and occasionally brick or lath and plaster.

The roof was wooden and 4-hipped, and the eaves which provided shade to the upper floor, were wooden and often decorated. Wood was also used in the construction of the upper floors (the ground floor was usually mud or slates), ceilings, the window casements, the shutters and the doors. Many architectural elements were standardized in size dimensions and proportion as a result of the long experience of the builders and craftsmen that moved in the area from the northern parts of Greece.

Image 4: The structure: Stone walls and the wooden jetties

The shutter was an important and versatile element in the building tradition of the area. It could be manipulated to provide shade, night insulation and even promote ventilation. The design of the shutters has evolved in different forms during the long architectural history of the area. Most of these types have been salvaged. There are two component and three component shutters. (Image 5) The one with the three pieces allows for greater flexibility since it can work as both an overhang and fin. In the late 19th century the German shutters were

Introduced, which consisted of two louvered pieces. The louvers were operable and could be manipulated to allow the air to penetrate the building or be completely shut.

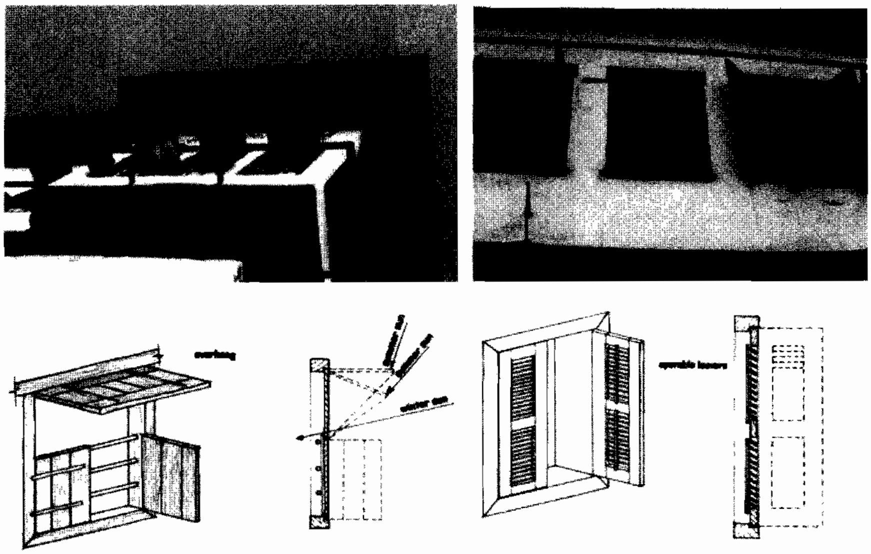


Image 5: The wooden shutters

2.1.4 Design guidelines

All of the above concerning the response of the buildings to the climate where further researched with the temperature measurements on two houses in different villages. I will present part of the results on one of them. The houses was built on the early 19th century. It sustains its original form, space articulation and elements despite the restoration and rehabilitation that took place in the early 1990's. The window panes are still single and no insulation was added to the exterior walls. The house is heated by the fireplaces (one on the first and one on the second floor) and a small heater on the ground floor.

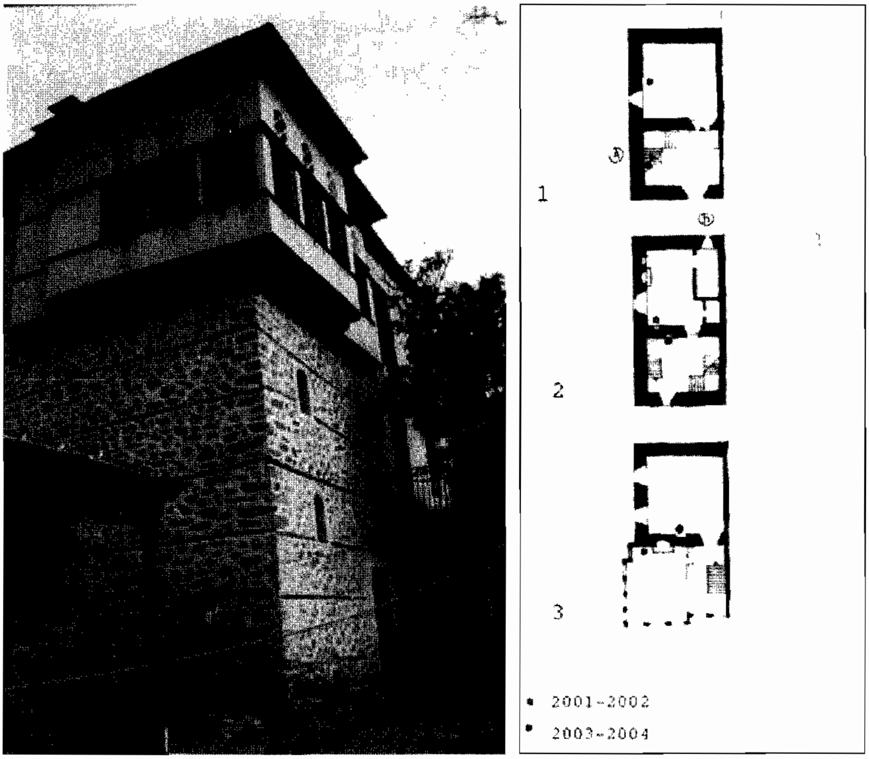


Figure 6: The house under study. The red and blue spots on the floor plan indicate the placement of the data loggers.

The tables show that the building's response to the climate is most satisfactory in the summer. The temperatures where taken with DATA LOGGERS and their position in the house is stated with the red and blue dots. The red dot represents the position the 1st year and the blue the second and third. In all the positions the ground floor retains a stable temperature which is very comfortable in the summer and cold in the winter but much higher than the exterior. The 1st floor follows the same pattern more or less. The 2nd floor demonstrates clearly the effect of the thermal mass of the thick stone walls in comparison with the wooden light structure. When the data logger is on the front room the temperature follows the deviations of the exterior. Conversely when it is positioned in the back zone its pattern is similar to that in the lower levels.

Table 1: Winter 2001. The data loggers on the red spots.

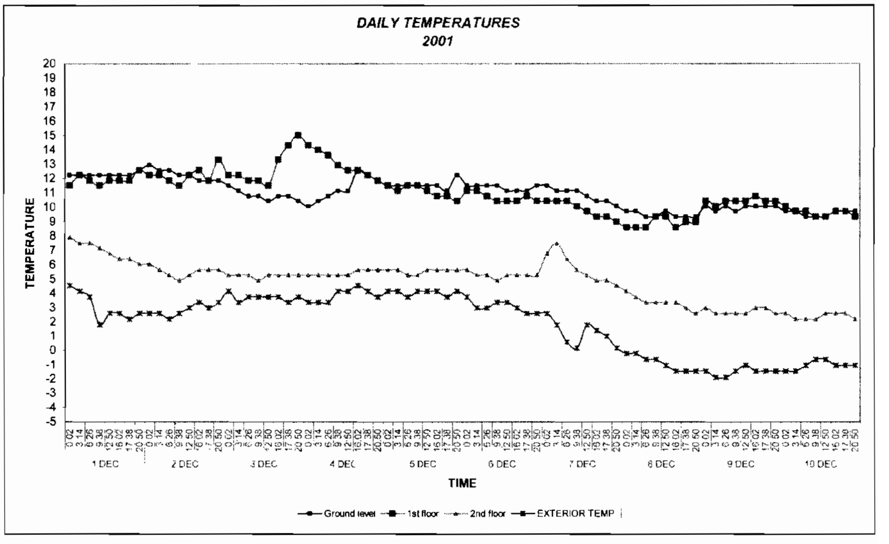


Table 2: Summer 2002. The data loggers on the red spots.

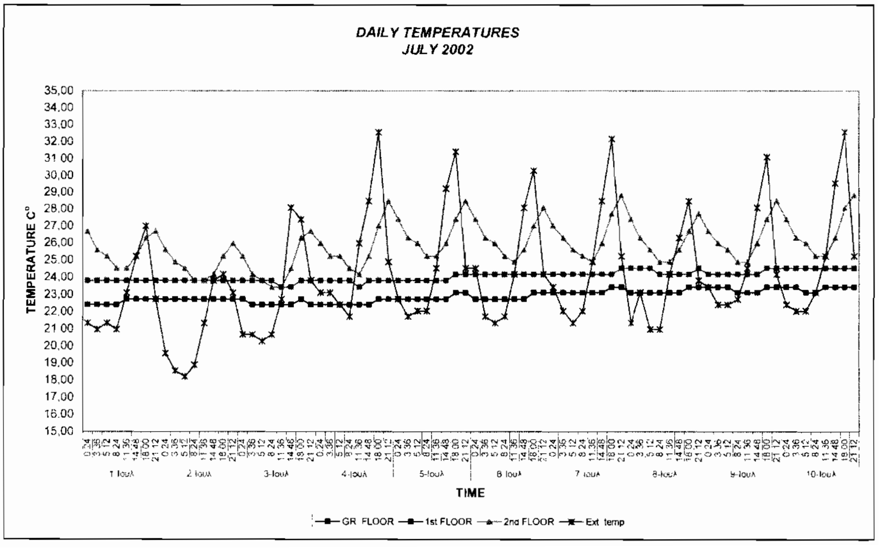


Table 3: Winter 2003. The data loggers on the blue spots.

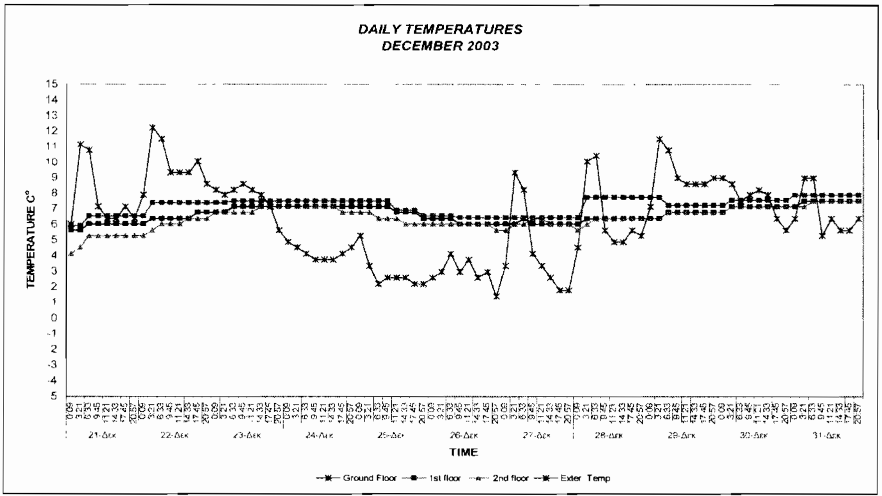
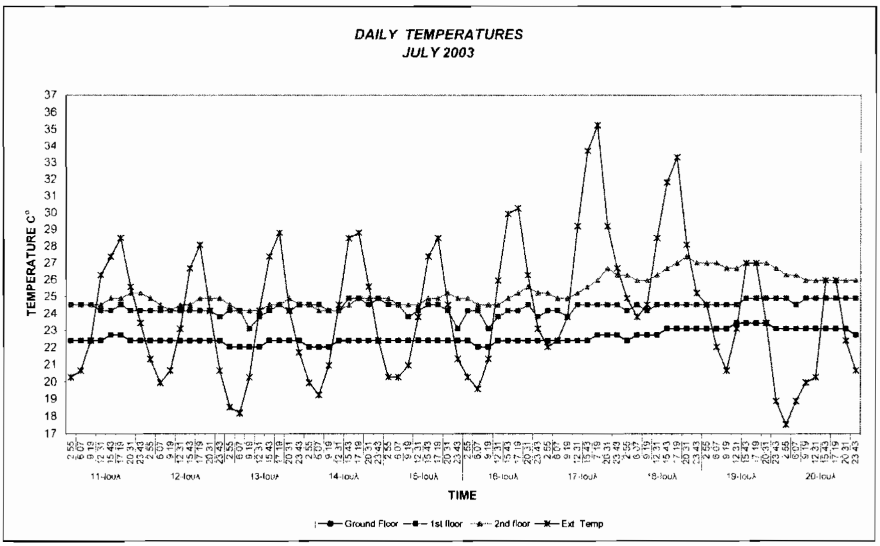


Table 4: Summer 2003. The data loggers on the red spots



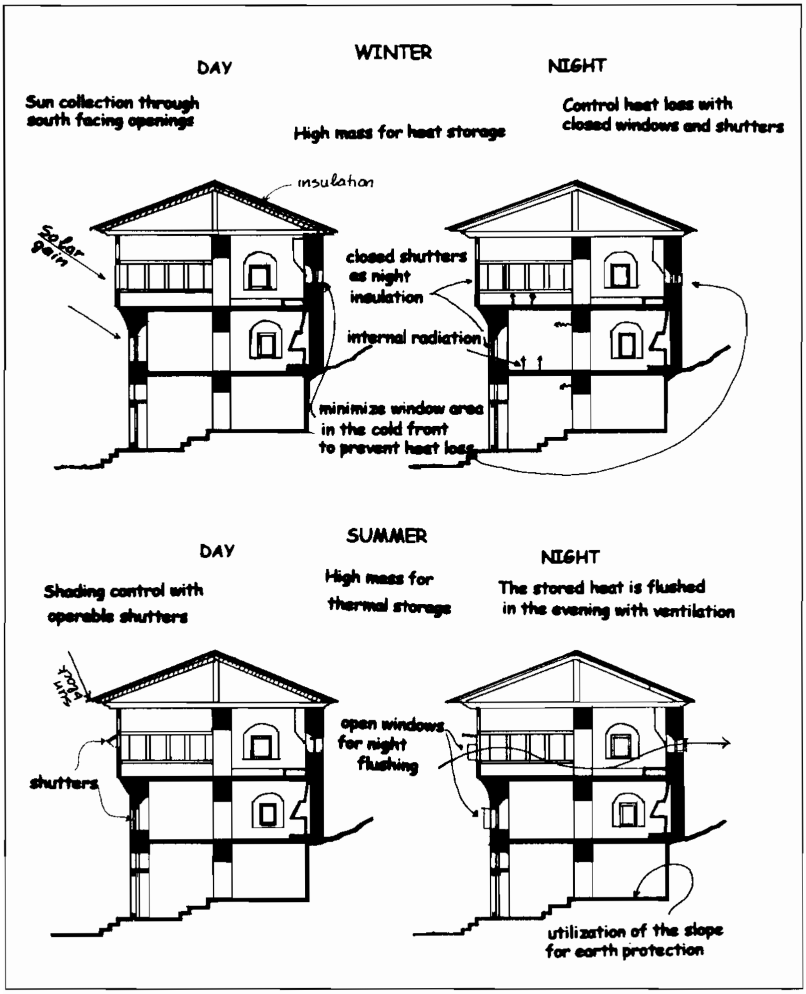


Figure 7: Design Guidelines

3 Conclusion

Winter: The climate analysis designates that the winter aspect becomes the most challenging in this specific area. Protection from the cold winds, solar gain and food insulation of the envelope are the more important guidelines.

Summer: Summer conditions and the configuration of the buildings make the indoor comfort easier to achieve. Shading and natural ventilation (cross ventilation and night flushing induced by the diurnal temperature range) can reduce significantly the indoor temperature and thermal comfort conditions.

The setting of the villages on the slopes is ideal for earth protection.

Advantages of building in the slope include the insulation value of the earth and the lack of diurnal swing. This factor eliminates the heat gain and loss into and out of the building.

Outdoor and indoor comfort is a very important element for the well being of the inhabitants of a place. Furthermore, for a place where the economy relies mostly on tourism, comfort becomes very essential and can enhance dramatically the tourist qualities of the place. Taking climate into account is a very important step towards the sustainable development in the level of both the community and tourism. Minimizing the use of non-renewable resources, while at the same time succeeding in creating comfortable conditions year round, is a very essential factor, for the well being of inhabitants, tourists and the surrounding magnificent natural environment.

In spite of the many qualities the vernacular structures appear to have, living conditions have become much more demanding. It is evident that new techniques and appropriate technologies should be incorporated to these structures to help them adapt to the new way of life.

References

Alexandrou, H. (1997). The revitalization of the traditional settlements in Pelion, Greece. Strategies for economic and tourism development in the context of preservation of the natural and human environment Thesis, University of California Los Angeles,

Givoni, B. (1969). Man, Climate and Architecture. Van Nostrand Reinhold Company, New York.

Kizis, G. (1994). Pelian Construction. The Architecture of the houses in Pelion from the 17^{th} to the 19^{th} century. Cultural and Technical Institution, ETBA.

Leonidopoulou-Stylianou, R. (1987). Greek Traditional Architecture: Pelion. Melissa Publications, Athens, Greece.

Makris, K.A. (1976). The popular art of Pelion. Melissa Publications, Athens, Greece.

Papoport, A. (1969). House, Form and Culture. Foundations of Cultural Geography. Prentice-Hall, Inc., Englewood Cliffs, New Jersey, USA.

Learning Lessons From Matmata

Mamdouh Mohamed Sakr
The Prince's School of Traditional Arts, Egypt

Abstract

North Africa is blessed by its innovative and spectacular vernacular architecture that has been developed through centuries of adaptation to the harsh climate and the barren environment. The troglodytes (earth-sheltered dwellings) are considered to be one of the most unique examples of North African vernacular architecture. A troglodyte can be simply described as a vertical shaft dug by man into soft sandstone, forming a circular courtyard, and then rooms are dug into the walls created by the courtyard. Matmata has many of the best examples of troglodyte architecture in the world.

Matmata's troglodytes are appropriate building types that served the functional and aesthetic needs of its inhabitants. These earth-sheltered dwellings are remarkable instances of human beings successfully adjusting to an often-inhospitable environment. This achievement has resulted from continuous experimentation and experience that has been passed from one generation to the next. Matmata dwellings area great example of sustainable architecture, they are energy efficient, environmentally friendly, and economical. They are a great source of inspiration for a number of fields such as architecture, environmental studies and even eco-tourism; these dwellings can easily ensure the economic sustainability of the whole settlement. This paper aims not only to analyze the dwellings of Matmata but also to re- introduce the concept of earth-sheltered architecture in the Middle East in a way that responds to the needs and problems of the inhabitants of the 21st century.

Keywords: *Matmata, Vernacular Architecture, Troglodyte, Earth-Sheltered Architecture, Sustainability, Tourism*

1 Vernacular Architecture and Sustainability

Cultural heritage is a non-renewable resource, and vernacular Architecture is the fundamental expression of the culture of the community, of its relationship with its territory and, at the same time, the expression of the world's cultural diversity. Moreover, vernacular built heritage can be seen as 'the essence of sustainability, being constructed with local materials and the minimum waste of resources. Despite this, in most countries the vernacular built heritage is neither protected nor considered worthy to be conserved.

Nowadays Vernacular architecture and Sustainability are two widely used terms they have a number of definitions, among which are the following:

Vernacular Architecture, "A term used to describe structures built by people whose design decisions are influenced by traditions in their culture".

Sustainability, "A term used to describe the process undertaken to meet the needs of the present without compromising the ability of future generations to meet their own needs".

Due to our present global crises, population expansion, natural resource depletion and ecological disasters, there is an urgent need to align development and the practice of architecture with the concept of sustainability. This idea of sustainability is not only creating a place which is self-sustaining but also being sensitive to local community needs and concerns; involving and recognizing the importance of all the peoples in the decision-making processes. Sustainability also considers the sensitivity of local history and culture, which means respecting the local materials, vernacular designs as well as being sensitive to the existing built environment of the given location. It also includes giving priority to the conservation and preservation of old buildings as cultural beacons in the history of a place.

The whole concept of sustainability encourages us to return back to, appreciate and analyze vernacular architecture and its concepts. Vernacular architecture varies widely with the world's vast spectrum of climate, terrain and culture. It contains inherent, unwritten information about how to optimize the energy performance of buildings at very low cost using local materials. Over the course of time, vernacular dwellings have evolved to respond to challenges of climate, building materials and cultural expectations in a given place. Vernacular traditions have been gleaned through a long period of trial and error and the ingenuity of local builders who possess specific knowledge about their place on the Planet. Accordingly there is a great value in understanding and applying attributes seen in ancient vernacular architecture to new buildings (Oliver, 2003).

2 The Relation between Vernacular Architecture and Sustainable Tourism

Architecture and tourism are closely interrelated; in fact architecture can shape and enhance the image of a tourist destination or destroy it altogether. Similarly, tourism, if developed in a responsible, balanced, participatory and sustainable manner, can become a driving force for environmental protection, heritage conservation and cultural pride. In other words, Sustainable environment requires Sustainable design solutions for the continuity of the traditional architectural environment.

Tourism has been a rapidly growing sector and a wide-sweeping socioeconomic phenomenon with broad economic, social, cultural and environmental consequences. It is likely that tourism will continue to dominate the international scene for many years to come. Environmental protection has become a major issue in the recent years, and as a result of environmental consciousness, a great number of alternative forms of tourism have been developed in the last two decades. Various names are utilized to demonstrate the typologies of the environmental tourism, 'Green', 'Soft', 'Eco', 'Sustainable', 'Responsible', or 'Alternative' are some of the terms to describe the new trends. These new trends prefer the places, which are not destroyed by the "mass of tourists". So today, the tourism industry proposes an ever-wider range of destinations and there are few spots left in the world, which are out of the reach of tourism. Moreover, the growing awareness for culture has set a tourism movement driven by a widespread desire to discover new places and different cultures.

Accordingly, the tourism industry is putting more and more emphasis on the uniqueness of the experience provided by each destination. Vernacular architecture contributes greatly to the fulfillment of this current tourism movement because it is at the very heart of the identity of a community or of a country. Indeed, vernacular architecture is the reflection of a lifestyle, of a social organization, of artistic practices, and of the architectural adaptation to climatic, geographical, cultural and religious factors. Respect for the sense of place, traditions, and cultures are paramount for the well being of the populations and the sustainability of tourism and of its quality. The sense of place depends on the use of specific materials found locally and the adjustments of architecture to societal customs and needs as well as to the environment. It is by respecting these aspects that one can ensure the specificity and uniqueness of the tourism offer.

Now there are many examples of traditional settlements all over the world that became major tourist attractions. The aim of this paper is to focus on earth-sheltered architecture; a vernacular building technique that can be adapted to our contemporary needs. Matmata's architecture will be discussed in depth to understand its characteristics and advantages, which led to the success of the town as a whole on the social, economic and cultural level. Today, Matmata is a well-known tourist attraction; crowds of tourists come especially to see and even experience living one night in one of its troglodytes (earth-sheltered buildings). A number of the big houses were turned into hotels and most of the population lives on tourism and folklore exhibitions in their homes (Figure 1). Matmata is one of the great examples of how the preservation and adaptive reuse of vernacular architecture in addition to the respect for the principles of sustainability and cultural diversity lead to a huge commercial success. So, how a local community can fully benefit from its cultural and artistic heritage, is a lesson to be learnt from Matmata.

Figure 1. A courtyard of a Troglodyte Hotel, Matmata
(Source: Author)

3 Earth Sheltered Architecture

Earth-Sheltered architecture is one of the passive energy solutions that exemplify man's struggle to survive and shelter himself against stressful climates and to achieve safe and comfortable living environment. For centuries these indigenous designs have been used by residents in different parts of the world, from the provinces of Henan, Shanxi, and Gansu in Northern China to different parts of the Mediterranean region, such as Sicily, Santorini and the Goreme Valley of Cappadocia in central Turkey. Matmata in southern Tunisia is a prime example of a whole settlement of earth-sheltered buildings. This paper aims to focus on its dwellings or what is known as the Troglodytes, which are exceptional examples of the architecture that melts within its environment. Their designs are adapted to the needs of their inhabitants and their way of life, and that is simply the true essence of vernacular architecture

Matmata and its Troglodytes

The history of this extraordinary place is unknown, except from tales and legends carried from generation to generation. The most probable one says that underground homes were first built in ancient times, during the Roman period. It is said that the Roman ruler sent two tribes to settle in the Matmata region, after one of the Punic wars, with permission to kill every human being in their way. The dwellers of the region had to leave their homes and dig caves in the ground to hide from the invaders. Yet other sources claim that these troglodytes were dug as a reaction to the Arab invasion. Whatever the real reason was, these underground settlements remained hidden in a very hostile area for centuries, and were only discovered in 1976. This was because of intensive rains that flooded the troglodytes, and forced the dwellers to seek help from the authorities in the nearby town of Gabes. Thus, the secret of Matmata was revealed to the whole world, and gradually the "Nouvelle Ville" was built few kilometers away from Matmata, but only few families moved to the new surface dwellings as most of the people continued their lives in their underground homes.

As Matmata is an arid region, and temperatures regularly exceed 50 degrees in summer, these dwellings were the inhabitants approach to escape the harsh climatic conditions, and their abundance was due to the favorable soil conditions. Matmata's terrain is hilly and the small valleys between the lime stone mountains contain deposits of loess (almost 20 meters deep), which are composed of clay with enough gypsum to act as a binding agent. This provides a firm and stable but easily worked material for excavating rooms (Kempe, 1988). The softness of the soil material is both the reason for troglodytes being possible, and for never becoming very old (Figure 2).

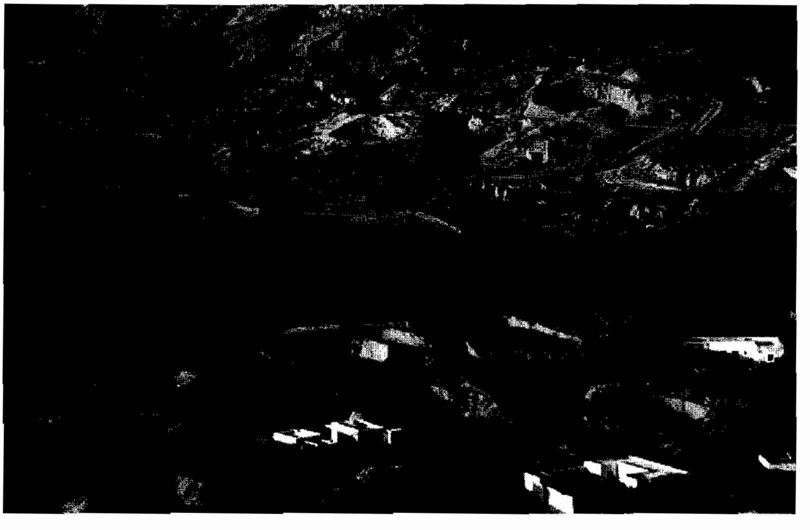


Figure 2. Matmata's Landscape dotted with Troglodytes (Source: Postcard)

The Matmata Troglodyte is a very common type of the various types of subterranean dwellings. It is a vertical design of a deep courtyard open to the sky and surrounded by walls and rooms. This sunken courtyard building is an underground structure that closely follows the introverted design of the famous traditional aboveground courtyard building. The troglodytes are isothermal; their temperatures are warm in winter and cool in summer, and stay relatively constant year round, as earth as a building material stabilizes the extreme temperature swings, both daily and seasonally. The shape, size, and other design details of a sunken courtyard dwelling vary between regions and even among households in the same region depending on the socio-cultural background, financial standard, and environmental features such as geomorphologic configurations, soil type, climatic pattern, and hydrological systems. However, the overall basic design remains similar.

4 Analysis of the Troglodytes

The design of the troglodytes depended on the courtyard, the central focal point where all the rooms and other spaces of the dwelling are distributed around it. Courtyards are usually semi-circular in shape ranging from 5 to 10 meters in diameters with a depth measuring about 10 meters from the ground level to the floor of the courtyard (Figure 3). The digging starts in the courtyard and after sharpening its edges, the openings of doors and windows are carved as a start to dig the rooms. The rooms are long and narrow in the lower level, and smaller in the upper level (if the soil strength permits). The ceilings are usually vaulted, to bear the loads of the soil above it and to accommodate day lighting and ventilation needs. The typical dimensions of the rooms in Matmata are 4 to 5 meters wide and 8 to 10 meters long with a height of about 3 meters for the large rooms, and between 3 to 4 meters wide and 4 to 5 meters long with a height of 2.5 meters for the smaller ones. The soil cover from the ground level to the room ceiling in Matmata ranges from 6 to 7 meters. Such thickness eliminates any potential for water leakage caused by possible heavy rainfall and it significantly reduces the heat gain and the heat loss rates into and out of the building (Golany, 1988).

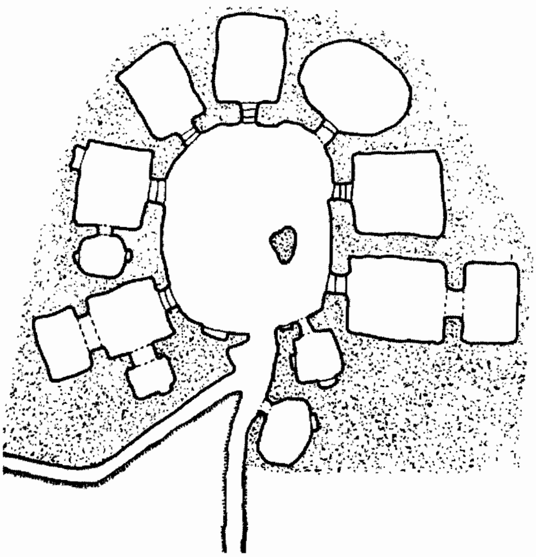


Figure 3. A Typical plan of Matmata's Troglodytes
(Source: Golany, 1984,Earth Sheltered Dwellings in Tunisia)

The number of rooms around the courtyard varies depending on the size of the family and its way of living, which may dictate a certain number of storage and utility rooms. There are also granary rooms, which are high rooms excavated on a height of 2.5to 4meters from the ground of the courtyard and their width ranges from 2 to 2.5 meters (Figure 4). Each room has an upper opening in the ceiling (close to the ground level) where grains are dropped directly. Usually there is a cistern in the middle of the courtyard for gathering rainwater. The courtyard is protected from the rainfall by building a short fence around its circumference using the clay that resulted from the excavation. The entrance of the dwelling is above the ground and is about 10 meters away. To ensure the safety and protection of the unit, the entrance is fortified and sloped downwards to the central courtyard through an excavated tunnel. The underground tunnel is gradated in height and for more protection the last part of the tunnel changes in direction, and there is usually another curved entrance. After this curved entrance there is a storage room for storing agricultural instruments and sometimes for sheltering sheep and goats.

Figure 4. A Courtyard in one of Matmata's Troglodytes
(Source: Postcard)

Building materials such as stone and gypsum are available from the ambient environment and they are used for the finishing coats of the internal walls and some of the fixed furniture (beds and storage cabinets). While olive trees, which are widely planted in Matmata, are used for doors and some simple furniture. It is also used for supporting the roof of rooms and subterranean entrance tunnel.

5 Contemporary Earth-sheltered Buildings

The simple yet genius design of an earth-sheltered dwelling whose spaces are gathered around a central courtyard became a source of inspiration for many architects. Since the 1940s, underground building constructions have been adopted in contemporary building designs all over the world for various purposes ranging from defense to preservation of landscape. The concept of using underground buildings received more widespread attention after the energy crisis in 1973 primarily due to its suitability as a climate control strategy and to the subsequent energy savings it provides, among others. Housing and military installations have been popular in the United States; shopping centers in Japan and Stockholm; oil storage spaces in Norway and Sweden; and parking spaces, theatres, libraries, and other examples of public and private underground buildings can be seen throughout the world (Golany, 1983). Examples of contemporary sunken courtyards can be found in large-scale projects such as the UNESCO buildings in Paris, the undergraduate library at the university of Illinois, the state capital of Texas at Austin, and the expansion of the Louvre museum in Paris (Al- Mumin, 2001).

Also, this building technique was used in residential houses such as the celebrated John Barnard's ecology house prototype in Massachusetts, which is an excellent example of a contemporary earth sheltered building, to the extent that it is even called a modern version of a Matmatan earth-sheltered courtyard dwelling (Baggs, 1991) (Figure 5). It was built in 1973 to test Barnard's idea of earth-sheltered living; and it all started when he had asked himself the question: How to make a house that resembles a park?" The house has a belowground central courtyard, which is the first of its kind in the United States. The sunken courtyard is one story high (3 meters) rectangular in shape, with 5 to 6 meters in dimensions, and the soil cover is about 0.5 to 1.0 meters in thickness. The internal courtyard is not only the visual and functional focus of the building, but also a climate modifier, because of its geometry, a thermal buffer zone is created. The resulting microclimate is less harsh and more tolerable than the outside weather conditions (Etzion, 1997). Thus, while the outside is hot, dusty, and harsh, the courtyard by contrast can be moist and cool producing an outdoor living space useable for most part of the year.

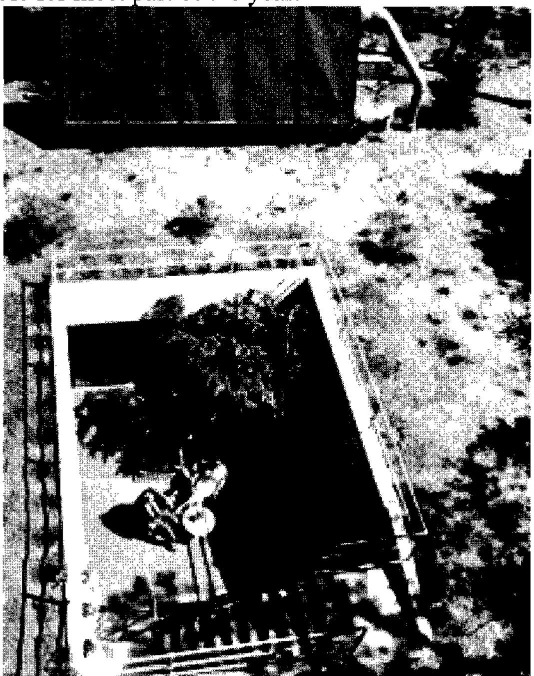


Figure 5. John E. Barnard. Ecology House, Osterville, Massachusetts, 1973
View into courtyard with solar panel
(Source: www.we-make-money-not-art.com/archives/2009/08/sorry-out-of-gas-architectures.php)

5.1 Advantages

It has been proven by historical, as well as modern precedents, that earth sheltered or underground construction is a viable alternative to conventional design, because of the resulting microclimates and the general reduction of temperature within the units, especially in climates with harsh climatic conditions. The hot-arid climate is understandably the primary cause of large cooling energy consumption. However, the subsurface climate is much milder than the extremities of the aboveground environment. Being cooler than the ambient air for parts of the year, the soil enclosing an underground building has the potential to lessen the cooling energy needs of a building by reducing the heat transfer from its surroundings.

Carmody and Sterling speculate that even at very shallow depths, the ground temperature seldom reaches the outdoor air temperatures in the heat of a summer day, conducting less heat into the house due to the reduced temperature differential. Not only is the temperature difference between the exterior and interior reduced, but the building is also protected from the direct radiation of the sun (Carmody and Sterling, 1984). In addition to its ability to create a pleasant microclimate, there are many advantages to living in an earth-sheltered home, such as:

5.1.1 Land use and Aesthetics

One of the more common motivations for building an earth-sheltered structure is to blend the building in with its natural surroundings. This is often the case on rural sites where the owner wishes to build a dwelling but also retain the 'untouched' beauty of the natural landscape. Although retaining the beauty of a suburban block is not often of much importance, once the earth shelter has been built the area of land available for growing plants is greatly increased over that of a block with a conventional building on it. This double use of the land, means that earth sheltered houses can be built on smaller blocks than conventional houses and still have sufficient space for outdoor living. This makes earth-sheltered housing particularly useful for medium-density housing developments, an area of construction that will no doubt increase in the future as the world population grows and cities become larger and larger.

5.1.2 Cost Reduction

Reducing the Cost of the building and there are several reasons for this:

A- Reduced Energy Costs

This is the main area where cost is reduced in an earth-sheltered house when compared to a conventional home. One of the key advantages to earth sheltering is a stabilization of temperature inside the building. Because of this, depending on the climate and the design of the building, some earth shelters can be lived in perfectly comfortably all year without any need for heating or cooling. This may not apply for the whole year in some parts of the Middle East, but it is certain that the amount of heating/cooling required in an earth sheltered building will be reduced, which automatically leads to a reduction in electricity costs.

B-Reduced Maintenance Costs

This is based on the sheltering effect on much of the exterior building envelope by the earth mass. Therefore, the building envelope is less likely to be weathered by various climatic elements. The earth-sheltered structure is subjected to smaller temperature fluctuations than surface buildings. The effect of this reduced fluctuation is less expansion and contraction in building materials, which minimizes thermal cracks, which are common in concrete blocks and paint. The gentle conditions under soil cover increase the structural longevity of building materials, which are protected from the various exposed conditions in harsh climates and its weathering effects.

5.1.3 Privacy

Earth-sheltered houses also provide the privacy, serene environments and social unity, which are essential in the conservative societies of the Middle East. However, in general they are appreciated for their effect in reducing the amount of noise surrounding the building. Accordingly it is possible to build earth-sheltered dwellings in places where conventional structures would be virtually impossible (for example: next to major roads or in airline flight paths).

5.1.4 Safety and Protection

Earth-sheltered housing offers a uniquely safe living environment in the face of naturally occurring disasters in comparison to conventional homes. The reinforced structure of an earth-sheltered home, surrounded by and covered with earth, provides maximum protection from high winds, hail storms, lightning strike, tornadoes with their accompanying damage from flying debris, and other natural disasters. Earth-sheltered structures will be less prone to collapse in an earthquake, which is when most loss of life occurs. They also offer a substantially better fire-retardant structure than aboveground houses, should a fire occur, the structure is likely to sustain less fire damage.

5.2 Disadvantages

It should be stated that earth sheltered buildings (as any type of alternative construction) also have some potential limitations and disadvantages, such as:

5.2.1 Public Negative Response

Several authors mention that there are some social and psychological problems to overcome if earth sheltering is to be implemented on a wide basis. They consider that the greatest hindrance to the consideration of earth-sheltered housing is that the public will not accept living in earth-sheltered buildings, especially if they are not aware of the benefits these houses provide (Golany, 1983). The fact that underground structures have few or no windows also contributes to the conclusion that they may be unsatisfactory due to the psychological feeling of isolation. The absence of windows for direct contact with the outside environment, and the subsequent lack of stimulation from the variety of changing weather conditions and sunlight, can add to the sense of confinement or claustrophobia. A windowless building also induces a lack of spatial orientation since exit points are not visible, creating a fear of not being able to escape in an emergency. However in the hot arid climates of the Middle East the solar radiation is intense for much of the day and shutters are used on the windows to reduce glare and solar gains. For inhabitants of these areas, psychologically speaking, the darker the room, the cooler it seems and minimal day lighting is accepted. Therefore, it is generally best to keep the sunshine from entering the building in these regions.

5.2.2 Construction Costs

Most people assume that the construction cost of earth-sheltered structures is higher than conventional buildings, yet this is still a controversial issue. It seems that the main reason for the increased costs is due to the added structural materials required to withstand the weight of the soil on the roof, and the use of reinforced concrete structures. However, it is not conclusive that the construction cost of every earth-sheltered building will be higher than its aboveground counterpart. Many architects and engineers have proven that the cost to construct an earth-sheltered house is similar to a conventional house, even when earth-sheltered homes are larger than typical aboveground houses; the total building costs are generally competitive. Other architects argue that earth-sheltered construction in many instances is less expensive than equivalent above ground structures (Terman, 1985). It is important to mention that as building with reinforced concrete became the most popular construction technique in the Middle East, one realizes that the increased structural requirements for underground buildings may not represent a real cost increase. It is important to understand that the increases that occur out of necessity in earth-sheltered construction can often be offset by reductions in other areas. For example, with much of the building's façades in contact with soil, exterior finishing costs are reduced.

5.3 Recommendations

Based on the above-mentioned advantages and the suitability of the earth-sheltered buildings to the harsh climate of the Middle East and the cultural and social preferences of its people, the implementation of such a building technique is highly recommended. Unfortunately this subject is lacking sufficient research, feasibility studies and pilot projects specific to the region.

The architectural design should not only take into account the social and cultural context, or the usual architectural design decisions like layout, level of fenestration, etc, but also apply appropriate solutions that alleviate some of the negative psychological effects related to underground buildings discussed earlier. Accordingly an earth-sheltered courtyard design - based on Matmata's Troglodyte - will be a clever response to such problems and concerns. All of the main living spaces of the house will have windows opening onto the courtyard, while the outside walls and roof are completely covered with earth. This configuration can provide the living spaces with natural light, view, access, and ventilation when needed. In this manner, the external courtyard provides a visual connection with the outside world, creating a feeling of spaciousness, minimizing the negative feeling associated with entering an underground building by alleviating the various psychological concerns about orientation, natural light, and view.

Another design consideration that needs to be resolved is the depth of soil cover on the earth-sheltered building. Depth of soil cover needs to be considered with respect to thermal performance, structural economy, and other economical considerations. Although deep soil cover means greater thermal mass, it also means more expensive excavation process and roof construction. Therefore, there is a trade off between the overall thermal effect of added soil mass and the extra strength necessary to support the added weight. A recommended earth cover of 1 meter over the roof will still be able to stabilize daily temperature fluctuations, meaning that average conditions, rather than extreme climatic conditions will affect indoor conditions (Giovani, 1994).

Finally, even if there is some debate between architects and developers as to the initial cost of earth sheltering, there is no disputing that there are large savings in the long term. However, there has been lack of studies that quantitatively measure the acclaimed benefits in energy and economy as well as the occupants' attitudes and satisfaction expected from this concept, especially in the desert climate. Such information is vital for the policy-makers to seriously consider adopting this new/old concept.

This paper aims to reintroduce the idea of earth-sheltered buildings in the Middle East. Such Passive building technique can be applied as an answer to a number of critical problems that are facing the metropolises of the 21st century. For example in a country like Egypt, the use of earth-sheltered should not be only for the sake of reducing energy consumption, as such building technique can help in:

Increasing the amount of green spaces within the densely built cities.

Creating new settlements for desert reclamation projects.

Preserving the natural landscape and scenery in a number of locations, where the presence of modern buildings will ruin the scenery (e.g. visitors centers in National Parks)

Creating appropriate buffer zones around certain monuments, heritage sites and Temples, instead of being surrounded by the dense urban fabric.

6 Concluding Remarks

Vernacular Architecture needs more attention, appreciation and studies; many examples of vernacular architecture are great sources of inspiration for a number of fields such as architecture, environmental studies, sustainable development and even eco-tourism. Among such examples are the earth-sheltered dwellings, which are remarkable instances of human beings successfully adjusting to an inhospitable environment. This achievement has resulted from continuous experimentation and experience that has been passed from one generation to the next.

While the problem of energy consumption has never been previously defined or faced as what is happening now, Matmata's vernacular architecture has utilized some passive design methods and made the maximum use of the potentials of its region and the limited resources of its environment. Accordingly, modifying and adopting a number of vernacular construction techniques could be the answer to a number of environmental and urban problems that face us in the 21st century.

The people of Matmata did not succeed only in preserving and maintaining their architectural heritage, but also in establishing a sustainable community benefiting from Tourism and other related services and crafts, these dwellings now ensure the economic sustainability of the whole settlement. Matmata is a famous tourist destination where architecture and environment complement each other. Such an approach should be analyzed and applied in many places throughout the World.

References

Al-Mumin, Adel (2001). Suitability of Sunken Courtyards in the desert climate of Kuwait. Energy and Buildings, Volume 33.

Baggs, JC (1991). Australian Earth-covered Building, NSW University Press, Kensington.

Carmody, A. & Sterling, R. (1984). Design considerations for underground buildings. Underground Space, Volume 8

Carmody, A. &Sterling, R. (1985). Earth Sheltered Housing Design. Van Nostrand Rheinhold Company, New York.

Etzion, Y. (1997). Adaptive Architecture: Integrating low-energy Technologies for Climate Control in the Desert, Automation in Construction, Volume 6.

Givoni, B (1994). Passive and Low Energy Cooling of Buildings, Von

Nostrand Reinhold, New York.

Golany, Gideon (1983). Earth-sheltered Habitat, Van Nostrand Reinhold, New York.

Golany, Gideon (1988). Earth-Sheltered Dwellings in Tunisia: Ancient Lessons for Modern Design, University of Delaware Press, Newark, New Jersey.

Kempe, David, (1988). Living Underground, a History of Cave and Cliff Dwelling, London.

Oliver, Paul (2003). Dwellings, The Vernacular House World Wide, London.

Terman, M.R. (1985). Earth Sheltered Housing: Principles in Practice, Van Nostrand Reinhold, New York.

Sustainable Management of Sensitive Environmental Territories

Moscarelli Fernanda, Cotelle Pauline
GESTER - Risk Management, Spaces and Societies, France.

Abstract

This paper's purpose is to show how traditional architecture can be a strategy for sustainable territorial development in spontaneous settlements. Our intention is to contribute and put forward practical methods for implementing sustainable development. This will be done through an experimental studies developed on a precarious settlement in south Brazil. In this work, we assume that: (1) sustainable territorial management needs to analyse actual governance, environmental and social conditions of the territory, (2) vernacular architecture can be a strategy to promote communities' resilience. The main objective of this paper is to propose a methodology based on fine comprehension of the territory. Furthermore it intends to highlight the close relationship between vernacular architecture, resilience and sustainability.

Keywords: *methodology, vernacular architecture, sustainability, territorial management, resilience*

1 Introduction

In this global context of environmental and social issues, the communities ability to adapt to their environment and answers to climate changes, appears to be a great challenge. In addition, the prevision of higher natural risks represents a serious limit to sustainable development, especially when they affect vulnerable people.

This is the case of several neighborhoods in developing countries where the absence of the State results in social, economical and environmental vulnerability. The island Grande dos Marinheiros, located in Porto Alegre, in the south of Brazil is a typical example to illustrate the land use complexities present in the Latin American context.

Considering its geographical and environmental characteristics, this island presents a specific condition inherent to its recent and constant sedimentary formation. In this sense, the island morphology is composed mainly by a bayou in the centre with elevated coastlines covered by marsh vegetation, houses and basic infrastructure and services such as water, electricity, roads, lighting and sanitation among others (Menegati, 1998). In addition, this island is an important place for the region because it acts as a sponge that avoids flooding Porto Alegre in periods of heavy rain.

Also this territory is inhabited by a blend of traditional people (fishers and farmers) and immigrants coming from other Brazilian regions. The traditional communities used to live in harmony with their environment through their economic activities, their traffic modes and their vernacular architecture. Their life style appears to be "well" adapted to the environmental constraints: humidity, spatial isolation, auto-subsistence and frequent flooding.

For a long time these existing traditional houses were not recognized as building heritage. According to Iglesias (2000), even if the architecture using local materials has a significant aesthetic and ecological value, it is still associated with low income residents in collective imaginary. However, today we assist in raising awareness of these building's legacy value and the importance of their preservation is one of the main issues present in this territory.

As suggested by Fuentes (2009), today in the European Union's context, the development policies consider the preservation of the vernacular architecture as a priority. The author focus on the possibilities of the reuse of vernacular buildings which can accommodate alternative new activities compatible with their character. This issue represents an appropriate and long-term sustainable preservation option.

In the sixties, with the construction of the *Regis Bitencourt* Highway crossing through the island considerable change has occurred, notably in the population composition. The addition of a new population resulting from the national process of rural-urban migration, has taken over the island, developing a different lifestyle not in accordance with the existing landscape, economic activities and local conditions (*Proposta para redefinição dos limites do Parque Estadual Delta do Jacuí*, 2002, p. 8). To develop this territory, this "dramatic" situation has to be overcome.

In the same period, many social and environmental movements took place in the region. In 1979, the Delta islands were defined as a regional park named *Delta do Jacui.* Since then major conflicts emerged in the islands since the park's institution was established without any dialogue with the inhabitants. Today, this political conflict is very strong and still present because it opposes citizens and organizations regarding the options and discussions of territory management.

The above description shows social-political, economical and environmental difficulties in this territory. So, in order to develop a methodology for "better" sustainable territory management, our study suggests taking into account the ecosystem, the lifestyle, the economic activities, the socio-political organizations of residents, without neglecting the territory representations and the existing heritage.

So, in the light of sustainable development principles such as the sustainable yield and the balance between emission and absorption,suggest by E. Daly (1991), territorial management should respond to the mutations in territories and societies and consider all issues in a global and inter-relational vision.

In addition, vernacular architecture can be seen as a strategy of territorial sustainability through a practical implementation of resilience, allowing some flexibility and adaptation patterns of land use while allowing communities to better cope with hazards. Indeed, in case of disruption, people can organize themselves and rebuild quickly and permanently their home, thanks to the expertise they have acquired and transmitted from generation to generation and also because the materials used for housing fit the natural landscape and its constraints.

Ken Yeang (1996) highlights that the climate should be a legitimate starting point for architectural expression in the endeavour to design in relation to place. Indeed, climate is one of the dominant determinants of the local inhabitants' lifestyle and the landscape's ecology.

Providing an introduction to the concept of vernacular design and the island context, this paper is organized in two chapters. The first discusses the proposition of methodology of territorial management and explains the links between the four separated studies. Several chapters focus on the description and commentary of different sectoral works based on bibliographic references. The second chapter is dedicated to the overall findings and recommendations for future implementation. This paper is aimed to highlight key elements for territorial sustainability as insights for vernacular architectures and their adaptation today.

2 Elaboration of a Management Methodology

With the intention to develop a method built on the territory and, therefore, according to specificities presented, our work needed to be four separate studies. Four groups were drawn up, keeping an intense exchange of issues, data, and preliminary results.

The first work presents a detailed analysis of technical data on local conditions. These data cover the juridical constraints, existing infrastructure (its insufficiency or weakness), the climatic and environmental characteristics with an emphasis on data relating to the ecosystem. This analysis differs from traditional ones in the sense that it is obtained through data relationships.

The second work is concerned in mappin the existing actors and their role in the case study. The main objective is the identification of the actor's associations facing the common or particular interests. This work assists the management viability.

The third paper deals the analysis of inhabitants representations about their territory. The aim of this study is to open a dialogue with local people and discover their values, their lifestyle and their relation with the island.

The fourth study deals the analysis of characteristics of existing vernacular architecture as a way to insert this in the rehabilitation of existing traditional dwellings and the incorporation of these principles in the qualification of housing not adapted to local conditions.

The synthesis of theses studies is presented as a decision to support future projects. The whole of the detailed descriptions about these methodologies is given below with the preliminary results.

2.1 Analysis of correlation between technical data with qualitative characteristic

This analysis, developed by Moscarelli (2005), seeks to examine the interactions between environmental characteristics (environmental, geographical and anthropogenic) serving as a support for decision making in the operations of qualification. Since the purpose of this work is not collecting data but the creation of a interconnected methodology, no data has been generated. They were collected from several developed works developed between the 70's and 80's on the island. Between 1990 and 2000 several other studies have actualized those or created new technical data. Moreover, the separation in categories and analysis of these data was the objective of this segmental work.

In order to develop this system of analysis, we adapted a methodology called the Grounded Theory (Strauss and Corbin, 1998). The choice of this method relies on two assumptions:

a) The existence of a large number of data on the case study without any confrontations,

b) The theoretical benchmarks are based on the principles of Sustainable Development which requires a systemic approach.

This method appears the most appropriate one for the organization of qualitative data. According to these recommendations, the analysis has been conducted in three stages:

a) Open coding, definition of analysis categories : the data were separated into analyzed categories and subcategories according to their specificities with the objective,

b) Axial coding, systemic analysis of the data: data were separated and analysed according to a correlation matrix (for example see Figure 1). Which means that the interconnections between the data were analysed category by category in both directions as shown in the diagram of the analysis presented in Figure 2,

c) Selective coding, the identification of the central category in the planning process: "the core". In our work, this category has been critical in the identification of the priority in management.

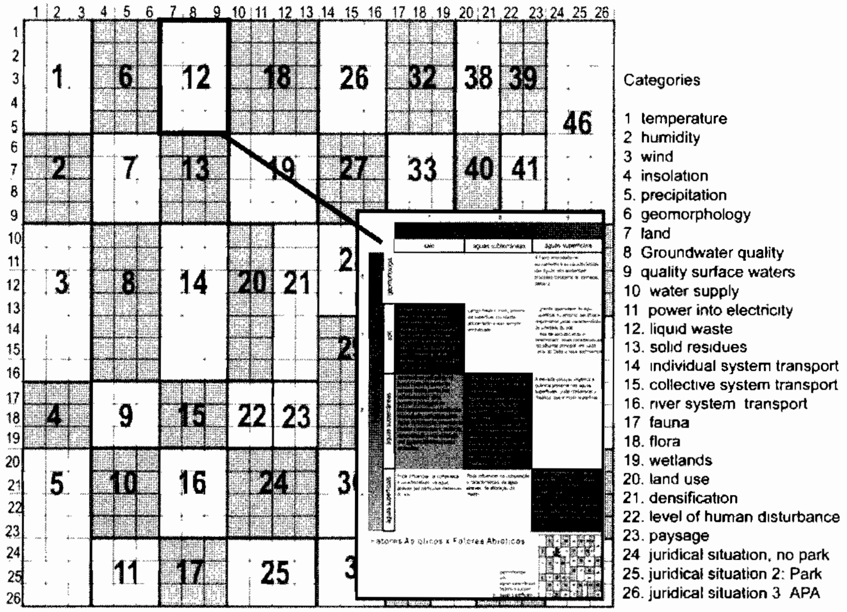


Figure 1: overview (first level of analysis) with all 26 categories (Moscarelli, 2005).

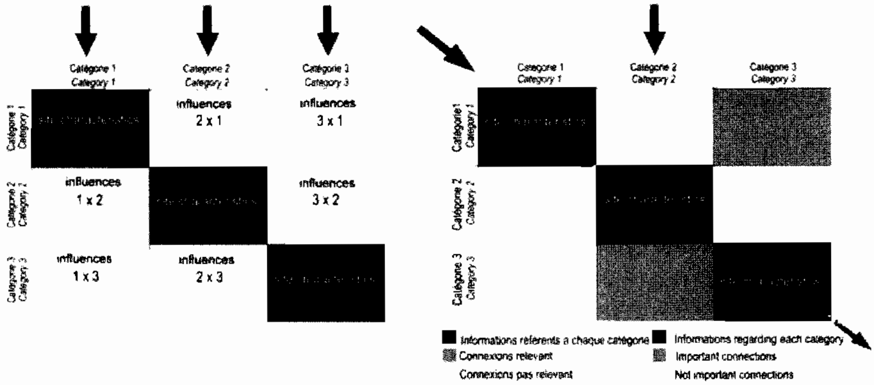


Figure 2: The importance of the category is hierarchy trough colour code: gray for an elevated level of pertinence to meet planning and white for the low pertinence (Moscarelli, 2005).

Subsequently, all the connections described were sorted and ordered according to their importance. In this step, we have refined the connections until the identification of a central category, the core. The objective of the central category definition is to build one master line to project territory orientation. From these tests three major results have emerged:

a) The higher the level of analysis is, the more restrictive are the number of priorities for urban management projects and greater has been our knowledge on the field, particularly as regards to environmental dynamics,

b) The identification of the central category,

c) Many recommendations on urban project strategies concerning environmental characteristics.

2.2 The analysis of the role of institutions in the planning process

A successful management project is often linked with the analysis of the initial state of the environment, with the fine relation between cost estimates / real costs and with the overall quality of the project. But other major factors are not always taken into account. Understanding the demands and aspirations of residents as well as community involvement are important factors to consider, in order to create a successful project.

Thus, this work, examind by Cardoso (2006), has been focused on the influence and position of the institutions in the face of the scenarios established, leaving people's representation for the next work.

The objective has been to regroup the positions of the actors in different spheres, more or less homogeneous, based in the arena system, where groups involved develop these arguments and debate.

By using the methodology of "social constructionist perspective" (Hannigan, 1996) and the analysis of the content of the actor's dialogue as a tool , this work has compared the results from interviews (key actors) with speeches integrated into the acts, manifest and other historical documents. This literature review has involved institutional records since the park was created until the execution of this work, acts of environmental organizations, residents associations and meetings conducted for the local religious community. Unfortunately, this material was not completed, allowing only a partial series of analysis of positions, symbolisms and interests of different groups. This work matched the following steps:

a) structured interview with key representatives of civil governmental and non-governmental associations identified in the study,

b) collection of documentary and historical material on the territory,

c) interviews conversation and documents analysis ,

d) Identification of positions of political and social actors.

The grid of the interview was divided into four stages: (I) the socio-professional trajectory, (II) the representation of the Regional Park *Delta do Jacui* and the change of status for Environmental Protection Area (APA), (III) the representation on the relationships between the different actors and institutions, (IV) its role in the history of the Park and the community.

These interviews were conducted over a period of four months. As a result, several concentrations were defined according to different subjects, showing the use of argumentative and symbolic resources to support various real political, social, scientific and economic interests. In our point of view, the knowledge of these biases and the strategies of the actors to defend these points of view are essential to the efforts of consultations needed for urban planning operations which are to develop.

2.3 People's perception as a start for the development of territoral management

The third study, worked by Profes (2006), focuses on the representation that residents have of their environment and themselves, as a means of identifying the emotional bond between people and their homes and landscape. That representation also includes people's profile, values, attitudes, level of satisfaction but also their perception of their way of living. Moreover, people's concerns about juridical change and the management projects have also been analysed. The study has mobilized scenarios referring to different choices in management and therefore has been structured in different steps outlined below:

a) An exploratory analysis: the necessity to register the families and the simulation of interviews,

b) Interviews elaborate with the population, according to the sample's criteria,

c) Observation studies on people's behaviour with their habitat and environment,

d) Analysis of the data in comparison with the results of previous works,

e) Community's representation of management scenarios (constructed in the light of the all works describs int this paper).

The interview grid has focused on six parts. The first part was related to the personal information about the interviewee. The second concerned the level of satisfaction of inhabitants with their environment (home, public space, social activities, etc..). A third was based on their representation of the qauality of services and infrastructure. The fourth part focused on their housing representation. The fifth stage, was related to their environmental representations. Finally, the last part has questioned community involvement and its role in the dialogue essential for the establishment of the organization.

This work has revealed a real will from the inhabitants to adapt to the environment in order to be more resilient. Moreover, doubts about legal changes and planning process are central in the discussions.

2.4 Vernacular architecture as a strategy for the resilience and landscape reshaping

This work focuses on an analysis of the vernacular typology and construction techniques (materials, "*savoir faire*" and spatial characteristics of housing construction) because, according to Caldeira (2008) who argues that cultural components are tangible products of human beings, and a result from their ability to live with the environment as well as artistic and / or historical objects.

In the same trend, the ICOMOS (1999), into the charter concerning the vernacular architecture, has defined the notion of heritage as "the fundamental expression of the community culture, of the relationship between one population and its territory, whilst being the heritage that represents the best global diversity. Into the charter, a vernacular construction could be considered if it shows the following characteristics:

a) Construction system shared by the community,

b) local or regional features which show its adaptability to the environment,

c) form, style and appearance uniformity,

d) informally transmitted expertise,

e) adequate response to functional, social and environmental demands of the society,

f) Suitable implementation of systems and expertise.

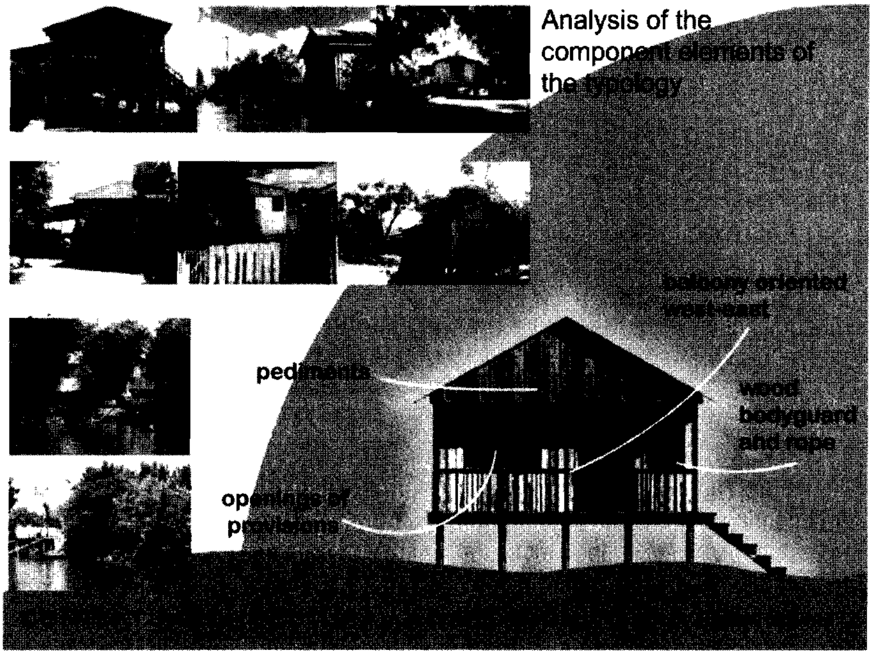


Figure 3: collection of facades photographs and typological characteristics of the vernacular architecture of the island Grande dos Marinheiros (Moscarelli and Magro, 2007)

To summarize, this type of architecture requires little energy and few resources because of its bioclimatic and functional character. Moreover, built with recyclable and biodegradable materials, it has the advantage of disappearing and becoming part of the environment at the end of its "useful life". In our opinion, vernacular structures are those that best reflect what we identify today as "sustainable architecture". Coming from people expertise adapted to weather and geographical constraints.

All characteristics that we can find in *Grande dos Marinheiros*'s vernacular architecture. Several elements illustrated in the figure 3 (photographs, computer rendered images) represent vernacular strategies for these constraints:

a) use of roofs constructed with baked sand and wood structures able to protect the house from constant changes in humidity and temperature,

b) key access and services with solar oriented east-west, while opening the bedroom windows from the sun in the north (southern hemisphere) whilst avoiding openings in the south,

c) use of covered balconies, allowing the deep openings (doors and windows) responding to summer sun and heavy winter precipitation,

d) use of wooden stilts that allow the protection characteristic of the moisture field and safety from floods (June, July and August)

e) Use of guardrails for safety and aesthetic composition,

f) Mimetic materials in match with the environmental components, in a "green landscape" despite the presence of many houses.

These vernacular strategies were initially taken into account by the first settlers from immigrations. But, with the growth of these demographic movements, trade between the traditional population and new residents are less frequent. As a result, many constructions have been built in extremy vulnerable situations and the urbanization has been orientated in a way that diverges with the principles of sustainable planning. These reflexions pose the question as to how this analysis of architectural heritage can aid in recommendations for the actual design and construction of the vernacular architecture, specifically in our case study.

3 Towards Sustainability Qualification of Island Grande dos Marinheiros

In the light of paper's purpose to present an approach to build a method of territorial planning, able to respond to both sensitive environmental territories and sustainable request, this chapter propose the significant results apply to case study.

The principal results of first analysis based on the inter-relational matrix, concern the identification of core categories such as water's supply which is considered as priority issues in territorial management. In addition, this analysis gave several technical recommendations about basic infrastructure and services such as:

a) Electricity: it's not recommended to use biomass energy, small hydroelectric and wind power. These options do not seem adapted for ecosystem characteristics. Our study has illustrated the possibility to substitute the informal existing network by burying them. This solution avoids disruptions caused to the intense borders vegetation at the same times and enhanced the natural landscape.

b) Transport: the study suggests that river transport is the most advisable regarding cost, travel speed and service quality. It seeks to prevent further restructuring bus public transport because the study results emphasize that one should avoid the consolidation of streets, which historically is destroyed frequently by flooding. The combination of collective boat and light individual transportation (such as bicycle, for example) appears to be the best option.

c) Water's supply: the implantation of networks mainland-island is not recommended. This action can brought imbalance on constant sedimentary formation. Furthermore, there is a great technical difficulty and high cost of implantation of this option. The viability of surface water appears as better solutions. However, its use is dependent on a control system restructuring of organic waste between municipalities around the *delta do Jacui* park. Also, the high historic rainfall seems to allow its incorporation in water supply. It requires multiple treatments (pH correction, chlorination) and it will always be a complement to another system because of their seasonal nature.

Another important result is obtained through to vernacular architectural analysis. A list of vernacular strategies is suggested to qualify existent or new houses (illustrated in figure 4):

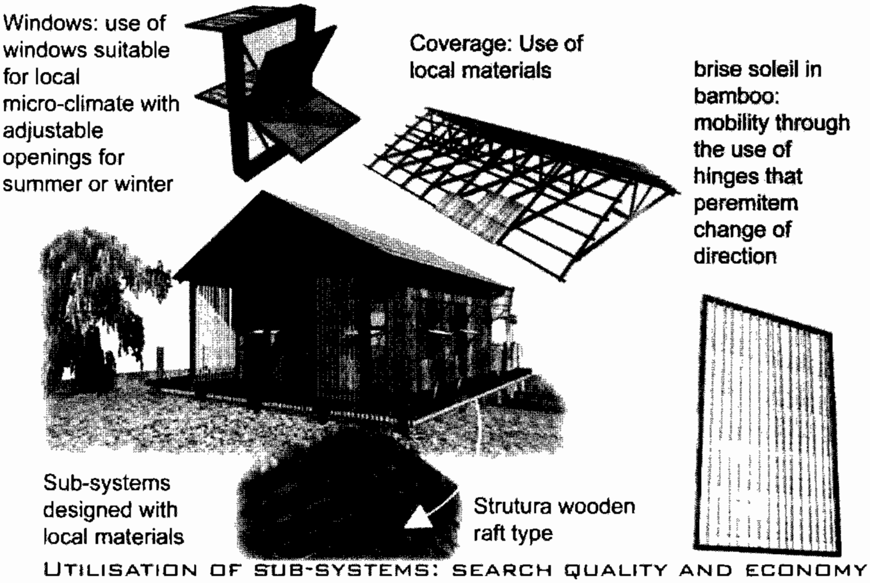


Figure 4: syntese of project strategies based in vernacular analysis to houses qualification (Moscarelli and Magro, 2007).

a) Integration of "savoir faire" and typical materials in subsystems for habitations qualification,

b) Incorporation of bioclimatic strategies of vernacular houses in architectural projects of territorial management,

c) Integration of design concepts based on spatial divisions, on windows positioning, on balconies, and pillars arrangement and so one.

As far as people's perception is concerned, theses recommendations cited above were presented to discussion with residents and were confronted to their representations. Such confrontations have generated several scenarios for territorial management.

In the same time, the institutional political analysis, presented in the chapter 2 identified the particular and collective interests. This analysis shows the different actors position regarding the territorial issues and regarding the several scenarios proposed. The main objective is to build strategies for participatory territorial management in the island Grande dos Marinheiros.

This work was developed with an intense process of discussion and consultation between actors: students, organizations, associations and inhabitants. During the development of this methodology we have succeeded in (I) have a deep knowledge about the complexities of the case study, (II) refine the general guidelines for future projects and (II) create a pedagogical process with the territorial actors.

Finally, this paper was aimed to promote strategies to make communities more resilient and to encourage tourism through the value of vernacular architecture. Also it is intended to demystify the usual image that is associated with traditional constructions: precarious and without aesthetic value. The key to develop sustainable cities in developing countries lies probably in the possibility to overcome this collective perception. This requires a real change in the paradigm.

Acknowledgements

We would like to express our thanks to the Technical Secretary of Environment of Rio Grande do Sul, the direction of the State Park Delta Jacui and all those who helped with data, work or their free time. We also would thanks the interesting of the community association in the studies developed.

Finally, we thank our colleagues involved in this set of studies that represented their master works: Cardoso, Profes, and the recherche projet group: Magro, Tomazinni, Ercole.

References

CALDEIRA, C. C. (2008). Conservação Preventiva: histórico. *Revista CPC - Centro de Preservação Cultural.* Retrieved december, 2008, from: http://www.usp.br/cpc/v1/php/wf09_downloads.php

CARDOSO, P. M. (2006). *Conflitos socioambientais em áreas protegidas : interesses e estratégias nas disputas pela legitimidade na redefinição do Parque Estadual Delta do Jacuí-RS.* Master Document. Economical Rural Development Post-Graduation Programme. Porto Alegre: Ed. Universidade/UFRGS.

DAILY. E. (1991). Elements of Environmental Macroeconomics. In: R. Costanza, Editor, *Ecological Economics: The Science and Management of Sustainability*, Columbia University Press, New York, 32–46.

FUENTES, J. M. (2010). Methodological bases for documenting and reusing vernacular farm architecture. *Journal of Cultural Heritage,* 11,119–129.

HANNIGAN, J. (1996). *Sociologia ambiental: a formação de uma perspectiva social.* Lisboa: Instituto Piaget.

ICOMOS. (1999). *Charte du Patrimoine Bâti Vernaculaire.* 12th Assemblée Générale de ICOMOS, October, 17 – 24. Retrieved december, 2008, from http://www.archeologia.be/legislation_textes-internationaux_charte-de-mexique-3.html

IGLESIAS, F. T. C. (2000). Arquitetura Sustentable de tierra em la Habanna. *Terra 2000: annals 8th International conference on the study and conservation of earthen architecture.*

YANG, K. (1996). *The Skyscraper Bioclimatically Considered: A Design Primer.* Wiley: Chichester.

MENEGAT, R. (org.) (1998). *Atlas Ambiental de Porto Alegre.* Porto Alegre: Ed. Universidade/UFRGS.

MOSCARELLI, F. da C. (2005). *Aplicação do método baseado em danos para análise de alternativas e tomada de decisão em assentamentos precários com complexidade ambiental : o caso da Ilha Grande dos Marinheiros, Delta do Jacuí, Porto Alegre/RS.* Master Document. Civil Ingeneer Post-Graduation Programme. Porto Alegre : Ed. Universidade/UFRGS.

PROFES, M. B. (2006). *Contribuições da percepção ambiental a intervenções mais sustentáveis em assentamentos precários em área de vulnerabilidade ambiental : caso Ilha Grande dos Marinheiros.* Master Document. Civil Ingeneer Post-Graduation Programme. Porto Alegre : Ed. Universidade/UFRGS.

Proposta para redefinição dos limites do Parque Estadual Delta do Jacuí (2002). Porto Alegre: Secretaria Estadual Do Meio Ambiente.

STRAUSS, A. L., & CORBIN, J. (1998). Basics of qualitative research: *techniques and procedures for developing grounded theory* (2nd ed.). California: SAGE.

Ecological, Social and Cultural Sensitivity

Research into the sustainable development of our built environment has emphasised the need to address a diverse range of issues. In there, the critical role of technology had been long emphasised. Initial concern focused on how socio-cultural aspects were impacted by the reconfiguration of our technological horizon, which in turn, was redefined by our growing need of and desire for specific technologies. An important development in the production of sustainable built environment in more recent times has been the realisation that this binary relationship between technology and society has proved inadequate. The myriad of factors impacting our lived world – ecological, human and material – has instead forced us to focus on the dynamic interrelationship between these, which could be broadly termed, 'sensitivity'. The word suggests both a need for understanding these forces independent of each other, as well as the imperative to react to these with urgency and commitment. The papers included in this chapter address aspects of this sensitive and proactive approach.

Razmkhah, Hanif and Dali address the important role of parks in the life of Tehran residents and make a case for their retention and sustained improvement. The authors address the distinctive, more immediate social role of these urban spaces in comparison to their western counterparts. In discussing the development of 'Ali Mendjeli', the new town under construction on the outskirts of Constantine, Makhloufi emphasises the importance of considering personal, social and spatial experiences in successful urban housing development. Bellu, Issini, Pugnaloni and Srisuwan emphasise the need for developing new and appropriate methods and tools for addressing socio-cultural integration, while addressing regeneration within evolving historic cities. Taking the case of Chaing Mai in Thailand they stress the importance of collaborative design involving all stakeholders. Dziura, Tahira and Colino on the other hand, discuss the important role of multi-functional buildings in sustainable city planning in Curitiba in Brazil.

Soumyen Bandyopadhyay
Nottingham Trent University, UK

Enhancing Urban Quality through Natural Architecture and Cooperative Design: The Case of Chiang Mai, Thailand.

Elena Bellu[1], Giovanni Issini[1], Fausto Pugnaloni[1], Charnnarong Srisuwan[1]
[1] *Polytechnic University of Marche, Italy*

Abstract

The objective of this work is to define and test a method of approach to urban and environmental regeneration in historic cities with strong socio-cultural integration issues. The research group has defined and tested methods and tools in order to approach the project of urban regeneration of degraded areas of historic Asian cities. The research carried out suggests a method of approaching the design for this type of degraded areas, combining innovative design tools, taking as reference system, the sharing of decisions with the people involved and the clear exhibition of the transformation strategies. The paper analyzes also a particular case study, wherein the research group tested the defined method. It covers the area along the Mae Kha canal, near the city of Chiang Mai in Northern Thailand. Cities prone to strong development, as the case study, must deal with the presence of illegally occupied areas, with no real collective identity, which need to be redesigned with a view to sustainable urban reorganization that places the focus on the needs of environmental, social and economic. Particularly, the work focuses on public areas containing cultural heritage, subject to occupation by poor foreigner communities. The strategy is based on a recombination of the site values, that creates new forms, giving a role to the inhabitants and put them in a particular recognizable habitat. In order to achieve the expected results, the tools of sustainable design, self building practise, and shared environmental and urban design, becoming essential.

Keywords: *Sustainable architecture, low cost housing, collaborative design*

1 Background

The focus of the present work is on a kind of urban decay which is frequent phenomenon in the context of Asian intermediate cities (population of less than five millions). This phenomenon involves illegal occupation of areas that fall within the urban fabric of historic and/or environmental value.

The wider question of the housing policies for poor in Asian cities, is deeply studied by NGO and research institutions from many years. Some indicators shows how this issue is important in the planning outlook of urban agglomerations in Asia. Cities and towns produce up to 80% GPD in Asian countries. Even for this reason, experts say that most Asians will live in cities by 2030 (Asian Migrant Centre, 2002; Abella M, Ducanes G, 2009). UNCHS calculates that to accommodate them is equal to building a town of 140.000 inhabitants every day for next 22 years. Observing these indicators, it's easy to understand the relevance of slum settlements in Asian cities (UNESCAP, 1996). UNCHS calculates 42% of Asians living in cities live in slums or informal settlements (Table 1), and the slum extension grow incrementally (UNESCAP-UNHABITAT, 2008 b). Figure 1 shows the migratory trend in East-Asian region.

The illegal occupation of the areas is often caused by domestic or international migratory processes. Several studies, carried out by International organizations, testify the intensity of the illegal migration among Asian countries, especially addressed to the richer nations (Thailand, South China). In some countries, as Thailand, the legal and illegal migrant flows are constantly rising, and the issues linked to the quick development of medium-size city are becoming very important for local authorities.

Table 1: Slums population in Asia. Source: UN-Habitat State of the World's Cities 2006/2007

Region	Total populations (in millions)	Total urban populations (in millions)	% of total population	Total slum population (in millions)	% of total urban population
Eastern Asia	1,364	533	39,1	193,8	36,4
South-Central Asia	1,499	429	29,6	253,1	59
South-East Asia	530	203	38,3	56,8	28
Western Asia	175	115	65,7	29,7	25,7
TOTAL Asia	**3,519**	**1,280**	**36,4**	**533,4**	**41,7**

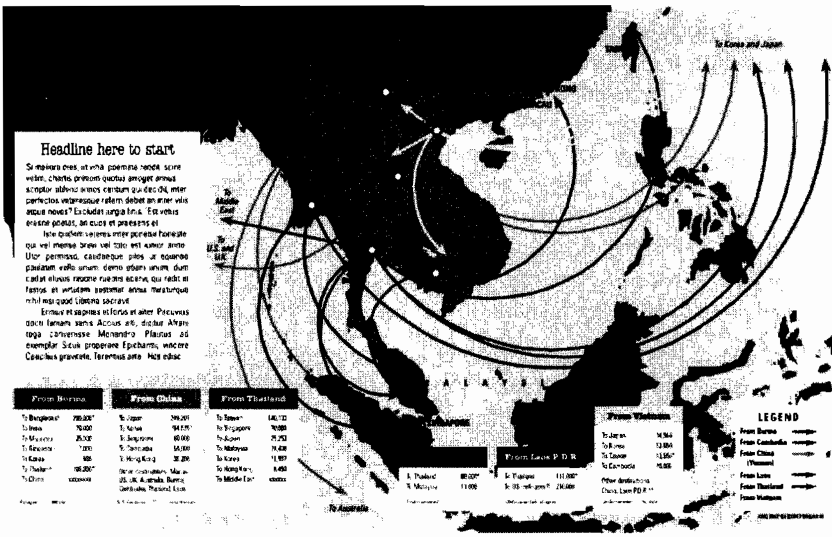


Figure 1: Migration flows in the Mekong Region, 2002. (Source: Asian Migrant Centre, Resoce book 2002)

In the case of Thailand, the AMP (Asian Migrant Centre) affirms that the documented and undocumented migrants in 2002 were more than one million (30% legal and 70% illegal), coming from Myanmar, Yunnan and Laos, and they mainly moved towards the northern and central districts (Asian Migrant Centre, 2002; Abella M, Ducanes G, 2009).

The migrant communities create therefore slums and informal settlements in public areas, in order to establish relationship with other migrants and part of the local community. Paradoxically, they suffer from social and urban marginalization in spite of their central position in the cities. The present work studies solutions for informal settlements characterized by the presence of ancient monuments. They may have historical or/and artistic values and they show different levels of codification and conservation by local bodies. UNESCO and ICOMOS in the annual report of Monuments and Site in danger, present many cases of risk situation related to the lake of proper planning and to the development pressures in cities (ICOMOS, Petzet M, Ziesemer J, 2008). The third characterizing feature of the studied site typology is the environmental pollution, linked to the lack of base infrastructure and to the improper lifestyle of the slum inhabitants. Agglomerations that are at risk of becoming an area of historical and environmental degradation are usually lacking in long-term planning, infrastructure and public services and also in the habit to deal with social problems and emergency situations. Factors which could increase these risks and make this degradation more severe, are both external and internal to the city. External factors: rural poverty; proximity to administrative boundaries of less developed or under conflicts regions and countries; natural disasters. Internal factors: strong imbalance of income among social classes; being an urban area which has a significant international tourism; proximity to international industrial park; bad urban governance; lack of planning policies for housing, environment and cultural heritage. The many complex issues that urban development of cities in developing countries have to be faced, require appropriate instruments which can provide complete solutions to this type of criticality. The difficulties of maintaining acceptable health standards and of avoiding the isolation and segregation of these areas are often taken care of by means of traditional urban planning tools which have the limitation of not being able to adequately analyze the complex social relations in cities.

The most common critical factors in historical and environmental areas subject to deterioration, are: lack of social and cultural relations in an urban context (segregation); social conflicts between squatters and ordinary citizens; illegality and crime; inadequate hygienic standards; attraction of illegal immigration; lack of primary infrastructure and consequent pollution of soil and water resources; not being able to identify historical, artistic and architectural values; loss of value of cultural heritage meant as a resource for urban qualification, economic and social development; risk of irreversible impairment of the physical integrity of historical and environmental heritage.

One of the context in which the research group works is the city of Chiang Mai, northern Thailand. It was founded in the thirteenth century in the valley of the River Ping and Mae Kha, within a square brick fortification. In the late eighteenth century, after the expulsion of the Burmese, King Kawila enlarged the city and build new fortifications using the technology of compressed clay layers. This project required the diversion of the original course of the Mae Kha. Its waters were diverted into the Ping River, while the original riverbed became part of the Kampaeng Din system of defence, placed along the left bank of the Mae Kha canal. The area between the Mae Kha Canal and Ping River is of recent urbanization, and houses tourist accommodation and facilities and commercial sites. Chiang Mai is now a major tourist destination, but also the arrival point for many migratory flows from the mountains and Myanmar whose border is around ten kilometres. On their arrival, immigrants tend to settle illegally in public territories leading to the emergence of pockets of poverty, especially along the areas of the Mae Kha canal and Kamphaeng Din (Ribeiro G, Srisuwan A, 2005). Figure 2 shows the overall urban design of Chiang Mai city, and the position and size of the Mae Kha canal. Anthropogenic pressures, determined by urban growth, squatter settlements and poor infrastructure lead to social tension and troubles along the canal which consequently cause environmental degradation, pollution and marginalization in the urban area.

2 Design Models

The Chiang Mai Department of Fine Arts and the Chiang Mai Municipality plan to propose a project of restoration of the ancient fortifications which includes Kamphaeng Din, recognized as a potential heritage which can increase cultural tourism. Therefore, the presence of the highly polluted canal, which flows a few meters from the wall and the poor communities that have settled down in this area, are seen as an obstacle for the implementation of the project.

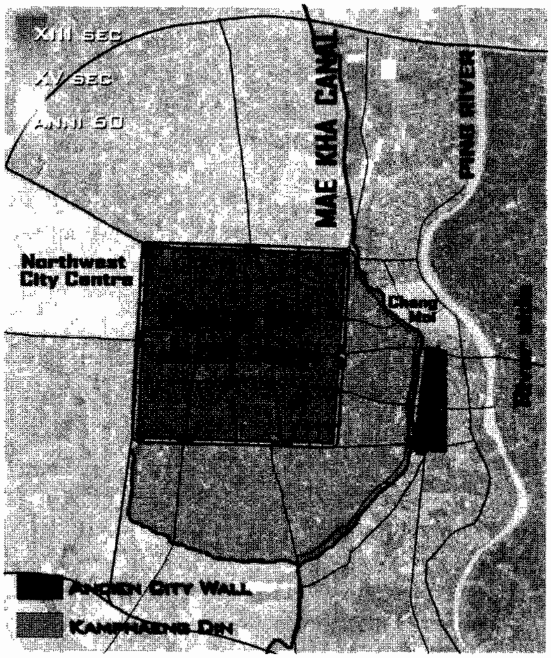


Figure 2: General view of Chiang Mai

The plan designed by local institution aims also to push the Mae Kha communities out of city (Ribeiro G, Srisuwan A, 2005). The weakness of the traditional approach of local governance is that it plans separate programs to face each problem, while the right solution should take care all the factors, providing integral answers. Environmental rehabilitation of the context cannot disregard a social project that can better integrate the community with the territory. The groups of research proposed therefore a design method to join the different needs, in order to assist public authorities to manage the area development through new indicators. International bodies (UNESCO/ICROM, UNCHS, WHO, UNDP) already established protocols and best practises in order to start good national and local governance of the specific issues. On the basis of these protocols the research team proposes technical and methodological instruments. The challenge is to define and combine different strategies which are able to face more than one theme, and to evaluate how the strategies can be convenient both for communities and for local institutions. The analysis and study design of the instruments taken into consideration demonstrates how urban design and architecture, shared and backed up by real participatory communication, are able to create conditions for providing new and re-naturalized urban landscapes, in order to strengthen the relationship between human and natural environment.

The research group decided therefore to apply the design instruments starting by a common approach: the communities involvement in the planning and architectural design and subsequently to a part of the building process. Virtual Reality and Multimedia tools allow to understand the planning and architectural design process (Gaiani M, 2003; Jupp G, Raghu R B, Skip V K, 1993). These kind of instruments were already applied as tools for urban planning in many western countries and also in some Asian megacities. The added value of the virtual reality and multimedia tools application in the typologies of area studied in the present work are the following:

- It allows to unskilled and illiterate citizens to understand the design strategies;
- It allows to architects, planners and politician to acquire feedback in order to define a successful project;
- It allows to preview the impact of new building and houses on the cultural heritage sites;
- It allows to native citizens to preview the city upgrading;

Virtual reality can have many ways of development and application. In the case of Mak Kha canal the research group tried to combine three needs: low technical complexity, interaction between the virtual environment and users, visualize both overall site and buildings. For a balanced technical solution the research group chose to avoid the use of immersive virtual reality systems. Certainly they allow to enhance the interaction and participation of users, but they also need complex technologies that maybe damp unskilled people. Moreover, there was the need to show contents to a large number of people in a short time. So, the technical instrument should be reproducible and directly accessible to users. The final option was to realize detailed 3d models, with different level of detail, to visualize the design contents. The interaction and participation were ensured by proper multimedia product. The multimedia system, realized by traditional tools (Flash, etc), allows both the visualization and the aided understanding of the design strategies, even adding tutorial audio in different languages (Vassilis B., 1998). The second level of direct citizens involvement strategies is the participation in the building process. It's well-known that such process can be done in different ways. All the work can be contracted out (private or public building enterprises), or the entire project can be built by the community members themselves (Anzorena, Eduardo J. S.J., 1996).

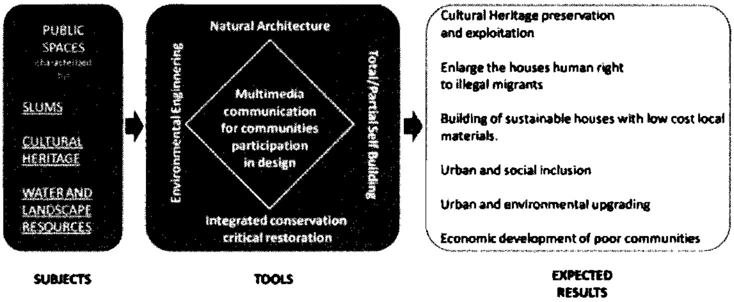


Figure 3: Scheme of the design strategies and tools

Depending on the specific case, the final work is done by a combination of the two, with the people doing as much of the work as possible themselves, and contracting out only the more heavy or specialized or technically difficult tasks in the upgrading work. Figure 3 scheme summarizes the design strategies. Starting by the site conditions, the four tools allow to achieve the expected results. The methods and tools used in the design process are based on Sustainable urban and architectural design practises. It's possible define four main tools. Each tool has been selected because it satisfies the overall policies promoted by International bodies, and it is able to answer to different needs, analysed in the previous chapter.

1-Natural Architecture is an emerging art movement that is rooted in the human need to reconnect to the earth, through the built environment. It uses simple and raw materials, made by hand using basic and primitive construction methods and turning them into artefacts artistically. In the case of Mae Kha area, we proposed structural typologies by willow trees. The structure are realized farming cut stakes. Because of their particular shape, they provide natural ventilation and lend themselves well to the creation of structures for open space, for public activities and tourist accommodation (Rocca A, 2006).

2-Environmental engineering allows us to combine the technological requirements of the river embankment design with the environmental and landscape needs of the area in which we operate, aiming to create a balance between anthropical and natural space. These types of projects in natural areas must take into consideration their aesthetic and natural aspects and which cannot at the same time neglect the technical value of the In the Mae Kha case, regimentation of water and action on the riverbanks is required in order to bring back the canal to its original function without having a strong impact on the territory. The works of protection on the banks are primarily intended to prevent erosion, especially as it could jeopardize the stability of slopes. Obviously, in this case a transformation of the bank will be followed by a regularization and shrinkage of the canal bed. In these operations, the limits of application are obvious, particularly in cases of high human activity. When the streams, for example, have large buildings along the bank strips, normally there is no space to accommodate works that lead to the reduction of the speed of running water or plumbing section. The project plans to control the flow and to restore the banks based on empirical experiences, In this way, the technical solution will be selected on the basis of their applicability in the Mae Kha site, according with similar application in other contexts (De Deppo L, Datei C, Salandin P, 2004).

3-The Shared Self Build is important because any action of natural type is likely to be temporary if not supported by a real sense of identity of the people towards the territory and the city. This practice is able to develop labour training, increasing the usefulness of an individual and helping social groups to mature. In developing countries the rate of population growth, immigration in the metropolitan area and the slow but steady process of degradation of the land of culture provide some evidence that Shared Self Build can facilitate the restructuring of the local economy through appropriate programs of social housing. Choose the "Shared Self Build" project stems from the desire to positively engage as many people as possible in the construction and regenerative process of the area. It is perfectly suited to landscaping interventions that require knowledge of the territory and local natural materials, which are the basis of the Natural Architectural projects and Bioengineering. These two technologies with low economic and environmental impact allow the beneficiaries, i.e. residents, to get involved in participatory processes, in the designing and fulfilment monitoring.

4-Integrated conservation and critical restoration approach. Regarding the need for restoration of the cultural heritage placed in studied typologies of urban area, the theory of critical restoration has been taken into consideration. As well-known, this theory disapproves the instrument of pre-established direct intervention, and wants restoration strategies be identified in each case. For this reason the design model doesn't establish any direct restoration method or strategy on the monumental objects. Just the recovery of the architectural heritage in relation to its context is the subject of our analysis. The aim is to create optimal environmental conditions to allow the integral restoration of the monument. At the same time, the external causes of degradation must be put to a stop. Restoring and maintaining the wall will not be enough to turn the area into a cultural and tourist attraction. In order to achieve this it needs to be reconnected with the urban context where it takes place, restoring the access to and the route along the Mae Kha canal, making it recognizable as urban sign (Carbonara G, 1997; ICOMOS, 1971; ICOM/UNESCO, 1964).

Combination of these four design methods, carried out by unskilled workers, allows to involve in the planning and execution activities citizens and poor communities, promoting a social architectural movement. Overall, the planning method is intended to respond to environmental, cultural, social and economic needs. Sustainability is the keyword to approach these needs, in order to define long term successful solutions. The goal is to maintain an economic development compatible with social equity, ecosystems and the historic city, working towards a liveable and workable equilibrium.

The main purpose of these methods is to make constructive processes understandable to unskilled workers which would restore the old meaning of personal fulfilment, and at the same time provide an opportunity to form communities and increase solidarity (UNESCAP-UNHABITAT, 2008a,b). The proposal of this project stems from an interactive process which involves a thorough understanding of the issues, needs and potentials of the city through different criteria, which would be translated into a model of transformation. Finding the right model will become basics: The use of pre-existence as intrinsic values and the ethical commitment to design in accordance with the principles of environmental, social and economical sustainability.

Gentrification process lives on the inner imbalances of the city. It runs on an existing social "differential" between citizens. Minimizing of such "differential" means hold up the gentrification process and so to aid its control by local authorities. The proposed design method, based on the Government initiative in the short-term period, creates the conditions to enhance the economic conditions of the Mae Kha inhabitants. When the speculative actions will start to affect the area, the majority of the inhabitants should have good income conditions, and so they will be able to contrast the displacement forces by wealthy citizens (Sampaio J. C. R., 2007). Participation is the first step of a social revitalization process. In the mid-term period it will create the best conditions to start the restoration and recovery of the historical and cultural values of the site.

This process benefits by the small/medium dimension of Chiang Mai city, where the Mae Kha canal area is the main holder of social imbalances.

3 Case Study in Chiang Mai, Thailand

Participatory process defined in the study design incorporates a series of basic steps to achieve a real social project:

1. Knowledge: basic training for those involved in the process;

2. Sharing objectives: through questionnaires and interviews investigating the real desirability and necessity of actions and agree on objectives;

3. Sharing design: analysis of alternatives and determining the best design strategies.;

4. Construction: increasing a sense of responsibility for the project, starting workshops and social construction sites where even unskilled labour contributes in the building phase.

The defined design model was applied in the Mae Kha case. Such site shows exactly the features of the area typologies. Existing works analyze the main issues of the Mae Kha area: informal settlements, monumental elements, pollution, tourist exploitation, lack of basic services that are not provided by local authorities. Population of the Chiang Mai province increased from 1,200,000, to 1,600,000 due the migratory flows rural provinces and from Myanmar. Tourism is the main economic activity. Thailand Tourism authorities calculated around 3,500,000 the number of guest arrivals in 2002 (Chifos C, 2006; Ribeiro G, Srisuwan A, 2005). The model tried to face these issues, designing suitable architectural and environmental solutions. Srisuwan and Ribeiro examined the relationship between Mae Kha area and local institution. The actors of the Mae Kha management are the communities leaving in the 17 informal settlements, NGOs, the Chiang Mai Municipality and other bodies by civil society, like the Lanna architect association and international donors, who carried out environmental project on such site.

In the case of the redevelopment area of the Mae Kha canal, poor communities living along the canal were interviewed in order to understand their social issues and needs. In the same way, information was gathered by citizens and researchers from the University of Chiang Mai, who had worked in the past along this area. The choices for the design were also shared with them. The instruments used for the sharing of design have been tuned to facilitate the understanding of the design solutions that more interested the residents, using virtual simulations and digital models of interventions in the area. A multimedia tool has been realized. It shown the design strategies and clearly explain the architectural and urban solution. A list of feedback has been collected following up the visualization step, and they have been used to optimize the project features. The following figure 4 is a sample of the virtual environment of the project, shown to the interviewed citizens. One of the main issue of the Mae Kha area is the mixture of slums with vernacular building, occupied by migrants during last decade. The main bad elements of the residential system along the Mae Kha canal are the houses overcrowding and the pollution of the surrounding environment.

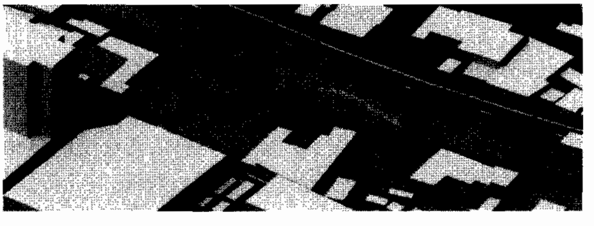


Figure 4: Virtual model of the upgrading design of Mae Kha area

Houses are aligned along the Kampaheng Din wall and they are directly faced on the patch between the canal and the monuments. This promiscuous status and the environmental decay avoid a tourist exploitation of the site because tourists should cross slums to visit the monument. Through Figure 5 is possible to understand the mixture between vernacular building and slums, and to observe the unsuited life conditions. According with the area analysis and with the citizen feedback, the strategy of housing upgrading starts by demolition of the added part, built with unsuited and unsafe materials. The strategy doesn't aim to realize new building for housing, while it's finalized to restore the existing vernacular building, built on the basis of the Lanna traditions of North Thailand. The project of restoration has three steps: the rehabilitation of the wooden structures; the enhancement of interior quality of spaces in terms of lighting, airing and healthiness; the realization of the sewer system.

Figure 5: Slums along Mae Kha canal.

This choice will allow to residents to carry out maintenance of building themselves. Demolition of slums between vernacular building will produce a decrease of people density in the area (Sangawongse S., 2006). This problem will be faced indentifying in the urban plan new areas for new sustainable residential settlements (Figure 6). The strategy adopted in the housing management is able to solve the issues linked by housing needs, but also to aid the achievement of the other objectives. In fact, the rehabilitation of vernacular building and the demolition of slums, will allow to have more public space and to support the tourist exploitation of the area. Moreover, spreading the house units on a longer patch, will allow to reduce the impact of the human activities on the monument and on the environment. According to the centrality of the area, the project shows a new system of sustainable of pedestrian and car mobility, from which we can then retrain all the other points. In the design strategies (Figure 6) the research group considered the important urban and environmental elements to preserve by new realizations. From the feedback, an analysis was carried out directly on site that showed the potential and critical aspects of the area. The design process is built on three levels. From an urban point of view, the creation of a single continuous pedestrian path is proposed that helps to reduce traffic primarily for citizens who move in the north-south direction, and which is also permeable to pedestrian tourist flow that moves transversely.

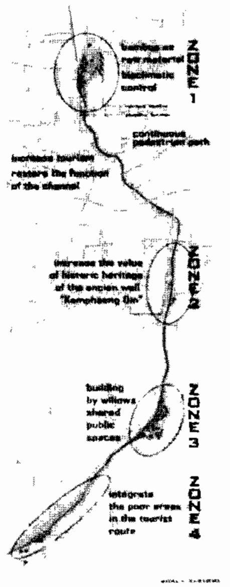


Figure 6: General masterplan of the Mae Kha canal upgrading

Moreover, the patch will partially overhang the water, in the riverfront section where in the buildings are close to the embankments. According with the citizens feedback, the design strategies proposed to insert in the area both public and residential functions. For this reasons the research group designed a harmonized system of small public areas that redefine the centrality of the collective functions of this area. The role of these public spaces is to transform the Mae Kha in a meeting area, where the poor communities can meet and establish relationship with the other citizens which offers to be a transit area, but also and especially as a staging point and meeting. Through vegetation and urban green spaces, the project tries to appease the hot humid climate, severely exacerbated by pollution and urbanization. All operations which are proposed in these areas and along the canal are based on the principles of Natural Architecture and Bioengineering and tend to "renaturalize" man-made space, recovering and enhancing the relationship with the habitat that surrounds it (Sheer B, Sheer D, 2002).The housing space will be partially screened by public area, through a green wall made by natural material (Figure 7). The structures that are inserted in public areas will be implemented through a constructive method called Mudhif. The technique consists in the planting of willow branches and roots in a defined perimeter. Then they are wrapped around a thin steel core that guides the growth of the plant. At the top, they are tied tightly so that they are able to support themselves. Over time, the branches take root in the ground and grow rapidly, continuing to wrap around the core of un-galvanized steel to reach the summit. When this process is finished, the branches are able to support the load by themselves, instead the steel structure (Figure 8). While the roots take on the static load, the steel pipes corrode gradually losing their function carrier. Such kind of building can grant benefits also for other issues. By means of them we avoid to realize traditional building for public services, that can have impact in the environmental and cultural image of the site. Moreover, the Mudhif structures are perfectly fitted to be inserted in park and public spaces, because they need very few maintenance (Kalberer M, 2006/2007). Environmental engineering was applied as tools for the upgrading of the Mae Kha embankments, and to enhance the quality of water. First the research group acquired existing data on the depth and width of the canal bed, the low and high-water marks. Particular studies were carried out to obtain records of the canal discharge, the speed, the solid transport and the landfill measurement (Firoz A S M, 1996; Kold, R et al 2002).

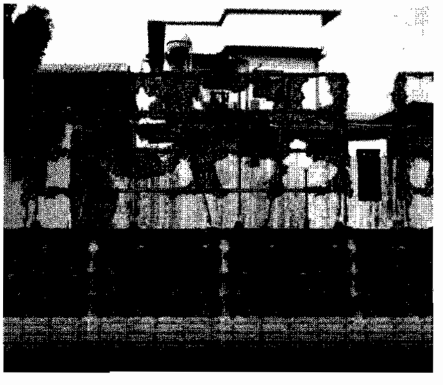


Figure 7: Screen system between private and public spaces

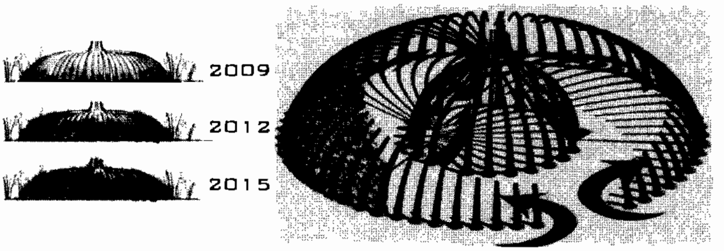


Figure 8: Public buildings made by Mudhif method

These information allow to recognize the main issues of the Mae Kha canal management: low speed and discharge of the river during the dry season; and the flood risk during rainy season; water pollution. Several studies demonstrate that Mae Kha canal was already pulled since 1978. The Kold et al. study, affirms that the slums along Mae Kha contribute only marginally to the pollution of its water, and the main contribution comes from the city centre sewage system. The project realized by the research group proposed the following preliminary operations: to realize a new sewer system through a new main pipe, parallel and close to the canal and secondary branches that will catch waste water from the residential blocks; Cleaning of the canal bad. The specific design solutions (Figure 9), deriving by environmental engineering are the following:

Renaturalize the river patch through new water filter upstream.

On the first section of the canal (1.6 km) it will be realized a tillable "bank mattress". The river slope will be lined by biological mat, made by coconuts and straw. It allows to constrains the erosion action on the canal bed and slopes.

On the central section of the canal (800 m) it will be built a grating system. It is integrated with the pedestrian patch and it sustains the structure for the slopes retaining.

Along the final section (1 km) it will be realized a wicker structure on the bed and banks of the canal. Its role is to reinforce the terrain close to the slopes.

The project strategies will allow therefore to recover the environment around the cultural heritage elements. Along the route you will encounter elements of the historical and cultural city, like the earthen wall "Kampaheng Din", which will be restored by the Department of Fine Arts. First such institution aimed to restore the fortification system of the city, evicting the informal communities. After an agreement with inhabitants, they accepted to keep the communities inside Mae Kha area, but the slums realised over the wall have to be demolished or moved. For the Kampahang Din conservation, the research team proposed to install a green bamboo grid coverage, built partly over the wall and partly above the public area.

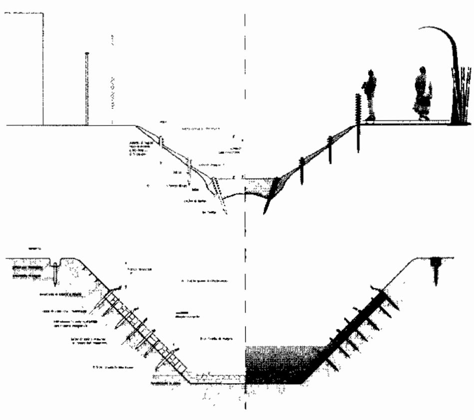


Figure 9: Environmental engineering applications on Mae Kha Canal

The Kamphaeng Din structure is based on rammed earth, with some parts of masonry made by bricks. The bamboo structure allows to repair the wall from the rain and creates shaded spaces which improve the microclimate.The project is based on a particular building technique that creates a comfortable shading system, which modulates the light, and in the same time it defines a mixed public-private space that characterize the area. Even this solution provides benefits for more than one issue. The cover allows to carry out a passive conservation of the Kampahng wall, and in the same time define new public spaces for inhabitant and tourists. Moreover, the cover doesn't compromise the physic integrity of the fortifications and it is reversible and easily recognizable.

4 Conclusion Remarks

The proposed model seeks to summarize and convey in one planning event the various needs of the place, and expectations of all those involved in the regeneration of the area. The model tries to dialogue with the three actors of the city (residents, immigrated, visitors) without forget the goals of environmental sustainability, social and economic benefits and the need to return to the community an area of historical and cultural interest. The liveability of the city is encouraged by acting on factors that allow to reconnect the central areas of a city, routes with their own identity and other urban spaces that have been transformed These areas will be therefore shared by both citizens and tourists. Along the new patch and connections there are also areas that are occupied by poor communities. These, in addition to being retrained, are integrated into the tourist system, to enable vulnerable people to identify their own role in the economic fabric of the city which will encourage them to leave their illegal status. It's important to understand that the configuration of space affects on its perception, facilitates and encourages certain behaviour. So the ultimate goal to be pursued through design coincides with the goal of a better quality lifestyle. Future development planned for the present study consists of an application of the model to other case studies and a subsequent and systematic collection of reviews by parties involved in order to also evaluate from a statistical point of view the way to sustain the choices for design. This experience has shown interesting results, made clear by some objective indicators such as: quantification of costs of the intervention (they will be lower than a traditional recovery action); administrative feasibility. This means that the project, with an initial involvement of the key actors, from government officials to residents, can be accomplished with existing planning instruments and in accordance with Thai law. Issues linked to gentrification should be deepened separately. We think that the Chiang Mai Municipality involvement and the role of NGOs are added values to realize a social revitalization that will support the cultural and environmental ones. The key of the project is the citizen participation, both in the design process and in the house realization. Such participation might be the first step of the social renewal of the Mae Kha area.

References

Asian Migrant Centre. (2002). Migration needs, issues and responses in the Greater Mekong Sub region. Hong Kong, P.R.China: Rockfeller foundation.

Regional Office for Asia and the Pacific. (2009). Prospect for future outward migration flows. China and Southeast Asia. International Labour Organization. Bangkok, Thailand: Abella, M., Ducanes, G.

Living in Asian Cities: The impending crisis, causes, consequences and alternatives for the future. Report of the Second Asia-Pacific Urban Forum. (1996). New York, USA: UNESCAP-United Nations.

Housing the poor in Asian Cities. Urbanization: the role the poor play in urban development. (2008). Bangkok, Thailand: UNHABITAT-UNESCAP.

Petzet, M., Ziesemer, J. (2008). ICOMOS World report 2006/2007 on monuments and sites in danger. Altenburg, Germany: E. Reinhold-Verlag.

Ribeiro, G., Srisuwan, A. (2005). Urban development discourses, environmental management and public participation: the case of the Mae Kha canal in Chiang Mai, Thailand. Environment and Urbanization, 17, 171-182.

Gaiani, M. (2003). Methods for using virtual environment for the web assistance to architectural and archaeological restoration. In M. Rossi, P. Solonia, Multimedia Communication for Cultural Heritage (pp. 283-324). Milano, Italy: Addison-Wesley Pearson Education Italia.

Jupp, G., Raghu, R. B., Skip, V. K. (1993). Communication in cooperative building design. In Proceedings of the fifth international conference on Computer-aided architectural design futures. Amsterdam, The Netherlands: North-Holland Publishing Co.

Vassilis, B., (1998). Virtual reality: A communication tool for urban planning. Retrieved June 20, 2000, from http://fos.prd.uth.gr/vas/papers/CAAD-TNDC/.

Anzorena, Eduardo Jorge, S.J. (1996). Housing the poor: The Asian Experience. Pagtambayayong Foundation. Philippines: Cebu.

Rocca, A. (2006). Natural Architecture. Milano, Italy: 22Publishing.

De Deppo, L., Datei, C., Salandin, P. (2004). Settlement of water courses. Padova, Italy: Libreria Internazionale Cortina.

Carbonara, G. (1997). Approaching restoration of building. Napoli, Italy: Liguori Publishing.

ICOMOS. (1971). The monuments for the man, Records of the II International congress of Restoration. Venezia (25-31 May 1964). Bologna, Italy.

ICOM/UNESCO. (1964). Venice Charter "International Charter for the conservation and Restoration of Monuments and Sites".

Housing the poor in Asian Cities, Low Income Housing: Approaches to help the urban poor find adequate accommodation. (2008). Bangkok, Thailand: UNHABITAT-UNESCAP.

Sampaio, J. C. R. (2007). Gentrification: it is possible to avoid it? City & Time, 3(2), 27-37.

Chifos, C. (2006). Culture Enviroment and livelihood: potential for crafting suistainable communities in Chiang Mai. International Journal of Environment and Sustainable Development, 5(3), 315-332.

Sangawongse S. (2006). Land-Use / Land-Cover Dynamics in Chiang Mai: Appraisal form Remote sensing, GIS and modelling approaches. CMU Journal, 5, 243-254.

Sheer, B., Sheer, D. (2002). Towards a sustainable urban form in Chiang Mai. In M. Romanos, C. Auffrey, Managing intermediate size cities. Dordrecht, Netherlands: Kluwer Academic Publisher.

Firoz, A. S. M. (1996). Water quality assessment of Huay Kaew Stream, Mae Kha Canal, and Mae Ping River. Chiang Mai, Thailand: Master's degree Thesis.

Kold, R. et al. (2002). Investigation of the Mae Kha canal in Chiang Mai, Thailand. Technical University of Denmark (DTU), Copenhagen: Unpublished thesis.

The Impact of Parks on Sustainable Urban Living: a Survey on Park Use in Tehran

Roshanak Razmkhah, Noor Rosly Hanif, Melasutra Md Dali
Faculty of Built Environment, University Malaya, Malaysia

Abstract

It is believed that enhancing the quality of life of citizens contributes to a strong and sustainable society. By providing people and the city with ecological, social and economic services, urban nature and parks have a positive influence on the quality of life of their users. This paper investigates the benefits which urban parks bring to citizens and the amount of satisfaction people feel towards them. A survey is conducted among users of different urban parks in Tehran (Iran) to explore people's motives for park use and a valuation of these parks is carried out as people are questioned about the degree of satisfaction they derive from different aesthetic and functional aspects of the parks. Results confirm that parks are of high value for the well-being and quality of life of citizens because of the various beneficial services they provide which loss can have serious consequences. Discussion and analysis of the results provide information of how to make parks suitable to people's needs and demands and how urban parks contribute to the sustainability of this city.

Keywords: *urban parks; city sustainability; quality of living; health; values; public participation*

1 Introduction

Creating sustainable cities is much about addressing quality of life in them. Increasing prosperity and life spans brought more free time to many people, increasing the need for leisure facilities and green spaces. (Sassi, 2006)

Parks in a city can play a significant role to enhance the quality of life of citizens. They provide important environmental services like air purification and nose filtering.

Perhaps the most cited benefit of a park for people who use it is "contact with nature." "A park is often considered an oasis of greenery in a concrete desert."(Cooper and Francis,1998). Many documents mention the range of ways in which contact with nature enhances the quality of life for people. (Chiesura, 2004; Jim and Chen, 2006; Oguz, 2000; Oezguener and Kendle, 2006). Parks provide visual relief, personal change (Francis, 1998); and relaxation.(Matsuoka and Kaplan, 2007)

Parks also provide important settings for recreation and play (Matsuoka and Kaplan, 2007; Chiesura, 2004, Oguz, 2000, Gobster, 2001, Jim and Chen, 2006). These include activities like jogging, walking, cycling, hiking, skating, games, picnicking.

Parks can also promote social interaction and human contact. Some researchers suggested that properly designed park can promote social interaction for their users.(Matsuoka and Kaplan, 2007; Gobster, 1998; Oguz,2000)

If parks in cities provide people with better services and benefits, the city becomes a better place to live and work.

Several studies have investigated the role of parks for the sustainability of the city in the western world (Chiesura, 2004). However there is a lack of research about the benefits which parks provide for people in a middle eastern country like Iran with its own local culture and value system.

1.1 Social sustainability of cities

A sustainable city is hard to define. Some sources define a sustainable city as a city which has achieved social, economic and physical development which benefits also future generations. According to the global agenda following the Rio Summit 1992, one of the principles which governments should ensure, includes fundamental rights of all people to an environment that is adequate for their health and well-being, incorporating non-economic variables as clean air and water, protection of the nature and health and education.

With the development of cities, social, cultural and political conflicts within urban boundaries increase (Marcotullio, 2001). Unfortunately the concept of social sustainability has not drawn as much attention as environmental sustainability development. Emphasizing on environmental sustainability has had significant implications for the design and strategies of infrastructures and resource conservation in last decades. However there is a growing awareness for creating social sustainability and quality of live, concerning promotion of creativity and development of human potential for all citizens, strengthening of our sense of belonging to our heritage and environment, democracy, healthy and harmonic living.

Parks can contribute to social sustainability by making citizens lives liveable, providing social, emotional and physical well-being and "providing people with satisfactory living conditions so that they can identify positively with their values and environment."(Moser, 2009)

In this study, the relation between urban parks and city sustainability is addressed through exploration of the benefits which urban parks bring to the citizen of the city of Tehran to improve the quality of their lives.

2 Methodology and Data Collection

As the study had a descriptive nature, conducting a survey was chosen as the method of research to explore the motives and perception of the users.

The survey was conducted among users of 10 different parks on 7 different districts in Tehran each in different geographical locations and with different socio-economic status of their population. 200 questionnaires have been distributed to randomly selected park users on mornings and afternoons on both workdays and weekends in winter and summer 2009.

The results presented and analyzed will be to answer the following questions:

Reasons for park use:

What are the main services parks provide to people? How does park use affect the life of citizen? Are the activities carried out by park users beneficial to them and do they have an impact on the quality of life of the users?

Public satisfaction on parks issues:

Are people satisfied with the existing parks? To what extend were the existing planning and design policies successful in fulfilling the user's demands and expectations?

3 Analysis

3.1 Reasons for park use

To explore the benefits which parks provide to people, park users were asked for the reasons of coming to the parks. By investigating the activities people involve in parks and the needs users expect to be fulfilled by urban nature, the role which parks play in people's life will be obvious.

To collect data about people's motives to visit the park, the respondents were asked: "Why do you visit this park?" The structural answers given were as following: To relax, to be with children, to sport, walking or jogging, to meet friends, watching people and get inspiration, to escape everyday life stress, for cycling or skating, to picnic. Multiple answers were possible.

A frequency analysis of people's motives to visit parks shows that "walking or jogging" is the motive most frequently mentioned by the visitors. This is not surprising as faced with limited and expensive sports clubs and facilities in Tehran, people turn to their local parks for exercising.

"To meet friends" is another important motive to visit the park. This can be because parks especially local parks are cheap and convenient and have a pleasant atmosphere so they are much-liked places to see friends and neighbors on regular basis.

Many respondents also mentioned "to relax" and "to escape every day-life stress" as their motives to come to the park. In the park the can forget the difficulties of living in a modern city and relax.

The less cited reasons " watching people and get inspiration", " to sport", " to be with children", "cycling " and "picnicking" follow in decreasing frequency. This shows that apart from being a place for physical activity parks fulfill important functions to both parents and children.

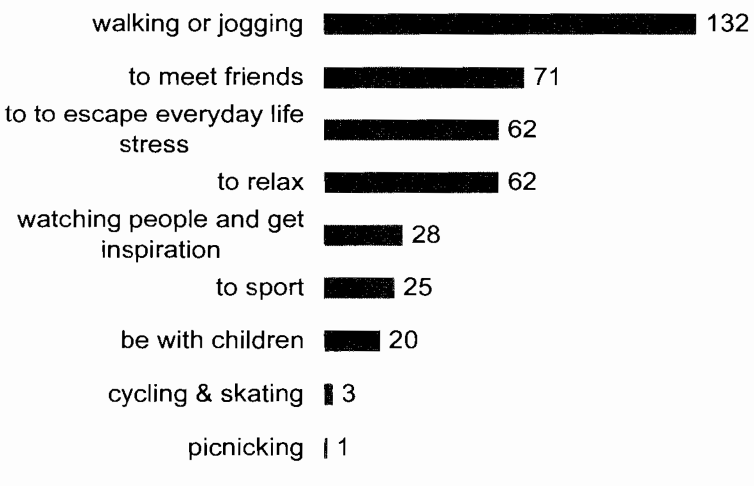


Fig.1: Motives for park use

The results show that physical activities were preferred by young age-groups, nevertheless walking or jogging was also popular among middle-aged users. Surprisingly "to sport" (using the parks sport equipments) was chosen mostly by elderly people. The motives "be with children" and "meet other people" were most mentioned by middle-aged park users.

Passive motives like “to relax”, “escape stress” and “watching people” were mostly preferred by elderly people, whereas “to relax” and “to escape stress” also applied to young age-groups. The motive “picnicking” was mentioned mostly by elderly park users.

3.2 Public satisfaction with parks

In order to evaluate the existing parks in Tehran, park users were asked to rank their satisfaction of different qualities of the parks which are of common concern (natural scenery, sport facilities and safety) along a 1-5 points measurement scale. In this scale different points were considered as following: 1,Very Bad; 2,Bad; 3,Needs Improvement; 4,Good; 5,Excellent.

A frequency analysis shows that with the point average of 4.2 people are most satisfied with the scenery in the park and find the natural settings of the parks attractive.

Safety scored the average value of 3.7 which shows that people consider the parks as relatively safe but there is still space for improvement.

The findings show that people are least satisfied with the sports equipment and facilities in the parks (average point 2.9).

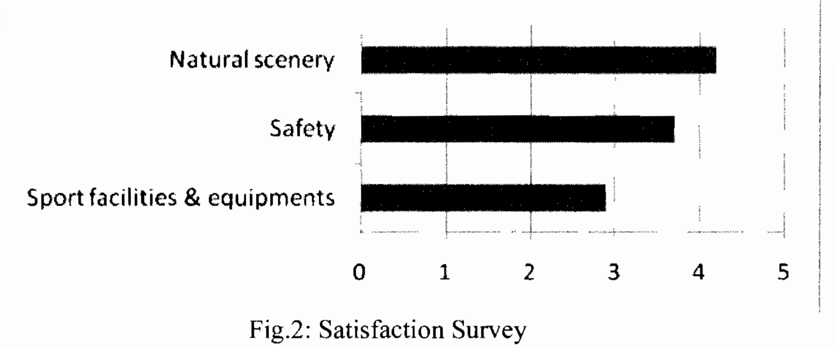


Fig.2: Satisfaction Survey

4 Discussion

The findings of the survey show that urban parks fulfill important human needs which are important for the well-being of the users.

Agenda 21 highlighted the need of meeting the challenge of urban health. As good health is multi-dimensional, parks help to maintain the physical health of the users by providing physical activities and benefit the mental and social health of people by providing them with a place for social interaction and escape from city-life. If we consider health as something to be protected and not something to be regained with the assistance of medical techniques after its loss (Smith et al, 1998), the significant role which parks play in the maintenance of the health of people becomes obvious.

Results also show that park users in Tehran have different preferences for activities according to their age. As expected physical activities applied more to young age-groups, whereas using the sport equipment was popular among older age-categories which can be due to the fact that older people have no memberships in sport clubs and gyms and use parks for their exercise routine. Therefore, it is important to include equipment specialized to this age-group in the design and planning of park facilities. The findings show that "walking and jogging" is the most cited motive by park users, so pathways for these activities should be included in park design and planning.

Hartig (1987, 1991) mentions that natural environments are a powerful source of restorative experiences and this study confirms this fact as many park-users from all age-categories use visiting parks as a way "to relax" and for "escaping everyday stress."

The findings also indicate that while people finding the natural scenery and aesthetics of the parks in Tehran attractive, they don't approve of the safety and especially find the sports equipment and facilities of the parks inadequate. This shows that besides integrating public opinions in park development procedures more accurate strategies and policies must be employed in park planning, design and management to achieve higher quality of parks and therefore people's satisfaction of their living environment.

Although standards are used in the designing and development of parks, they don't reflect the demands of parts of the population and don't take into account the individual and local differences. In order to make useable and attractive parks, which are developed to function to take full advantage of their possibilities for use, research has to be undertaken to recognize the user's needs, attitudes and preferences. The design of the parks should give priority to the most desired activities by people and should provide choice and challenge.

5 Conclusion

In this study, the role of urban parks as source of important social benefits to citizens resulting in city sustainability has been addressed. Also the efficiency of existing park planning and development policies and strategies has been evaluated through a satisfaction survey.

The results from the survey in Tehran confirm findings from previous researchers that parks provide people with essential services. In contrast to visitors in western cities like Amsterdam (Chiesura, 2004) who most frequently mentioned passive motives for their park use (to relax and be in nature), users in Tehran seem to have mostly active reasons for park visiting like walking and jogging. This shows that parks in Tehran have great benefits for its citizens in terms of physical activity and exercise which help people to live fuller, healthier and more satisfying lives.

According to several researchers creation of harmonious living environments and the maintenance and development of social values have been mentioned to enhance social sustainability of cities (Chiu,2003).In the past Tehran had several places like the bazaar, mosques, streets and baths operated as locations for people to meet, talk and discuss and for recreation purposes after work. Especially the bazaar was the heart of major Iranian cities for most social, cultural and political activities. As today the role of these places is fading away, parks are among the only remaining public settings for social interaction. Also due to rapidly increasing land prices in Tehran, more people cannot afford to live in houses with gardens with fruit trees and flowers anymore, so travelling to parks can be their only opportunity to come in touch with nature. Understanding the latter the design criteria for park development set by the municipality of Tehran and consequently the parks, deal much more with the aesthetic beautification and settings of greenery than functionality of spaces in parks. However to provide people with the much-needed space for special interaction, which is also confirmed by this study as the second important reason for park use in Tehran, more gathering places and proper seating should be included in the parks.

8 out of 10 of the studied parks also lacked in court games facilities and jogging tracks. As the first important reason for using the park was cited walking and jogging, proper paths for these activities created upon standards and according to the four season climate in Tehran are needed, so they can be used in snowy winters as well as during the very hot summers.

The findings also suggest that different age-categories have different preferences in park use and engage in different activities. This information shows how to make parks usable for all age-groups and also how equipment should be specialized to increasingly match the needs of main target groups.

Also the results of the survey also remarks the amount of satisfaction park users feel about different dimensions of the park and indicate that people expect improvement especially in the safety factor and in the arrangement of sports facilities and equipment. The need of more effective and up-to-date policies in park planning, design and management is revealed.

Non-material elements of human happiness are important factors in the quality of life of people. Availability of parks in our cities is a major asset for the citizen's health and quality of life and can assist us to proceed in the direction of sustainable development. More people would choose to use parks if they were safe, attractive and interesting. Therefore the policies of park developers should reflect the user's needs and opinions and valuation of existing parks must be made part of the development process. While parks benefit citizens in terms of pollution reduction and psychological, social and physical health, they also provide great opportunities for public involvement and participation as Agenda 21 encourages non-governmental organizations to work together with their government to create livable communities.

Unfortunately politicians and policy makers in Tehran have not enough information about the value and actual use of the city parks. So they don't support increasing of the budget for park development and management in these hard financial times. While programs exist for increasing the number of the parks to reach the world standards for green space per person, quality of parks is not given as much attention as quantity. To create usable parks, user's needs must be put first. Public participation and consultation in park development takes into account people's needs as well as the culture and history of the area which results in more usable and efficient parks which itself will lead to sustainability of our cities.

References

Chiesura, A.(2004).The role of urban parks for the sustainable city, Landscape and urban planning, vol.68.

Chiu, R.L.H.(2003). Social sustainability, sustainable development and housing development; The experience of Hong Kong, In R. Forrest & J. Lee, Housing and social change: East-West perspectives, pp 221-239, Routledge,USA.

Gobster, P.H.(2001)Visions of nature; conflict and compatibility in urban park restoration.Landsc. Urban Plan. Vol 56.

Hartig, T., Mang, M. & Evans, G.(1991). Restorative effects of natural environments experiences. Environ. Behav. 23.

Jim, C.Y., Chen, W.Y. (2006).Recreation-amenity use and contingent valuation of urban green spaces in Guangzhou (China). Landscape & Urban Plan 78.

Kaplan, R. and Matsuoka, R.H.(2008),People needs in the urban landscape: Analysis of Landscape and Urban Planning contributions, Landscape and Urban planning, vol. 84.

Marcotullio, P.J. (2001). Asian urban sustainability in the era of globalization, Habitat International 25.

Marcus Cooper,C. & Francis,C.(1992). People places: Design guidelines for urban open space, John Willey and sons, New York.

Moser,G.(2009). Quality of life and sustainability. Journal of Environmental psychology, vol. 29, Issue 3.

Oezguener, H. & Kendle, A.D.(2006). Public attitudes towards naturalistic versus designed landscapes in the city of Sheffield (UK). Landscape urban plan. 65.

Oguz, D.(2000). User survey of Ankara's urban parks. Landscape Urban Plan 73.

Sassi, P. (2006). Strategies for sustainable architecture, Taylor & Francis, New York.

The Multi Functional Architecture in Curitiba, Brazil: Urban Planning for Sustainability

Giselle Dziura[1], Daniela Tahira[2], Mariana Barbosa Colino[3]
[1] Department of Architecture, Positivo University, Brazil
[2] Institute for Research and Urban Planning of Curitiba, Brazil
[3] Department of Architecture, MB Architecture, Brazil

Abstract

This paper outlines "multi-functional buildings" in the context of city planning and development which heterogeneous function _concerns two or more distinct functions at the same time: housing, work, commerce and others, as instruments of intervention in urban areas. These buildings also reveal the possibilities to increase the performance of the physical occupation by promoting interaction amongst their inhabitants and focusing on urban planning for sustainability. The study shows a wider perspective of an interdisciplinary understanding of the urbanization process in the city of Curitiba. Curitiba is situated in the south of Brazil, and is considered a world-wide reference in urban planning. The example chosen is the "Massa Plan" located in the structural axis of the city.

Diversity is the key for sustainability. A sustainable community promotes multi functional spaces instead of mono-functional, and determines urban compact centers with a diversity of services, quality of life and promotes togetherness. Other functions include businesses, schools, sites for entertainment, relaxation, leisure and lodging. Places to live and work. Such multi functional buildings can be instruments of integration, to intensify or to renew urban space.

Keywords: *multi functional buildings, public spaces, Curitiba, multi functional architecture*

1 Southern Structural Axis of Curitiba - Urban Planning

The structural axis of Curitiba (Fig.1) is the result of one of the main proposals of the "Preliminary Plan of Urbanism", in 1964. The winning project was prepared by Serete Society of Studies and Projects and Jorge Wilheim Associated Architects. Although this urban spatial configuration has undergone changes concerning the appropriation of its public spaces, the diversity and functions of the buildings, in other words, the multi functionality is still an essential factor for the occupation of structural axis.

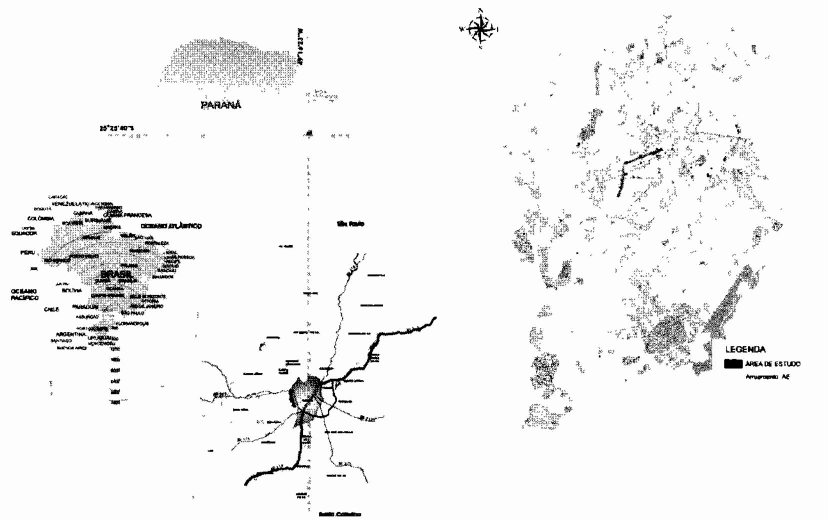


Fig. 1 – Location of Curitiba's Metropolitan Region in South America and Parana State, 2005 (IPPUC, 2005) and location of study area

According to the structural axis concept, there are tangential sectors to the city center that are divided into Structural North and Structural South (Fig. 2). The guidelines of the Master Plan proposed to the City Council outlined: linear growth, hierarchy of streets, preferential development of the city in the northeast-southwest axis, polycentrism, density, extension and adaptation of green areas, characterization of pedestrian areas and creation of an own urban landscape.

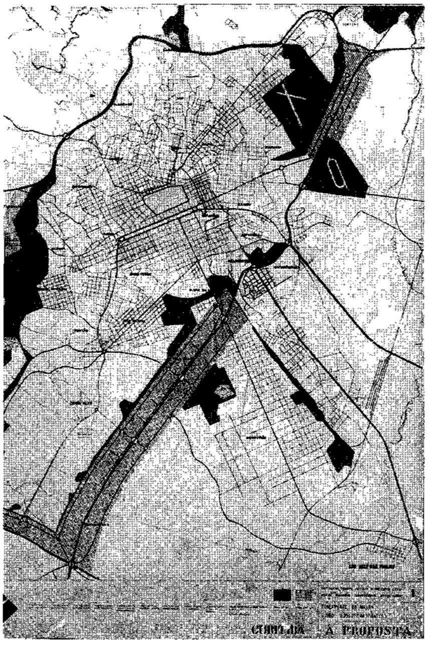


Fig. 2 - Road System proposed by Serete/Wilheim Plan, 1965 (Wilheim e Serete,1965)

In the 1970s, the Preliminary Plan of Urbanism was developed with some changes made by the Institute for Research and Urban Planning of Curitiba (IPPUC), resulting into a synthesis called the Serete/Wilhelm-IPPUC Plan. One of the changes resulted the "Massa Plan"which consists of a peculiar architectural and urban configuration characterized by multifunctional buildings of which the ground floor and mezzanine levels are used for commerce and services and their architectural configuration is covered galleries; the remaining part of the building is allocated for housing or offices. Thus, the "Massa Plan" corresponds to an architectural typology based on parameters of a specific legislation.

In this urban context there is analysis of the implications of sustainability between the building and the city (Fig. 3 and 4).

Fig. 3 – Image of the Southern Structural Axis in Curitiba, Sete de Setembro Avenue, in 2008 (DZIURA, 2009)

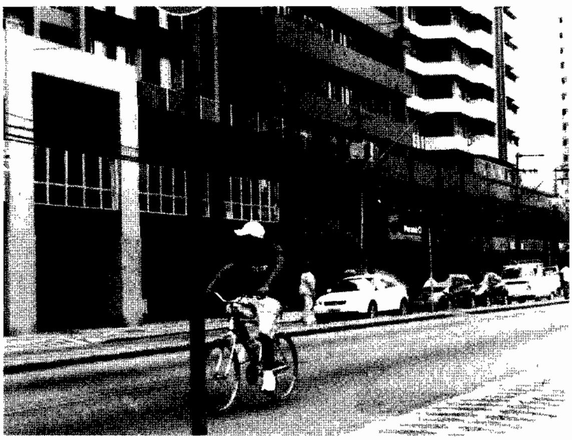


Fig. 4 – Image of the buildings that compose the Massa Plan, Sete de Setembro Avenue in Curitiba, 2008 (DZIURA, 2009)

The "Massa Plan" is described in the ordinance n. 190/00 and establishes criteria for building constructions located within the structural axis. They should follow these specific guidelines: occupancy; alignment of facades; continuity of commercial use at the front area, use of trade or services on two floors: ground floor and mezzanine; the ground floor is to be constructed 4 meters from the alignment creating a covered shopping arcade, the ground floor must occupy at least 50% of the land area, and may extend to 100% with the distribution of the developed space at the front side of the property.

These criteria influence and lead to the production of sustainable urban spaces as a result of a process that involves public policy, housing demands and socio-cultural realities.

2 Urban Dimension of the Multi-functional Buildings

As part of Jacob's (2003) speech on the multi-functionality of buildings and their urban dimensions, she raised the diversity of functions within cities. She promotes the necessity of combining different uses at different times of the day, and varied reasons for occupation that brings life to the urban space. The diversity of functions is one of the four conditions that the author considers to improve urban vitality through urban planning.

The organization and connection of the multi functional building to its immediate surrounding depends on the transition areas between public, semi public and semi private space. Its dynamics however are modified physically or socially with a system of human activities inside or outside the building itself. Therefore, these buildings may be instruments of integration, intensifying or renovating an urban space, as well as contributing to its segregation, in case it is isolated from the city.

The spread of urban enclaves has led to discussion of the processes that lead to the reduction of public spaces of postmodern cities. Caldeira (2000) states that fortified enclaves are private spaces, closed and monitored; they promote negative relationships with the city, where public spaces are becoming increasingly marked by suspicion and restrictions.

Buildings that are closed to the urban environment and that transform public spaces into private ones are part of the scene of several Brazilian cities, and among them, Curitiba.

The starting point of this analysis is the proposed buildings in the Southern Structural axis of the "Massa Plan", where social forces are in conflict with planning, which sometimes means spaces are created for humanization, the cities image, as sources of investment, and out of demand by governments.

It must be emphasized that the spread of shopping arcades around the world suggests an increasing of the capitalist society in which a wide range of new products dumped daily from the factories require city spaces for the huge demand. . According to Lefebvre (2001), the urban space appears as an expression of social relations and the production of a society. It means that as the relations of a society are changed, the place where such relationships are mediated is also changed. Thus, the architecture is the stage of social relations production of a society and it changes itself and "re-generates" itself.

Moreover, the notion of social space that, by definition, is a space that "is both labor and product - a materialization of social existence" (Lefebvre, 2001), it does not seem to be built into the physical space of the postmodern city. This is presented as a product that can be exchanged, bought and sold, becoming much more an abstract space. The city of Post-Modernity seems to miss places as spaces for human life. Its spaces are appropriate abstractly through the double character of the centrality of capitalism: the place of consumption and the consumption of the place. (Lefebvre, 2001).

Therefore, studying the transformations of public spaces adjacent to buildings is to understand that there is a dynamic purpose for the presence of commerce function inside the buildings due to the advent of capitalist practices.

From another perspective, one can observe that despite its subversive side, the phenomenon of speculation emerges as a key that enables postmodern urban plans, as they have the ability to attract investment and contribute to the development of urban life.

The importance of public space in post-modern cities is analyzed by Giurgola and Mehta (1994) that observed that the postmodern cities lost their representative value concerning progress, so that the significance of using the street has changed. For the authors, the street - a way for pedestrians - should be a place that is conducive to meetings, with the possibility to compare it to a living room. In this image, the facades of the houses would be the walls. "To give life to the street, it must be animated by the back-and-forth of the residents and improve the exchanges they have with each other. Take your project plans and properly distribute the houses on the edges of the streets, restore them to a human aspect"(1994, p. 95).

Additionally, Gehl (2006) notes that public space for the pedestrian determines the quality of an urban city. And if the city is the meeting place it is the pedestrian public space and its spatial relationship with the architectural objects that contributes to the quality of the city.

Arnheim (2001, p. 210) states that such architectural objects not only reflect the attitudes of the users of the spaces, but also influence human behavior. According to the author, "The buildings have a large part in determining the degree of each citizen as an individual or a member of a group, and the reason we take decisions freely obeying the spatial boundaries". And adds that the physical layout of a given space refers to the grouping of parts of the building, the distance between them and its symbolism. However, the visual expression pointed by Arnheim, it adds to the functional aspects, urban, technical and cultural ones.

Gehl (2006) adds that the buildings should no longer be considered an end in themselves but an instrument to enhance social life in the city by attracting the public space, where one can develop urban activities perceived by the city.

It's worth mentioning Rossi (2001) and his thoughts on the inseparability of architecture and the city, a factor outlined in this study. It appears that the architecture becomes a substantial part of what is identified as a place. It is through it that a memory of places is developed and men make it possible to understand the city as a work. "So the urban fact and its architecture are one, are pieces of art" (Rossi, 2001, p. 117). However, the "works" of postmodernity introduce the idea of relocating a city's public spaces into buildings.

An overview is observed that during this process the continuous and homogeneous vision, that seemed avant-garde, has been obscured, which has entered into a universe of intellectual pluralism and discontinuity, which has lost one of its most important qualities of urban life, the richness of its complexity and contrast.

Therefore, it is needed to discuss the intervention in spaces (public or not) in the cities and the reflection on it. There are mutability, flexibility and possibility of dialogue in the planning process and the architectural projects.

Despite the efforts of private capital in making public spaces more internal, the city continues to be needed as a place of mediation, social contact, and remains the area of greater, greater diversity of function and a greater potential for producing social contact. Multi functional buildings can contribute to urban sustainability if they can communicate to the city, promoting the permeability of space without being an architectural barrier.

The meaning of multi functional buildings is still vague in literature but they represent the relationships between the different functions of the building and the permeability of public and semi-public space without isolating the building from the city.

3 Sustainable implications for Multi Functional Buildings and the City

Given that "implication" means relationship and result in advance, through facts, actions or behaviors, it can be stated that multi functional architectural interventions can be considered as strategies and opportunities for urban sustainability.

The “Massa Plan”, composed that multifunctional building is characterized in certain sectors as a sustainable community, and this promotes space with several integrated functions, determining urban areas that have a diversity of services, quality, proximity and accessibility. There are also included are other functions such as businesses, schools and places for health, leisure, to live and to work. This variety of functions reduces the "desert" city after business hours making possible the continuity of the activities on the streets. This increased activity on the streets raises security.

The proximity of the functions reduces the need for mobility and might reduce the flow of private vehicles. The“Massa Plan” is strategically located where public transportation infrastructure is accessible. There is also the major task of sustaining what the structural axis promotes in Curitiba: the integration of land use, transportation and road system that enables the reduction of energy resources, contributing to the mitigation of pollution and stimulation of physical permeability for pedestrians.

Buildings in the “Massa Plan” must take into account their immediate surroundings. There is a transition element that contributes to increase the permeability of space: the covered galleries throughout the buildings (Fig. 5) on the ground floor. It extends the width of sidewalks, increasing the space for public use. As pointed out by Alcock, Bentley and Mcglynn (1999, p. 12): "only places that are accessible to the public can provide alternatives. The vitality of a place can be measured by its ability to be penetrated or passed through it or within it can be moved from one place to another. "It is understood here that the urban vitality is related to sustainability so, the city and the buildings ought to be planed to guarantee that there will be life in the city, with economical viability of the activities with social and cultural diversity.

Multi functional buildings contribute to urban sustainability as they provide:

a) minimization of physical, visual and socio-psychological barriers, paying attention to their forms that allow the visualization of the gradient of the internal spaces, and the reduction of architectures;

b) presence of various functions - including housing - and uses that are required at different time of the day and night;

c) connection between external and internal spaces, favoring the passage of the pedestrians persons in the urban fabric; (Fig. 6);

d) entries dimensions must invite pedestrians to access the building without causing extreme monumentality or being reduced to the point where access is not perceived. The resulting architecture within the Structural Axis of Curitiba addresses specific legislation for the development and planning of buildings, called "Massa Plan". In addition to this, there is the street configuration composed by the transportation and road systems.

e) consideration to the relative density of the environment, which should be high enough to promote greater flow of pedestrians and more permeability between the public and semi-public spaces;

f) presence of common areas, to attract and encourage the interaction of people, as a possibility to find see or feel, respecting the categories of use and ownership for public, semi-public, semi-private and private spaces;

g) presence of leisure areas, which may or may not be located in public spaces.

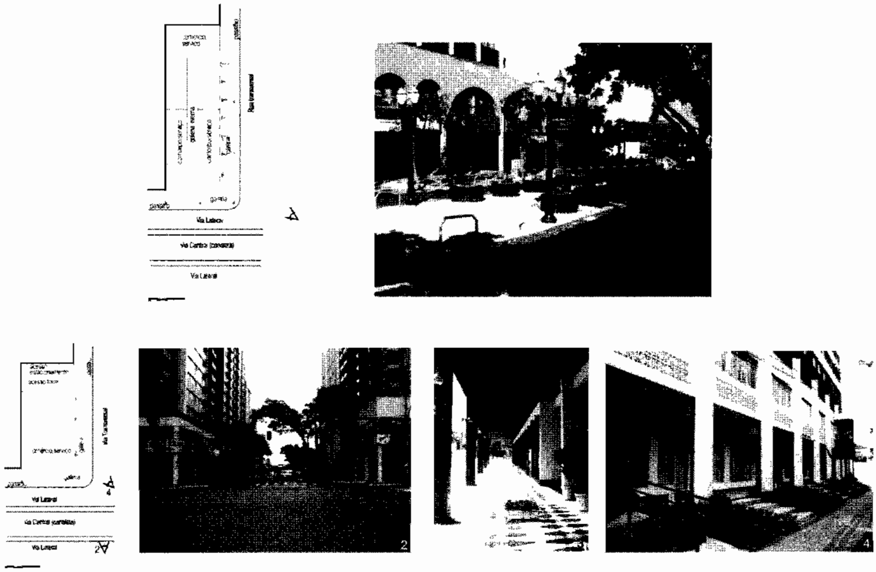


Fig. 5 – Covered galleries of the Southern Structural Axis in Curitiba, 2008 (DZIURA, 2009)

Fig. 6 – Reduced spatial permeability and contribuition to the spatial permeability of Southern Structural Axis in Curitiba, 2008 (DZIURA, 2009)

The contemporary city, in relation to Brazil, has changed from a space for human relations and social demands to an area of economical relations. The multi functional buildings created in the structural axis of Curitiba try to create architecture within the urban context, with spaces that seek interpersonal contact, and attempting to address the local residents.

The multi functional buildings of the "Massa Plan" work as a sustainable urban tool as the structural axis extends throughout the city from north to south and also form east to west, ensuring multi functionality in each urban sector of the city, providing different neighborhoods easy access to private services, and even creating a unique architectural language for different neighborhoods throughout the city. Prioritizing decentralization of community services to areas of demand. It is worth mentioning that urban sustainability in Curitiba through the installation of the "Massa Plan" in structural axis are complemented by political and administrative decentralization of the city, as they are distributed and located in various buildings throughout these structural axis, ensuring not only the decentralization of business and services but also the decentralization of public services..

The contribution of this paper is a mere seed for further studies and sustainable interventions on the scale of buildings and the city simultaneously. The multi functionality elements of the "Massa Plan" in Curitiba have been one of the city's experiences in sustainability. It is a practical example of how regulatory practices, measurements and priorities combined can promote sustainability from individual buildings to the public city scale level.

The increasing urbanization throughout the world, added to environmental issues, climate changes, pollution, are some of the ingredients enforcing major changes concerning the building and city planning. The study shown reinforces the importance of multi functional buildings to achieve that. They are simple and basic instruments to guarantee varied and necessary functions of a city, as well as the connection of public spaces, public transportation and the integration of the citizens themselves.

References

ALCOCK, A., BENTLEY, I., MCGLYNN, S. (1999) Entornos vitales: hacia un diseño urbano y arquitectónico más humano. Barcelona: Gustavo Gili.

ARNHEIM, R. (2001). La forma visual de la arquitectura (2.ed). Barcelona: Gustavo Gili.

CALDEIRA, T. P. do R. (2000). Cidade de muros: crime, segregação e cidadania em São Paulo. São Paulo: Editora 34.

COMPANHIA DE HABITAÇÃO POPULAR DE CURITIBA (COHAB). Base de dados cartográfica digital de Curitiba. Sistema de Informações Georreferenciadas. Curitiba, 2007.

DZIURA, G.. L. (2009). Spacial permeability and urban care in architectural design: from Modernity to Post-modernity in multifunctionals buildings located on the Southern Structural Axis of Curitiba, 1966-2008. 2009. Thesis (Ph.D.) in School of Architecture and Urbanism, University of São Paulo, São Paulo.

GEHL, J. (2006). La humanización del espacio urbano: la vida social entre los edificios. Barcelona: Reverté.

GIURGOLA, R., MEHTA, J.(1994) Louis Kahn. São Paulo: Martins Fontes.

INSTITUTO DE PESQUISA E PLANEJAMENTO URBANO DE CURITIBA (1965). Curitiba de amanhã – Plano Preliminar de Urbanismo. Curitiba: IPPUC.

____(1966). Proposta das diretrizes básicas do Plano Diretor. Curitiba: IPPUC.

____(2005). Banco de dados. Curitiba: IPPUC.

JACOBS, J. (2003). Morte e vida de grandes cidades. São Paulo: Martins Fontes.

LEFEBVRE, H. (2001). O direito à cidade. São Paulo: Centauro.

ROSSI, A.(2001). A arquitetura da cidade. São Paulo: Martins Fontes.

WILHEIM, J., SERETE. (1965). Plano preliminar de urbanismo de Curitiba. Curitiba.

Projects for Accessibility and "Sustainable" Planning: Case of Alexandria, Egypt

Vincenzo Donato, Cristina Pallini
Department of Architectural Design, Politecnico di Milano, Ialy

Abstract

From a project oriented view point the concept of sustainability concerns a variety of themes. The evolution of any single city brings to light the fact that architecture and town planning have often expressed more than a merely stereotyped conception of 'style,' wherever its most significant achievements have responded to structural needs. For 'sustainable urban development' we may assume the necessity of a 'priority vision,' according to which economic, ecologic and social potentials should be valued.

This paper questions the notion of urban sustainability considering the port of Alexandria and is region at various levels. Today extending for many miles along the sea coast, the city entered a period of crisis in the 1950s when a mass exodus of foreigners followed transfer of the main activities to Cairo, while the surrounding area was subject to reclamation work as part of a plan for national development. An important event occurred in 1989 with the rebuilding of Alexandria's world-famous library, bringing with it a hope for revival of the city's ecumenical tradition and of the place it formerly held in world culture.

While most of its five million inhabitants survive in a variety of unauthorised settlements and the rural areas have suffered severely from the pollution of Lake Maryut Alexandria is expanding by creation of "gated communities," paralleled by intensive building for tourism along the western coast. This growing trend towards the 'american way of life' is destroying any identity of place.

Criticizing the unsustainability of the Alexandria of today, this paper focuses on potentials for polycentric development of the city as a vital part of its region and the Nile Delta, also considering that debate is in progress on the accomplishment of important infrastructural projects that may offer fresh opportunities for involving the topography and centuries-old life of the metropolis in designing the future city.

Keywords: *Alexandria, Egypt, port, urban development, accessibility*

1 The "Library" Effect

Since the mid-1980s, when the project for rebuilding Ptolomy's legendary library was presented to Unesco, Alexandria has emerged from a period of oblivion, becoming once more the happy hunting ground for archaeological missions, for architectural and urban historians, writers and journalists inspired by the magic of its cosmopolitan past. *Alexandrie entre deux mondes*, *Colonial Bridgehead*, *City of Memory* are three titles of important works on the legendary history of 19^{th} and 20^{th}-century Alexandria, "a transitory model of conviviality."

On 26 June 1988 President Hosni Mubarak laid the first stone of the new Library in Chatby. The plot overlooking the sea, probably that of the ancient library, was to be partly devoted to a new congress centre close to the university's humanistic departments. In a prominent position on the Grand Corniche facing the Selselah peninsula – extending outwards to the Fort built on the ruins of the ancient lighthouse – the Library was to overlook the shades of one of the wonders of antiquity. In exploiting such an evocative potential, the Library project put aside the complex problems of the city which, according to the Italian architect Franco Zagari, recalled "days of colonial and commercial splendour, isolated by the Delta and the desert, but now as if abandoned, existing only in its inhabitants, a lively, industrious, kindly people though seeming to have just arrived, as if camping out before taking possession."

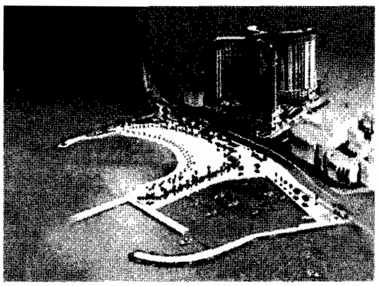
In the Alexandria of today the Library fulfils a vital role, visited in the daytime by school children, tourists and even by ordinary people as a meeting place. No other place in Alexandria seems to express such significance, at the same time appearing alien to the throb of city life. So would the contrast with ordinary people strike the onlooker; the crowds meeting at sundown in the centre, decadent with its flavour of dust and sand blown by gusts of wind from the sea or from the south, places of daily toil, business, haste. The men sitting at their tables, smoking narghile, indolent, deep in thought or merely absent-minded, look just like those who climb into the blue tramcars at Ramleh Station. The contrast between these men of Alexandria and the tourists who visit the new Library contributes to its decadent fascination, and though hindered by problems congestion, Alexandria has once more resumed its role as an attraction for international tourism.

2 New Building Sites: A Tour Of Alexandria And Its Region

A tour of Alexandria and its region gives some idea of the large amount of building activity under way, showing that the models adopted for the new settlements are those of Dubai's great hotels or the gated communities of Arizona. Extensive forms of construction, following projects mention of which shall be made here, are endangering all territorial resources, whose preservation is vital for a sustainable development. The natural features of the region – Lake Maryut and along the coast from Alexandria out to El Alamein and beyond - are already at stake.

2.1 San Stefano Gran Plaza

San Stefano Gran Plaza can be reached following the Corniche, opened in 1930 and widened between 1999 and 2005 to take five lanes of traffic in each direction, at the same time improving the image of city with new pedestrian promenade, plazas and seating areas. Half-way between the centre of Alexandria and the former Royal Residence of Montazah stands the San Stefano Grand Plaza, replacing the old Hotel San Stefano and aspiring to rekindle the splendour of earlier days. Opened in 2006, the colossal San Stefano Grand Plaza consists of two tower blocks 35 floors high on a semicircular plan – one tower facing the sea, the other towards the city. Only a few minutes from the Nouzha airport, and equipped with a private harbour and a beach, new San Stefano offers the highest standards of privacy and comfort, a rarefied atmosphere in no way related to real Alexandria.



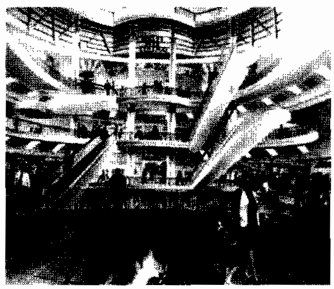


Figure 1 and 2 : San Stefano Gran Plaza.

2.2 Leaving Alexandria for Alex West

Joining the city centre to the major regional and national roads Moharrem Bey Bridge, has steered rapid development of large shopping malls on a strip of land stretching across Lake Maryut, once an "inland sea" for transportation, irrigation and supplies of fresh water, now shrinking and polluted. Further reclamation works are required for the "New Alexandria" project: three large areas for housing, commercial and mixed uses. A series of semi-detached houses under construction can be seen (with a large hoarding for each letter of the name ALEX WEST) along the new road on northern shore of the lake. Alex West is gated community, where ten models of two-family houses stand along wide tree-lined avenues, and the ground has been shaped to form artificial levels for golf courses and tended lawns. Edged by a five-star hotel, a business and conference centre, shopping malls, Central Park will be the heart of Alex West. A visit, and material available on the internet, gives us a preview of the townscape as it will be. The varied styles of the main public buildings evoke the eclectic architectural tradition so much of which is to be found in the historical part of Alexandria, whose dust and chaos future inhabitants of Alex West will be able to ignore.

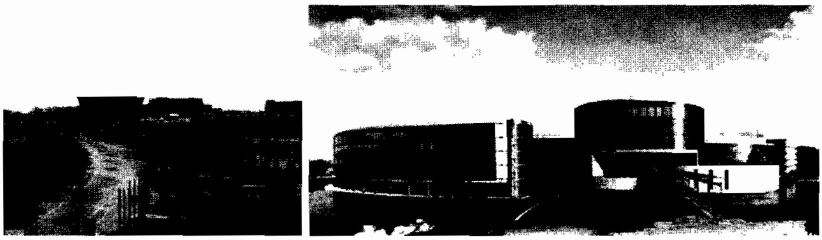


Figure 3 and 4 : Alex West.

2.3 El Alamein and Porto Marina

The old coastal road leading on to the Libyan border passes Agami, Bianchi, Hannoville, all prestigious holiday resorts until half way through the 1980s but now little more than residential suburbs. Still further west, well beyond the SuMed oil pipeline, is a seemingly endless succession of tourist villages built during the last thirty years by the Government or by professional associations. At last here is El Alamein 106 km west of Alexandria; a better climate, a bright blue sea, cleaner beaches, the Museum of the Second World War and the great military cemeteries recalling the hard-fought battles of July and October 1943. Before the turning to the Italian cemetery there is the new motorway across the desert to Cairo; opposite lies Porto Marina, a tourist metropolis that, dead in the winter, comes to life at the end of May with its rich clientele. Extending for eleven kilometres Porto Marina has recently been enlarged and equipped with a large shopping mall. Its artificial lakes and lagoons are ideal for water sports, its colossal architecture recalls that of Las Vegas, with the Venice Canal Mall built along an artificial canal complete with gondolas and gondoliers.

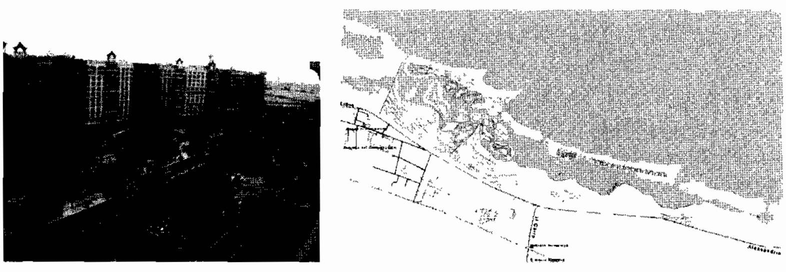


Figure 5 and 6 : Porto Marina.

2.4 The Sahel and its new tourist resorts

For three months every summer, Egyptians flock to the string of holiday villages along the Mediterranean coastline for 450 km from Alexandria to the Libyan border. European tourists – accustomed to a chilly climate – are likely to find these beaches ideal even in the winter season. A new private-public partnership has emerged with the intent of developing sections of the North Coast into a year-round holiday destination. The further west you go, the better are the buildings and the beaches. We will therefore continue as far as Hacienda Bay. This smaller still-unfinished village is quieter and more exclusive; its houses are in Mexican style with luxuriant displays of bougainvilleas. After Sidi Abdel Rahman we come to Marassi, where another large all-year round tourist estate is going up: several districts, each named after one of the most picturesque localities in the Mediterranean: Santorini, Safi Sands, Port Zarsis, Valencia, Altea, Marina, Riviera. One architectural style after another, a diorama of the entire Mediterranean.

Figure 7 and 8 : Hacienda Bay and Porto Marina

2.5 Along the Desert road to Cairo

A new road links El Alamein to Wadi El Natroun on the Desert Road from Alexandria to Cairo, now fast becoming a major axis of urbanization. On the Desert Road, at a 35 minutes drive from central Cairo, we come to CASA, as yet only one fifth built-up. A little further on, 64 km from Cairo, lies Cascada, including plots for detached houses ranging from 190 to 705 sq. meters with large gardens, pools and lakes, tennis courts, football fields. At km 49 is Palm Hills Botanica, offering homes with a wide choice of modern architectural designs and sizes. On approaching the Cairo, there is Westown Cairo under construction to become a new "urban hub" outside the historical city. Big signs at km 38 - near the satellite cities of Sheykh Zayed and 6 October - advertise Autoville, the largest automobile showroom in Egypt, and Designopolis, a shopping centre for home and office furniture

Figure 9 : Rendering of a house at Palm Hills Botanica

2.6 On the way to Rosetta

The landscape is totally different leaving Alexandria eastwards, along the new International Road completed a few years ago in direction of Rosetta and the border with Israel. Here we can still admire a Nilotic landscape of palm groves, banana trees, mango and gawafa fields, inland lakes and agricultural villages some of which have become dormitories for people working in Alexandria.

3 City, Region, Accessibility: Polycentric Development as A Sustainable Scenario

More than forty years ago Peter Hall brought to the fore the potential of polycentric settlements vis-à-vis the unsustainable growth of many world cities. Following John Maynard Keynes' macroeconomic theory and studying the Randstad Holland and the Rhur area, Hall also clarifyed the importance of a macro town-planning approach.

The Nobel prize Arthur Lewis, in his book entitled *The Evolution of the International Economic Order*, wrote that uncontrolled urban development deeply affects the structural subordination of developing countries, undermining all kind of financial and human resources.

Since the 1999 Potsdam Conference polycentrism has become the target of EU official documents, presented as a virtuous form for "balanced and durable spatial development" in large urban settlements, so much so many subsequent studies have been focused on potentials for polycentric development.

In opposition to the imitation of 'alien' town planning models, which is precisely the case in Alexandria, the idea of polycentrism is based on the individual features of a given context discovered in the *longue durée* (one long enough to identify which geographical, and political factors have fostered the variety of activities as well as economic and cultural progress).

Along this line of thoughts, the problem of a sustainable urban development for Alexandria should be approached taking into accounther her age-old relationship with the Nile Delta, a 'paleo-polycentric' region including large cities like Rosetta, Damietta, Port Said, Damanhur, Mansura, Tanta, Zieta, Zagazig, Benha. A fundamental resource for its rich agriculture, since completion of the Aswan High Dam (1970) the Delta has faced a dramatic change, its soils have become poorer and large amounts of fertilizers have been used ever since. Environmental problems are rendered even more critical from erosion and from the presence of about half of Egypt's population.

Presevation of the individual features of a given territory is the key for a sustainable development. For the revival of this unique polycentric settlement preserving the stamp of history, a macro town-planning approach complemented by a patient work of interpretation is mandatory, in view of gaining the necessary 'priority vision.'

At the western edge of the Delta, Alexandria has been a focal point thoughout her history, for both external and internal economies. With its large population and multiple activities, comprising many forms of income produced and distributed, the Alexandria of the future - where the most attractive conditions of employment were to be found - shouls seek to play a leading role for this region. In this scenario, the unsustainability of the Alexandria of today becomes even more evident. A traveller who leaves early in the morning heading to Cairo by car passed the alienating and featureless landscape of Lake Maryut with its dark and dense water, among brightly-lit factories, the flames of oil-refineries, the dim and distant lights of villages lost in the sandy horizon: such today are the vast and chaotic industrial outskirts of Alexandria, interspersed by the new gated communities built "to de-clutter the historical city."

In view of forecasting a sustainable scenario for Alexandria and the Delta region the age-old supporting structure can identified in the network of canals, railways and agricultural roads. Accessibility may thus play a crucial role, providing the combination of different modes of transport and, most of all, favouring as much as possible rail transport of people and goods.

What follows is a proposal for the city's strategic areas and functions, the port in the first place. In other words, we propose a 'priority vision' to decide which parts of the city should become new poles of activities.

Figure 10 : Alexandria and its region

4 Alexandria: A Port City

Alexandria today is "the port" of Egypt, wherein the internal dynamics of the country's development and the indirect effects of world trade could, if properly exploited, strengthen the city's role and significance in relation to potentially important market areas. The Fordist nature of its industrial development, which directly benefits from the port, must undergo rapid change in order to strengthen its competitive advantages. These would include industrial and commercial administration of the Free Zones, the capacity to import goods for processing and re-export. If applied to non-traditional products in particular, this could help to develop a strong and stable relationship between production and research.

Seen against these possibilities, the unsustainability shown by the city and its organization become sharpened, vis-à-vis problems of population movement and accessibility, for workers and for the public in general, to their places of origin and destination.

While the "Turkish" and "European" towns are undergoing a process of change including a considerable amount of demolition and rebuilding, a debate is in progress on the provision of important infrastructures: widening of the port westward, completion of berths for the larger pleasure cruisers, reshaping of the port-canal area. Other ideas concern adaptation of the Ramleh tramway to a suburban railway and its extension westward, a rail connection (also westward) to serve the port of Dekhela and the manufacturing areas of Amreyah and Burg el Arab, and, finally, building a new underground passenger station and through line under Cairo Central Station. All these projects could create new opportunities for involving the topography and centuries-old life of the city in the metropolis of the future.

What then are the chances of promoting such new development for Alexandria and its surroundings? The most important seem to be those offered by its position in relation to the new shipping routes now used by a growing amount of international trade. Over the last ten years, an increasing flow of trade with China, India and South-East Asia has shifted the economic axis eastward. In this context, the Mediterranean has acquired new importance and the crucial role of the Suez Canal has been confirmed, its volume of traffic having now doubled. Practically all goods of eastern origin pass through the Suez Canal, the undoubted economic advantage of which will last so long as the delays for a passage through it are shorter than the time needed to circumnavigate the Cape of Good Hope.

The Suez Canal at present contributes only 3.3% to Egypt's gross domestic product (GDP), but calculations show that the country could considerably benefit by retaining part of the value of the goods that pass through the Canal. By retaining 5% of the total annual value of goods passing through Suez, Egypt's GDP would increase by 15%; by retaining 10% of the same value its GDP would increase by 29%; by retaining 15% of the same value, its GDP would increase by 44%. Though approximate, these figures are of considerable interest and show the cardinal role that Egypt could fulfil within a new order of world economy, partly due to her geographical position and partly to her territorial, economic and human resources.

It should also be considered that 99% of Egypt's import-export trade is seaborne, a figure that reflects the vital importance to the country's economy represented by this form of transport. Its main port is Alexandria-Dekhela, both for quantity of goods handled and for the number of ships that call there. Next comes Damietta, more important only for transhipment, then Suez that handles a smaller quantity of goods but deals with the many ships in transit through the Canal. For Alexandra-Dekhela, however, the port together with its infrastructures should be planned in order to direct industrial development in the most appropriate way. Availability of low-cost labour and of space for expansion, added to the government's policy of tax relief, are all good reasons for believing that, by taking full advantage of the new Far East-Mediterranean trade axis, Egypt will be able to adopt the necessary and decisive measures for developing its economy, itself in turn becoming a centre of production, processing and export of goods.

The quantity of imported goods (284 million tons in 2005) and the number of TEUs (734,000 in 2005, equivalent to 30.3% of the Egyptian quota), undoubtedly prove the essential role of the port of Alexandria-Dekhela in Egyptian economy, a port through which to supply the whole country, due partly to its proximity with the capital, Cairo, and partly to the efficiency of the infrastructures linking the two cities.

Dekhela's hinterland, one of the country's duty-free zones, is however still under-exploited, contrary to that of other Egyptian ports. Its export trade is in fact smaller than that through Damietta, Egypt's first port of transhipment. For the most part, therefore, the goods that arrive at Alexandria serve the internal economy though, as mentioned above, Alexandria, and its surrounding area could become an important centre of manufacturing, processing and export.

It is therefore reasonable to presume that, geographically situated as it is, Egypt would be able to derive considerable benefit from this new state of affairs. The difference in labour costs, compared with those prevailing in Europe, indicate the advisability of carrying out locally the first stages of processing on imported goods.

An analysis of the most important types of goods exported by Far Eastern countries would therefore be useful for deciding which branches of Egypt's industry could be developed for this purpose. Eminently suitable among these are electronic components which could be processed, prior to being mounted and re-exported, benefiting from the presence of skilled labour already historically famous for its precision work in the case of textiles.

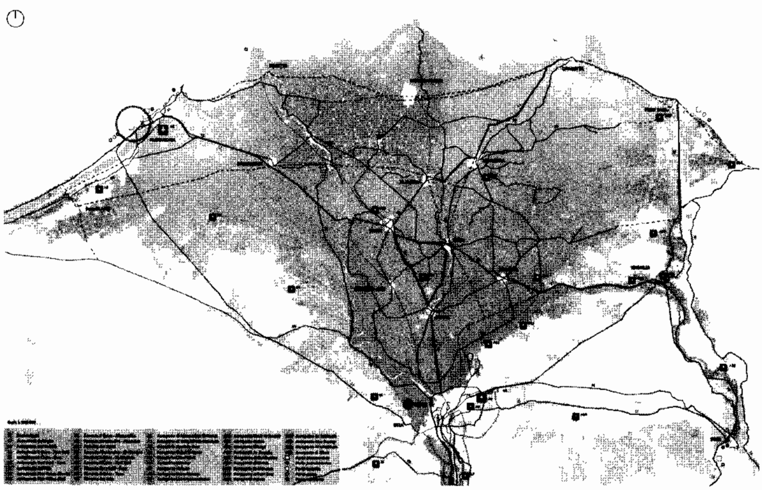


Figure 11 : An outline of the new transport system for the Delta region

5 A "Priority Vision" For the New Port of Alexandria

Alexandria *ad Ægyptum*, as the Romans said, sufficiently near Egypt to benefit by its riches, sufficiently distant for independence. The city and its region are still in fact an essential force for growth and progress of the country as a whole.

Today, Alexandria handles about 70% of the Egypt's maritime trade. It is a second-generation port that serves a large number of industrial enterprises, mainly petrochemical, iron and steel, situated in its vast hinterland, among other things a duty-free zone. Further west is the vast protected harbour of Dekhela, a third-generation port built in 1980 to create adequate space for loading and manoeuvring operations, no longer possible at the old port; it also provides the greater bathymetric depth for the post-Panama and post-Cape ships that require greater draft.

After studying the Port Authority's preliminary plan (and following the debates held during the workshop in Alexandria of November 2007) we have developed an alternative proposal, as regards organization and the positions assigned to the various functions. Our project proposing creation of a single port unit joining Alexandria and Dekhela has been parameterized in relation to tentative forecasts on the increase in maritime traffic. These forecasts are based on the continuous and growing development of trade: for some time past, trade and particularly seaborne trade has shown a higher rate of activity and percentage of growth at macroeconomic level in world economy.

The basin of Alexandria-Dekhela port is amply suited for material and spatial development to cope with its new functions. This port possesses all the commercial, industrial, and civil features needed to make it a completely efficient port of call, with space available for enlargement and, compared with other North African ports, offering the further advantage of deep water enabling it to receive vessels of the dimensions expected in the future.

The reasons underlying these possibilities of development and increased importance, the need to allocate resources and investments, lie not only in the evolution of Egypt's internal economy, but also in the need to avoid loss of time in consolidating its level on the international scene in the face of possible competition from other Mediterranean ports. Egypt's potential advantage is partly due to the position of its ports in relation to the markets to which goods passing through Suez are destined, and partly to the size and dynamic nature of the country's internal market. In recent years both these factors have led to measures for increasing the capacity and efficiency of Egyptian ports, to some extent in line with world growth in seaborne trade. Some ports, such as Damietta, are seeking business and becoming more competitive in container transhipment to compete with trends in other countries. Among the Egyptian ports, Alexandria in particular with its industrialized hinterland, must equip itself for the competitive role it deserves.

The dimensions to be given to the various areas of the port have been calculated taking the organization of Rotterdam as a reference for efficiency. We consider reasonable to increase the potential of Ro-Ro traffic, seen as a possible key to development of the Alexandria area, but in any case investing in transhipment essential to a modern port; although this means heavy and carefully chosen technical investments, Ro-Ro activity requires quite as much in terms of personnel. The Port Authority's preliminary plan was considered not merely from its technical, though complex, aspects but rather as a means for favouring Alexandria's economic system as a whole, fulfilling a directly social function able to provide sources of income and wellbeing for the local population.

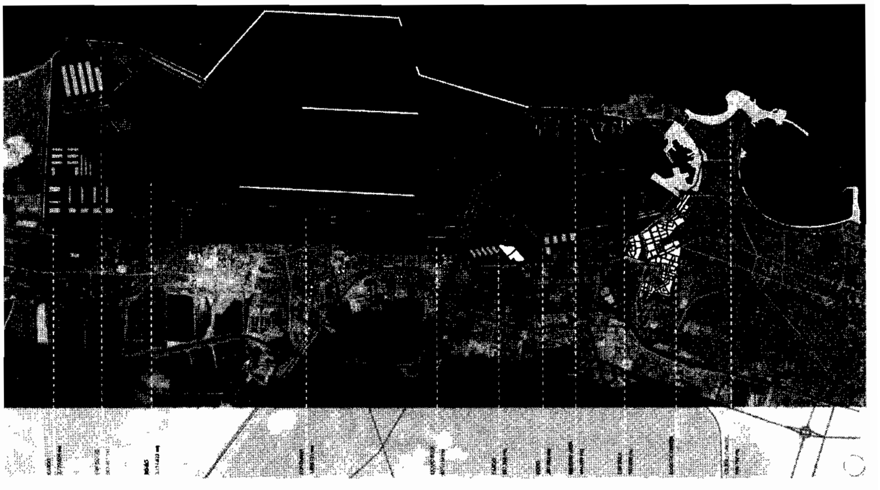


Figure 12 : Proposed Master Plan for the Port of Alexandria-Dekhela

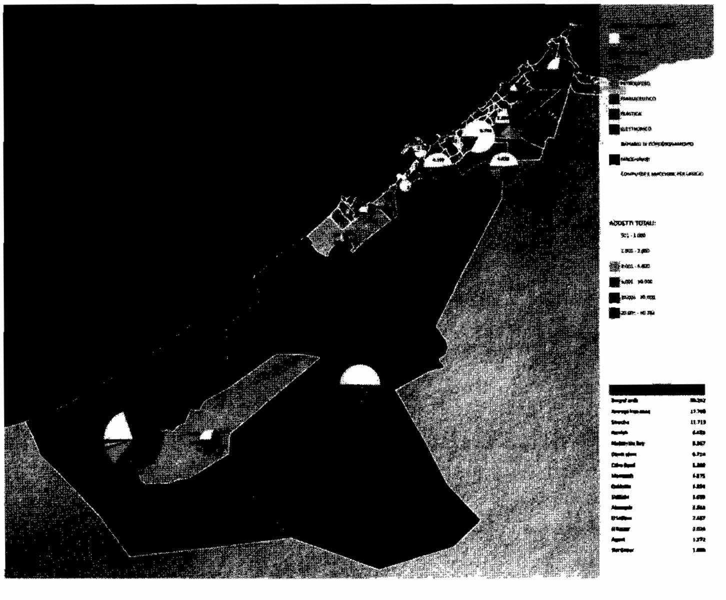


Figure 13 : Personnel employed in Alexandria divided by districts

5.1 The proposed road and rail network

Increasing the potential of a port infrastructure implies designing new rail and road connections, including branches to serve the port area sufficient for handling the increased work load, especially that depending on incoming and outgoing Ro-Ro traffic.

Conditions for road traffic will presumably improve to ensure fast connections in the required directions. Widening on roads for fast traffic is fundamental, and could then be extended to provide uniformity in the transport network. Particularly noteworthy is the road widening on routes crossing Lake Maryut, aimed at reducing traffic on the motorway below linking Alexandria with the industrial area and duty-free zone of Burg el Arab.

The dimensions given to the local suburban railway line are such as to unify it with the national network to create an integrated transport system for the whole metropolitan area. Cairo Station at Alexandria is at present a terminus, which could be transformed into a through station by laying a double line underground (below the present station), thereby greatly increasing its potential capacity as a passenger line to serve the towns that have rapidly grown up towards the west; this line should be continued farther, passing south of the gulf of Dekhela and the port, and again westward for many miles over the strip of land facing onto the sea. Improvements will be made to an existing line destined for goods transport serving the industrial areas and the port. The railway network could thus fulfil a double role: a continuous and efficient public service able to satisfy the future demand of a growing population and an infrastructure to serve industry and the area around the port.

In view of a sustainable urban development, it must be clearly understood that an infrastructure can also considerably alter a landscape. On this basis consideration had been given first and foremost to rail and tram connections, and secondly to roads, realizing that a city of the third millennium cannot effectively fulfil its rightful role of promoting Mediterranean culture without adequate infrastructures able to provide internal and external accessibility for developing relationships throughout the entire urban area. In addition to becoming a cultural centre for a territory of vast proportions, Alexandria must create a close network of transport connections with its immediate surroundings.

It must be clearly understood that an infrastructure, of whatever kind it may be, not only connects places and people but can also considerably alter a landscape. On this basis consideration had been given first and foremost to rail and tram connections, and secondly to roads, realizing that a city of the third millennium cannot effectively fulfil its rightful role of promoting Mediterranean culture without adequate infrastructures able to provide internal and external accessibility for developing relationships throughout the entire urban area. In addition to becoming a cultural centre for a territory of vast proportions, Alexandria must create a close network of transport connections with its immediate surroundings.

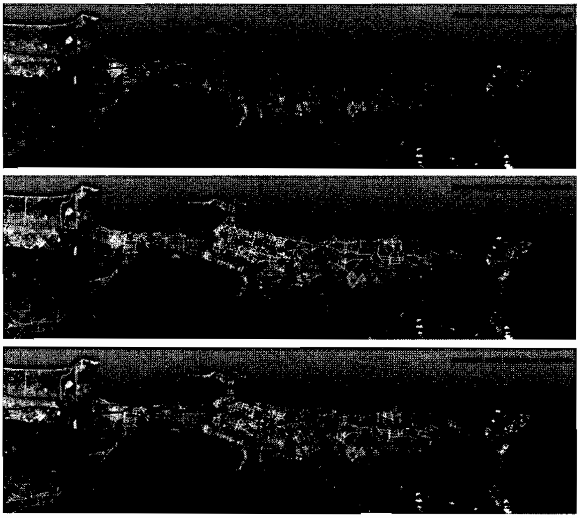


Figure 14 : Master Plan for the road and rail network in the area from Aboukir to the harbour of Dekhela

6 6 Concluding Remarks – The Enigma of Alexandria

Which future for Alexandria? The question put by the geographer Jac Smit in 1997 is still valid, in spite of the great success enjoyed by the Library. His article is timely, explaining as it does the possible alternatives for Alexandria, in the late Seventies. In those days the inhabitants of Alexandria numbered about 2,500,000 - roughly half the figure of today, then equivalent to the population of fourteen lower-ranking towns – while in the preceding decade its rate of growth had been slower than the average for the larger Egyptian towns. Although lacking any clear definition of its role at national level, Smit believed that the city's chances of development depended on a strategic geographical position for the port with roads, railways and canals, on availability of vast desert areas ideal for urban expansion and miles of beach perfect for increasing the tourist trade. Smit wondered whether Alexandria should be encouraged to develop or, like Cairo, to be decongested: "a primary candidate for industrial and trade growth like Singapore, or a decaying seaside, post-colonial, port city like Rangoon?"

It should be remembered that the heritage of Alexandria depends not only on its literary myth, nor even on its archaeological remains and the fine buildings aligned along its dusty streets, but rather because its urban structure has preserved the stamp of its foundation, of its roots planted in a strategic position. The port stands where routes from the Nile and the Sahara oases meet the

Maghreb-Syria route, crossing others from Europe to the Red Sea and on to Arabia, India and the Far East.

To use Jac Smit's words, the "enigma of Alexandria" evinces a periodical need to reinvent an *ad Aegyptum* geographical role for the city: close enough to Egypt to benefit from the country's resources; far enough to preserve its independent identity. It is just the recurring nature of this problem – a 'priority (we may say strategic) project for the city, for its infrastructures, resources for industry, its trading relations and social cohesion – that makes of Alexandria such an important point of observation for research on sustainable urban development, showing as it does the need to work out an overall project for the city in all its complexity, both for strategic areas and functions as well as for transport facilities.

Along this line of thoughts, the 'sustainibility problem' may reverse the function of planning, which has often been reduced to an increasingly subordinate role. This attitude appears in the handling of a number of planning projects when the planners are facing problems of a sociological nature without due consideration of what a city's history can teach.

Acknowledgements

Contributions to our studies have been received from Dr. R. Pugno, economist, lecturer in Economic Evaluation of Planning at the Faculty of Civil Architecture, Politecnico di Milano, and from Dr. E. Sacchi, expert in port organization and planning. A. Alpini, G. Boni, Viola Bertini, E. Ciapparelli and C. Taddei, students at the Urban Planning Workshop II have carried out research and prepared some of the maps included in the text. Apart from the many documents consulted, most of the statistical data used was taken from the following sources: http://comtrade.un.org/; http://epp.eurostat.ec.europa.eu/portal/; http://portal.unesco.org/en/; http://www.apa.gov.eg/; http://www.aseansec.org/; http://www.egyptweb.com/; http://www.egyshipping.com/; http://www.euromedtransport.org/; http://www.fao.org/; http://www.intracen.org/; http://www.lethsuez.com/; http://www.oecd.org/home/; http://www.portofrotterdam.com/e; http://www.un.org/; https://www.cia.gov/; https://www.cia.gov/library/publications/the-world-factbook/

References

Alexandria Governorate and University of Alexandria (1984). *Comprehensive Plan Alexandria 2005, Final Report*. Alexandria: El Shorouk.

Bibliotheca Alexandrina (2005). *MedCities: The Mediterranean City: Dialogue among Cultures*. Alexandria.

Bernand, A. (1996). *Alexandrie la Grande* (1966). Paris: Hachette/Pluriel.

Breccia, A. (1927). *Il Porto di Alessandria d'Egitto. Studio di geografia commerciale*. Cairo: Institut Français d'Archéologie Orientale pour la Société Royale de Géographie d'Égypte.

Casiroli, F., Donato, V. (2006). *Europa delle città Europa delle regioni - Europe of the cities, Europe of the regions*. Milan: Clup

Clavel, J.-P., Meissner, J., Lombard, F. (1988), eds. *Bibliotheca Alexandrina, Architectural Brief and Competition Rules*. Unesco.

Commission européenne (1999). *SDEC. Schéma de Développement de l'Espace Communautaire. Vers un développement spatial équilibré et durable du territoire de l'Union européenne.*

Dix, G. (1986). Alexandria 2005: Planning for the Future of an Historical City. *Ekistics*, 318-319, 177-186.

ESPON (2005). *Potentials for polycentric development in Europe. Annexe D, Moorphological analysis of urban areas based on 45-minute isochrones.*

Ferro, L., Pallini, C. (2009), eds. *Alessandria d'Egitto oltre il mito / Alexandria Beyond the Myth.* Boves (Cuneo): ArabaFenice.

Forster, E.M. (1968). *Alexandria. A History and a Guide* (1922). Gloucester, Mass: Peter Smith.

Hall, P. (1978). *The World Cities.* London: Weidenfeld & Nicolson.

Ilbert, R. (1987). *Alexandrie entre deux mondes. ROMM*, 46.

Jondet, G. (1921). *Atlas historique de la ville et des ports d'Alexandrie.* Cairo.

Lewis, W. A. (1978). *The Evolution of the International Economic Order.* Princeton University Press.

McLean, W. H. (1921). *City of Alexandria Town Planning Scheme.* Cairo.

Manzi, E. (1982). Egitto rurale e urbano tra congestione insediariva e sottosviluppo. *Rivista geografica italiana,* 54-101.

Mostafa, H. (2006). El-Salhel. Etypt's North Coast is the Hamptons and Cape Cod, Egyptian style. *Egypt Today*, April.

Raafat, S. (1999). Adieu San Stefano. *Cairo Times*, 1 January.

Riad, H. (1964). *Egypte Nasserienne.* Paris.

Wiener, L. (1932). *L'Égypte et ses chemins de fer.* Bruxelles.

Zagari, F. (1990). Bibliotheca Alexandrina International Architectural Competition, Unesco-UNDP – Rome: Carte Segrete.

Inhabitants/Authorities: A Sustainable Housing at Stake: Case ofAli Mendjeli New town in Constantine

Lilia Makhloufi[1]
[1]*University of Jijel, Algeria*

Abstract

Offering many dwellings, Ali Mendjeli new town which is under construction actually, presents an alternative to the spontaneous growth of the existing agglomerations and to the extension of peripheries, absorbing and welcoming the surplus of populations of Constantine. The new town has an advantaged situation: 25 kilometres only from the medina, halfway between two satellite towns, at the crossing point of big axes of communication from or towards Constantine and in close proximity to the airport. Having a capacity of 300.000 inhabitants, this new town is supposed to respond today's population needs, its construction capacity is important, it is aired and endowed of important facilities. These last years, the new town involved a major transfer of the population guaranteeing everyone the right to a home in optimal living conditions.

The actual residents of the new town have neither a generic name nor a specific citizenship but, they have distinguishing features: more than 5831 homes have been assigned to the families of demolished shanty towns, 1165 to the people coming from the medina and 1121 to the victims of landslides. The aim of this housing policy is to establish equity and social cohesion. Certainly, housing is a basic requirement for everyone. Good housing strengthens communities and provides a better setting in which to raise families. It improves health, educational achievement and employment opportunities and provides a long-term asset to be passed on the future generations. But, is the new town really a place where people want to live, now and in the future? We will try, in this paper, to reflect on housing, while observing the effect of lifestyle on architecture and urbanism, but particularly on the conception of one's home.

***Keywords**: old town, new town, dwelling, identity, lifestyle, sustainable housing*

1 Ali Mendjeli: A New Town Submitted to Socio-Economic Emergencies of Constantine

Constantine "the City of bridges", is one of the biggest cities of Algeria and probably one of the most oldest cities of North Africa. Situated in the north-east of the country, about 80 kilometers from the Mediterranean coast, Constantine was built on a plateau at 640 metres above sea level. Its old town or "medina", commonly called "the Rock", is unique by its site. This natural fortress "nest of eagle, perched on a narrow rocky tray, limited by the dizzy steepness" (Modot, 1974: 387), rich of its twenty-five centuries of history, is characterised by tiny teeming streets inextricably linked that topples until the limit of the ravine, and by places which are submissive to sunniness and climate. It juxtaposes spaces having each a specific function (residential, economic, religious or military) and structures the surrounding urban districts. During many years, the socio-economic development associated with the demographic expansion generated a considerable urban development. However, because of the site constraints, the growth did developed its tentacles to large distance, with an overload in the centre of the city and tendencies of urbanization without infrastructures and services in the suburban areas.

The evolution of the last decades generated many problems. Changes in rhythm and scale, growth of the urban population, multiple illegal implantations, produce a blurred image and discontinuities prevail over adjustments. The result is the development of a town that answers with difficulty to the demands and aspirations of its inhabitants, all the more that in Constantine, the situation of housing is alarming, marked by a deficit that exceeds 40.000 dwellings: 15.000 lodgings affected by landslides, 3500 constructions decayed in the old town, shanty towns estimated to 11.638 hovels and a deficit following the natural increase estimated to 10.000 lodgings. The 21st century urban life cannot be considered without taking into account the sustainable development, "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations, 1987). This is the most widely known definition coming from the Brundtland Commission, but what does it recover in Constantine? What are the actual needs of the population? And where are the prerogatives of our decision-makers? A quick survey of Constantine's medina, its colonial core and the shanty towns, will help to recognize the existence of a particular context and the necessity of a set of principles for building the basis of a sustainable housing.

1.1 The new town of Ali Mendjeli facing an old housing threatened by collapse in Constantine

The Constantine's heritage constitutes an inexhaustible source where one can draw teachings concerning architectural and urban production and at the level of which one finds a harmony between the society, the cultural identity, the daily practices, the lifestyle and the physical and natural environment. On the one hand, the medina is characterised by a traditional urban structure, associated to a big sense of community. Its public spaces constitute the support of district life and have a regulating function of pedestrian flows, in the sense where these define and filter the passers-by, make all activities linked, while preserving the intimacy of the residents and while conferring conviviality between neighbours. On the other hand, the colonial core is composed of a succession of closed islets in coherence with the Haussmann conception. A rigid street alignment is respected with a real homogeneity of construction that gives its consistency to the whole. Indeed, the French interconnected the neuralgic points of the city by conceiving the town in a systematic way, hierarchized and interdependent.

Today, the medina is in state of ruin and the colonial core (more precisely the extremity of the ex-suburb Saint-Jean) is submitted to an important problem of landslide. The emergencies encountered in the city centre brought the political powers to intervene, launching important programs of housing, achieved in the briefest delays. Let's mention for example the 6000 new dwellings scheduled on the site of Ali Mendjeli new town in order to receive the inhabitants of the Boulevard Saint-Jean, considered like a high risk site. Indeed, the natural fragility of places, the rainwater infiltration and the dilapidation of the adduction network in drinking water, provoked landslides which damaged the foundations causing the downfall of a certain number of dwellings. Actually, numerous are those who denounce the dilapidated state of these spaces, the absence of management but also of maintenance on behalf of authorities and occupants and fight for their safeguard whereas the action of authorities limited itself to the rehousing of some truly damaged inhabitants. Certainly, improving the quality of life in the city centre of Constantine includes social and economic aspects, political and institutional intervention, but also and especially cultural components. Today, for a sustainable urban development, the preservation of heritage for the future generations becomes more than ever indispensable.

1.2 The new town of Ali Mendjeli facing a precarious housing to proscribe from Constantine

In Constantine, in response to the proliferation of real cores of shanty towns, concrete steps have been taken to guarantee better living conditions and to legalize the situation of the population in these underprivileged districts. The promiscuity of housing, the absence of rudimentary hygiene (collection and disposal of wastewaters and of domestic wastes), are factors which amplify risks of epidemic. Infrastructures and basic facilities for these underprivileged districts have been financed by the local community, without possibility of ulterior recovery of costs by taxes. Let's underline that most of the people living there were craftsmen, their activities procured them a random income and the households sometimes accumulated several small jobs to assure the daily income, the access to a decent dwelling being truly out of range for a lot of households. In order to improve the quality of human life, the rehousing in the new town of Ali Mendjeli has been chosen as the better solution enabling district eradication and struggle against poverty. After the transfer of the inhabitants, the unsanitary sites have been demolished.

The urban policy of the local authorities, to fight against the unsanitary habitat, permitted to diminish the demand of dwellings but the strategy remained insufficient. The politicians tried to resolve a statistical problem without taking into consideration the local social specificity. Average size and income of households, number of families, density by hectare, were some indicators that led to a merely statistical approach. But the rehousing brought difficulties such as the capacity of financing by households (weakness of incomes and non access to banking credit). Nevertheless, for a sustainable urban development, every country should seek to reduce the harm to health caused by poverty. Indeed, no-one wants to be caught in a situation of poverty, with a consequent lack of pride in one's disctrict, poor environmental quality with unsafety, unemployment and multiple inequalities. In order to ensure a better quality of life for everyone, now and for generations to come, it is necessary to renew with larger socials problematic such as to accommodate the poorest population.

2 New Town, Urban Development and Housing Issues

The residential life, work, purchases, leisure and activities take place henceforth in separated places, within agglomerations always more vast. If this picture is also worth for the new town of Ali Mendjeli, the more active families disperse themselves daily between different places. This new town corresponded to a big project of urbanism; a particular importance had thus to be granted both to public facilities, to infrastructures and to their realization, in order to ensure a balanced situation on the social as well as the economic plan. In this same optics, the new town had to be achieved progressively following a general plan, in order to realize a coherent assemblage of various districts, of different types of architecture and dwellings around an attractive and modern centre. Wanting to create an attractive urban setting in which nothing should lack or nearly, but again and especially an urban and social life, the local authorities have made the bet to give the population more than a dwelling, an urban environment thanks to a dense network of tertiary facilities and big projects crowned by the university and the medical centres, the arrival of students and senior executives in a substantial number can entail the creation of new activities (Figure.1).

In the new town, planning presented simple plans that might suppose that the realization was going to be simple too. Its conception wanted to promote a step where the daily is structured by the attendance of facilities (scholar or cultural, social or sanitary, administrative or commercial), a real will of integration of facilities in the districts and a reflection on the places of the collective life. Urban planners thought that a satisfactory life quality got itself thanks to a strong population density, solely capable of guaranteeing services, transportation and animation of the district. One finds thus constants features: the density of lodgings, the presence of facilities, the whole lot connected by public transportation; the objective being the will to arouse a feeling of city, to create an animation. The supplying of appropriate public services implied a great concern.

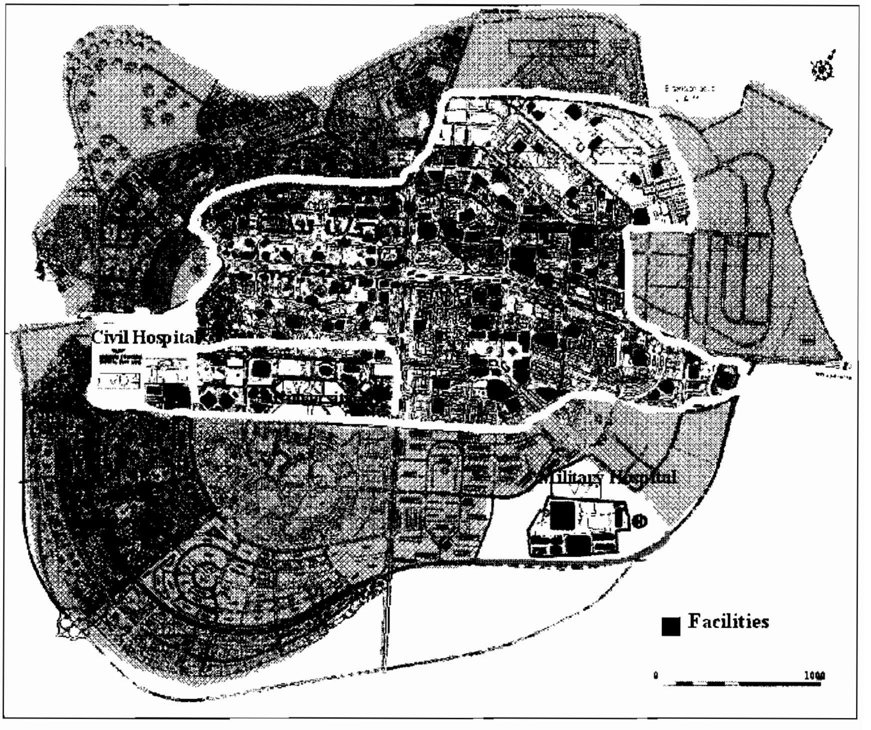


Figure 1: Distribution of facilities in a new town under construction (Scale:1/50000)

To satisfy the basic needs of the population and to achieve a better quality of life in the new town, planners put in service facilities since the arrival of the first inhabitants. These last, find close to them, primary schools, colleges, day nurseries, sports halls, social centres and trades of first necessity. While moving a little away, they reach high schools. By bus they can join at last the administrative city, the post office, the banks, the university and the hospitals. It is the diagram that prevails in practically all the new town. But today, as the city tries to define its role, it undergoes periodic adjustments, taking into consideration the social disparities and lifestyles, makes feel itself more and more. Indeed, the perception of the new town is bound to the logics of action and interests of all concerned actors, from where the difference between inhabitants and the other users.

2.1 Housing offer and degree of households satisfaction

To build blocks of flats is, for our decision-makers, a good answer to housing shortage, despite the fact that the inhabitants denounce the formal and architectural poverty of these innumerable buildings of concrete. Certainly, the lodging being above all an object defined by its spatial dimension, it is characterized by three attributes: the metrics, the scale and the substance. Nevertheless, the lodging constitutes also the concrete matter of the social space and contains the material contexts of the social life, in its contemporary as well as historic dimension. Elementary form of territory, the lodging crystallizes stakes of societies and institutes itself as basis of every projection towards the future, a spatial reality at the same time material, immaterial and ideal. Let's mention for example the case of shanty towns, the lodging can reduce its material envelope to little thing and in this case, it becomes above all a social construction; from where the importance of the individual, of the subjectivity, of representations, in the analysis of the lodging.

Therefore, we analysed the housing starting from the inhabitants which besides, practise and live the space in a subjective and personal way. Within the framework of our survey, we have established a questionnaire for a few 300 people. Destined for households of Ali Mendjeli new town, the questionnaire treats first the questions relating to the lodging, then those relating to the district and at last those relating to the new town in its totality. Let's underline that each part of the questionnaire has been detailed according to the observations that we have noted during the interviews that preceded the actual investigation with the inhabitants. Therefore, we took into consideration the impression of the tenants/owners concerning the assigned lodgings and the problems that they met following the installation (to pay one's bills, for example). The question of work was evoked as well in order to determine the locality and the frequency of the displacements. We considered then the impression of the tenants/owners concerning the residential district, the trades, the school establishments, the leisure and other activities; and lastly, we took into account their feeling concerning the new town, the relation with the district of origin and the chosen transportation means.

The treated sample (300 people constituting a representative sample of the population) is not stratified rigorously, nor completely random. The people were interrogated because of their inscription in the considered spaces and their availability, first condition of the exchange. Indeed, at first, we submitted our questionnaire while going from one house to the next, however we encountered multiple refusals. Therefore, we addressed it to different school establishments (primary schools and secondary schools), to offices (Public Office of Real estate Management, administrative City, etc), without forgetting people practising in a private capacity (doctors, dentists, pharmacists, varied shopkeepers). Let's underline that all the persons that we interrogated lived in the new town since a few years. Above all qualitative, the committed survey justifies well that it is less the static representativeness and the mathematical rigor that prevail than the capacity to seize the problems that inhabitants meet as individuals and as community in their new residential spaces within a new town. However, the distortions of the sample owed to absences or refusals are frequent. Cases of non answers can also depend on the asked questions, of the implication level of the interrogated people and of their socio-cultural features. The obtained results have been interpreted while using the software Sphinx version5.

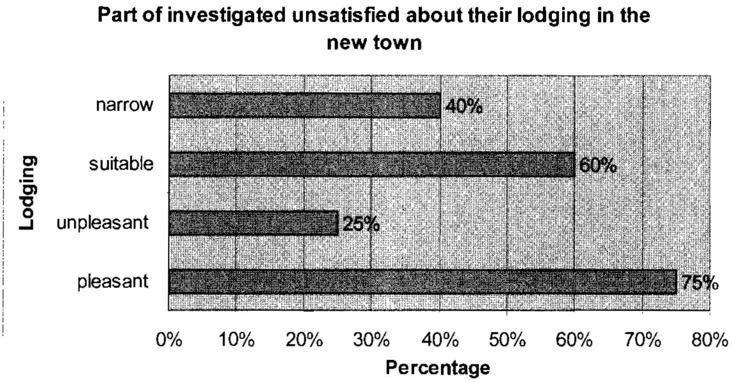


Figure 2: Part of investigated unsatisfied about their lodging in the new town

In our investigation, 66.7% of the interrogated inhabitants were tenants and 33.3% owners of their lodging. According to Figure.2, only 25% of the investigated find their lodging unpleasant and 40% find it narrow. Indeed, a big majority of the investigated find their lodging suitable (60% of the investigated) or even pleasant (75% of the investigated). But as regards finishes, 57% of the investigated estimate that the quality of finishes is unsatisfactory and required some works at their expense. Indeed, the inhabitants delighted, in a first time, to find in these apartments modern comfort of which they had been deprived until then, mentioned subsequently problems of bad workmanship, not waterproof roofs and bad plumbing. This kind of problems comes back constantly to the centre of proceedings, and complaints are addressed to the Public Office of Real estate Management (OPGI). This fact reflects the state of emergency of construction operations and of assignment of lodgings. However, the appreciation of the quality of life in the new town cannot be associated to the only assignment of lodging and to the only logic of its market, except to accept a reduction of its complexity.

3 Housing Production and Inhabitants' Welfare: Case of Social Housing

In the new town, it appears difficult to escape a repetitive architecture, considering the rigorousness of the economic system of the construction and the constraints due to the prefabrication process, on the one hand. On the other hand, the "standard" solutions adopted: for a household between 5 and 7 persons a two-roomed flat with kitchen (F2) is assigned and for 7 persons that will be a three-roomed flat (F3), led to important modifications in the apartments -let's underline that the production of the one-roomed flats, assigned formerly to households lower to 4 persons, has been stopped in 2003 following the official visit of the President of the Republic-. The residential spaces of the new town let appear obvious maintenance difficulties. The tenants changed the lay-out as well as the façade (Figure.3).

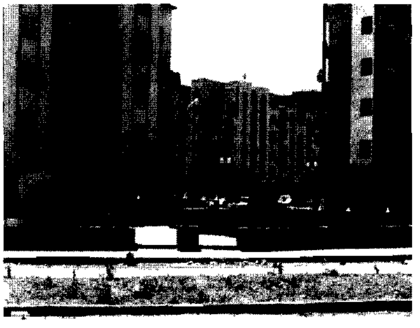



Figure 3: façades of buildings in the new town before and after transformation

Formerly, the conception of housing was usually marked by the full/empty ratio, in other words to open for reasons of aeration or ventilation, lighting and sun, to close in order to preserve the comfort of each member of the family and its intimacy from all kind of impropriety. This dialectic concept considered as well the relationships between individuals as the physical devices that unite or divide the privative, collective and public spheres of the habitat. Architecture was a tool that offers different levels of intelligibility, e.g.: volumes, façades, exterior/interior ratios, dynamics or statics, integration into the environment. Nowadays, the sustainable housing asks a series of questions about the sustainable design performance of the existing buidings. It covers environmental issues like water and energy, as well as social issues like safety, security and accessibility. It provides recommendations (short-term measures to long-term measures) that can be used to design or construct more sustainable homes, these must be water, energy and waste efficient, accessible, safe and secure but also cost-effective. Today, designers and architects consider orientation of the building, location of the rooms, amount of insulation, window size and location, ventilation and shading in order to achieve the best energy rating, to provide greater comfort, lifestyle opportunities, as well as financial savings. However, in the new town of Ali Mendjeli, the problem of achieving sustainable housing seems as much cultural as technical, from where an investigation to understand better the present context and the actual needs of the inhabitants.

3.1 Beyond the flat, living in one's home

The inhabitants of the new town denounce the architectural poverty of their buildings of concrete and don't hesitate to ask plumbers or masons for help, in order to remodel, indeed to renew the inside as well as the outside of the apartments. Let's mention first, people coming from the medina and their attachment to a vernacular architecture. Wanting to re-create an endogenous system whose rooms would look onto a central core, in the new apartment, inhabitants proceeded to certain changes: the hall took the central place, to be converted in case of need to a place of meeting where they can meet around a low table to take a coffee or a meal. The entrance hall will replace, whether people are aware of it or not, the central patio of the traditional house. The hall will become this way the core of the residence, a place of fully-fledged life, but also a space to receive friends or near family. In some cases, the drying area has been transformed in kitchen and the kitchen in bedroom. According to the interviewed -let's underline that we won't unveil the identity of our interviewed in this paper, anonymity being thus respected- coming from the medina : "we get used to dry our linen to the big air in a patio submitted to variations of the sunniness [...] we don't see the utility of what had been designed".

People originating from shanty towns, who live now in apartments in the new town, add some brick walls to obtain a dwelling adapted to their needs, "we only benefited of a two-roomed flat [...] disappointed, we transformed it in a three-roomed flat [...] we get used to tiny rooms", and it is not rare to find more than one household in the apartment. Using one apartment for two households sometimes, explains why people choose to divide their space of life. Otherwise, it is frequent to see that the balcony is not anymore autonomous but became a part of the living room or the kitchen, without thinking about problems of thermal insulation or humidity. According to the interviewed: "the balcony is exposed to the indiscreet looks of passers-by [...] a veranda will allow us to make use of the balcony, in all intimacy".

As for victims of landslides, they call into question the image of the new town in general and of its apartments in particular (Figure.4): "the depreciation of the new town, when this one is not chic, doubles itself of the one of a concrete-city compromised by the illegibility of places [...] and other burrs that badly sign the concrete and the coat of plaster". Formerly, these persons lived in big apartments within the colonial core, in full city centre. They got used to a certain way of life that they try to reproduce in the new town. But, once on site, they find their selves, in the best of cases, in only three rooms (F3) that don't correspond to their customs. Certainly, the closed islets in which they lived presented several inconveniences, the one to prevent a good diffusion of light, notably (rooms looking onto courtyard were often very dark), "but we had an impregnable view on Constantine". Thus, the view and the standing prevail over comfort in housing.

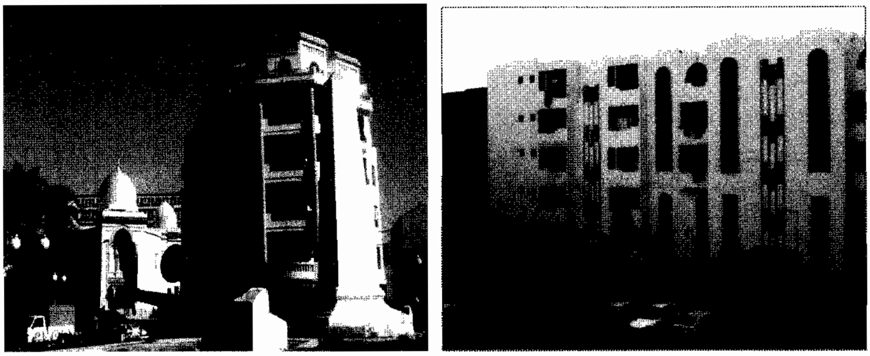


Figure 4: example of residential building - in the colonial core (on the left), in the new town (on the right) -

The decision-makers are confronted to difficulties that they must surmount. Some dissuasive measures have been taken to thwart the alterations worked out by the new residents and to warn them about the risk of damaging the building structure which can get unsafe. From our interviews to the OPGI -made in order to actualize our knowledge on the evolution of the real estate heritage in the new town- it emerged that: "services of the OPGI don't have the right to go inside the apartments, in order to estimate the damages [...] complaints from worried neighbours addressed to the OPGI (because of resonant nuisances or uproars) allow the OPGI to open an investigation [...] only a report done under control of a process-server is necessary to estimate the acuteness of the deteriorations". It is difficult to have an exact evaluation of the number of inhabitants who have remodelled their apartment, without any authorization. Several families have been told, after intervention of the court, that it is forbidden to modify the façades and of course to modify the inside. The judge stipulated that tenants have to put back the apartments in the state in which they found them. If they refuse, they risk being condemned to prison, that is why the inhabitants refused definitely all hold of photos.

But for the architect, whom I am, the acuteness of these transformations is contestable. While examining the conduct of inhabitants concerning dwellings and the one of the OPGI control services, the investigation has demonstrated that these latter are badly adapted to the needs of households, that no sociological survey has been led beforehand, and that if one applies the standardization of lifestyles, it is translated by a ceaseless need of space for inhabitants. Otherwise, the architectural conception of buildings in the new town is so rigid that it would be erroneous to believe that all transformations are possible, according to how the inhabitants feel, and that because of prefabricated walls in reinforced concrete impossible to pull down. In fact, what occupants do is to adjust apartments to improve their well-being, by destroying some baffles, non bearers. Consequently, their modifications can in no way harm the building structure.

It is therefore a question of personality. People lack a picture of reference, a proof of identity and anchorage in their lodging. Indeed, for everyone, the images evoked by one's home and town are inextricably linked to processes of identity. The image of the flat is linked to how it is used by the residents from the moment they move in, whether by choice or constrained by circumstances. Let's recall that the lodging goes beyond the simple material dimension and also includes the social matter. Our position is not attached to the past. It is not praised a kind of architecture in particular. We merely want to seize dimensions making possible to act up. We try to adopt another stance facing the contemporary housing. We would not consider the construction process and the economic context as independent from the social context and to accept that they are only subjected to their own logics. In the new town of Ali Mendjeli, the problem of achieving sustainable housing is above all cultural. Therefore, a broad view of inhabitants' welfare is necessary, a long term perspective about the consequences of today's actions of our decision-makers is required and the full involvement of civil society to reach viable solutions is becoming more than ever imperative. Actually, to protect their well-being, different groups of inhabitants have learned to be at a given time more militants and more tenacious. Conscious that the scheduling permits to structure the change, they try to influence this one, but do they have their place in the decision-making process?

3.2 Rehousing and participation of inhabitants in decision-making process

The reconstitution of the main territorial adherences preceding the arrival in this new town offers a first preview of the residential origins of the inhabitants. Rehoused by the local authorities, most of them are from the central districts of Constantine. For a lot of households, these districts are the privileged places of their installation since their arrival to Constantine. For some of them, it is a space of transit at one moment or another of their residential trajectory. For the rest at last, the set of the residential trajectories in Constantine took place within a same district and in a much delimited space, case of shanty towns. While observing the inhabitants of the new town and what they had converging, while admitting their oddness and their exemplarity appeared "common features" like the installation in the new town, the learning and the experimentation of the social lodging, but again and especially the residential stability in Constantine, from where the importance in our survey concerning the new town of Ali Mendjeli of the opinion of these persons.

In the new town, the emergency of rehousing operations and the particular difficulties of realization constantly go beyond the hold in consideration of the social disparities and lifestyles, from where the presence of individuals regrouped in association. One counts actually about twenty associations representing rehoused people from the shanty towns of Constantine, of its medina, or those coming from Saint-jean area. But, these associations that give themselves as objective to defend and to improve the local social life and the living environment don't enjoy a sufficient power to be integrated to decisions and don't have an office to exercise their activities. Not very listened and little partners to decisions which concern them, inhabitants have undertaken to defend what they have come for: the identity of districts and optimal living conditions. This type of structures didn't have, till now, legitimacy to express and to defend the collective interests. This exclusion has even pushed them to contest. Wanting to ensure buildings as well as amenities that are attached to them, terraces of cafés have become places of regrouping.

The requests concerning the assigned housing are addressed to the Director of Urban planning and Construction of Constantine, to improve the established urban fabric: "the too linear volumes, of an immediate proximity, let appropriate themselves with difficulty, too many discontinuities and hollows subsist leaving a flavour of incomplete, [...] without forgetting the absence of collective spaces management". As for others, that will be for possible exchanges of dwelling, of level or of building, requests might be sent to the Public Office of Real estate Management. If associations linger to receive an answer, they could then contact the Wali (the prefect) of Constantine. The citizenship expresses thus itself by the regrouping of individuals within associative structures, wanting to defend requirements of the new community and to put the leaders' speeches in accord with their acts, to answer the social expectations.

In our point of view, establishing a real relation of partnership with citizens can provide real opportunities for the civic associations to make decisions affecting their community. Active inhabitants involvement can help planners to achieve better outcomes by making them aware of the population needs and preferences. When properly administered, this partnership can result in more meaningful participation and more creative outcomes to persistent problems. It enables architects and planners to make decisions that reflect community needs and values, and the community can give a personal stake in its success. Let's recall that the new town defines itself also from its social actors, their representations, their behaviours and their practices. "The possibility to identify us positively to a place [...] to develop the pride to live in", this is the essential stake for the new residents. Thus, one can regret a proof of identity, of anchorage in the territory and the absence of a feeling of adherence in a newborn territory. Does the residential transfer threaten the sustainability of the new town?

4 Inhabitants and Feeling of Adherence: Which Stakes? Which Consequences on the Sustainability of the New Town?

The goal of sustainable urban development is to enable all people to satisfy their basic needs and enjoy a better quality of life, without compromising the quality of life of future generations. The term sustainable development includes also human development, values and cultures. We are referring to sustainable human development in order to emphasize issues such as the importance of housing quality and participation in decision-making process. In the new town of Ali Mendjeli, the material and symbolic effects of the residential transfer came out to a modification of the combination that settles between, on the one hand, the relation of the inhabitants to the space, and on the other hand, the practices that take place in this space, otherwise said, at the transformation of the territorial system: a new type of housing (the apartment), a new lifestyle, another spatial configuration of the private space, a new use of the public space, without forgetting the geographical situation of the new town which implies new forms of reports with Constantine and more precisely with the district of origin.

Actually, the frequent round trips between the previous and the actual place of residence don't permit to speak about two distinct territories. On the one hand, in the time, since one corresponds to the past, bygone, and the other to the present and to the future, and on the other hand, in the space, seeing that to each one correspond representations and practices spatially determined. Nevertheless, the reflection on the new town of Ali Mendjeli leads to the definition of the pros and cons, to a hold of position towards this big project and the challenge that it raised. Indeed, every year, thousands of lodgings are taken in site in this new town. For their occupants, to lodge is necessary, but insufficient. Around that, they expect to find a district, with its exchanges, a town full of life. Indeed, beyond the simple addition of housing, of services, of streets, the city defines itself by its districts and its characteristics, the animation, life that results from the combination of all these elements. Therefore, a successful urban planning must consider the urban character and respect the local identity.

4.1 Beyond the dwelling, living in one's district

We asked the same question to a few 300 persons about their territorial adherence, our interlocutors evoked in first position the district of origin, followed by Constantine, they mentioned then the new town of Ali Mendjeli. Therefore, we kept the old addresses of the persons that we interrogated in our investigations and our interviews like an explanatory variable of their opinions, their attitudes, their practices and their representations. However, the everlastingness of the ties with Constantine is unequal from an inhabitant to another and it is rarely complete: for many, the residential change implied new practices and for some the residential rupture caused a quasi-total rupture of these ties (case of inhabitants coming from the eradicated shanty towns).

According to our investigation, 67% of the interrogated inhabitants regret their previous district. The fact that they are attached to it by social and economic ties make of their district of origin, the emblem of a disappeared citizenship. Probably because it belongs to a bygone past in their eyes, the previous district appears like a homogeneous space and sends back to an idealized time, conflicts and tensions forgotten, that was the space of the family and the good neighbourhood. According to the interviewed coming from the medina: "the attachment to the district of origin is bound to what represents its buildings, its atmosphere, its setting of life [...] or the knowledge, the experience and the exploration of certain parts of the old town rather than others", which assigns to these central spaces a range of values and positive or negative representations that interact on the perceptions of the inhabitants, in particular those that live there since several generations. In this sense, Constantine with its history, its emblems, its lifestyle, constitutes the territory of reference. This territory of origin, of identity, of representations and also of practices, takes all its sense because it is constantly put in interactions with the space henceforth inhabited, also represented and lived, namely the new town (Figure.5).

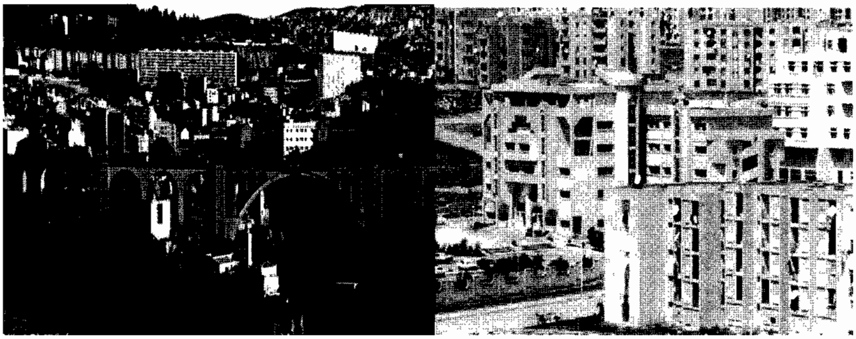


Figure 5: Previous and actual district (old town/new town)

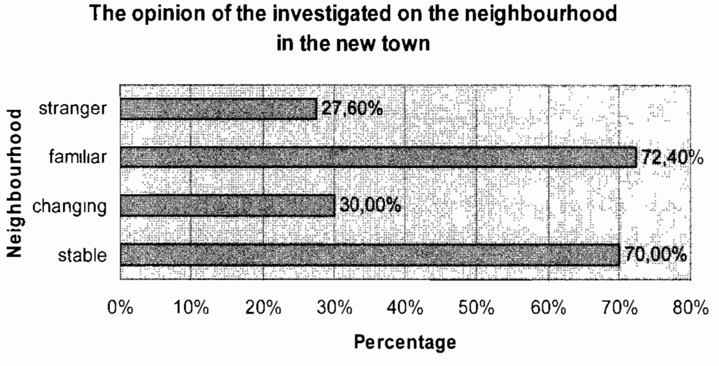


Figure 6: The opinion of the investigated on the neighbourhood in the new town

Space of origins, the initial district becomes a distinctiveness reference of "before the rehousing", a place of identity; according to the interviewed: "to refer to it allows to say from where we come ourselves but also to know who is the neighbour". A process of reconstitution of one's identity, an identification all the more necessary because the rehousing muddled the original adherences of identity. In the new town of Ali Mendjeli, the residential transfer interferes on the territorial system and on its development. The latter, constitutes itself in part according to the previous district. Indeed, the identity forms the major tie between the human beings and their setting of life. It is a powerful motor of the production of the social space. The appropriation of the space is not only a purpose, it is also a means. For the inhabitants, there was a fracture of this order and not a simple transfer. The references of identity towards the district of origin are thus omnipresent in the constitution of new social relations.

Otherwise said, while assigning to their previous district values, signs, ways of life and specific social ties, they distinguish at the same time their district from the other districts of Constantine, and distinguish themselves from the other inhabitants of the new town. By this operation of passage between a nominee space, qualified, delimited, with the inhabitants that lived in, it becomes possible to recognize the neighbour: 72.4% of the investigated find their neighbourhood familiar and 70% find it steady (Figure.6). Indeed, the authorities rehouse the families of a district according to the socio-emergencies of the moment certainly, but also according to the availability of blocs of flats in the new town. The beneficiaries find themselves thus with a familiar neighbourhood once in the new town and that encourages most of them to adapt themselves instead of moving. Indeed, according to them: "the multiple familial and professional networks but also those of neighbourhood give a sense to the new residential spaces".

The worry for the dwellers' welfare in their new environment is accompanied by a willing to endow every district with sufficient collective services, but the local authorities meet difficulties to manage the time factor and it becomes necessary to admit that a generation at least would not enjoy the whole of facilities foreseen to term. After having thrown away their reference marks, modified settings of adherences in which they organized themselves, the uprooted population expresses concern about a lost past and an uncertain future. For the inhabitants, the events that had enamelled the history of their districts of origin made of it more than a space, a territory apart, probably exceptional and in any case distinctive from others, the residential history being really meaning because it is discerned by its inhabitants like a common history, an attachment founded on a collective memory.

Currently, all happens as if the appropriation of the new living space within the new town, or the edification of a new territoriality, made itself according to the previous district. However, that construction process of territorial system deserves to be shaded. What we observe is an experimentation, a learning always in development, of a new town that builds itself from representations of its inhabitants: representations of oneself when it is about lifestyle, representation of the living space, representations of the urban model of the new town (by opposition to the old centre of Constantine) and that implies, according to the inhabitants, some new norms to fit, some new behaviours and attitudes to adopt. In order to promote local participation, our decision-makers must create an unprecedented partnership across local agencies and provide resources and tools to help inhabitants realize their own visions for building more livable, walkable, environmentally sustainable new town.

5 Conclusion

The analysis of the content of our investigations and our interviews indicates that the representations of the residential spaces of our interlocutors depend closely on their experience at the same time personal, social and spatial. Thus, constrained by user attitudes, sustainable housing cannot conceive itself outside of its context and must defined itself according to the will of the local actors and their prerogatives certainly, but also and especially according to the inhabitants needs. The construction, design and type of housing are critical to the long term quality of life for the inhabitants who will live in these spaces. Therefore, greater efforts must be done to build inhabitant participation into all stages of the development process from drawing up plans to handing over keys and beyond. If inhabitants are given a feeling that they belong and are part of the new town, able to contribute to decisions affecting their lives and the lives of their children, friends and neighbours, the new town in general and its apartments in particular will become more sustainable.

For the present as for the future, the local authorities must learn to put the inhabitants first, not fees or speed of construction, while going beyond the simple information of the population, while accepting to approach "topics that annoy", while admitting the contradiction and while accepting to be disavowed sometimes, because that they do want it or not, the adherence of citizens to projects that concern them is, in the present context, the key of a sustainable urban development. Creating buildings and urban environment that people enjoy living in and working in requires best practices at the same time economic, social and environmental. Building and strengthening a sustainable community imposes to improve the quality of life of the population and to consider the longer term implications of decisions. That's why effective inhabitant participation will be indispensable in years to come.

References

Bureau fédéral du Plan. (1999). Sur la voie d'un développement durable? Bruxelles : Ministère des Affaires économiques.

Department of the Environment, Transport and Regions. (2001). Achieving a better quality of life. Review of progress towards sustainable development. Government annual report 2000. London: DETR.

Jean, Y., & Calenge, C. (2002). Lire les territoires. Tours: MSH.

Makhloufi, L. (2007). Identity in Transition: Residential Spaces Undergoing Profound Conceptual Change - Case of: Ali Mendjeli new town. In J. Al-Qawasmi & A. Mahmoud & A. Djerbi (Ed.), Regional Architecture and Identity in the Age of Globalization, Volume1/3, (pp. 271-284). Amman: The Center for the Study of Architecture in the Arab Region.

Makhloufi, L. (2009). Le logement comme moteur du développement territorial en Algérie : quels défis ? Quelles opportunités ? In C. Mager (Ed.), Développement territorial : jeux d'échelles & enjeux méthodologiques, (pp.141-148). Lausanne : Observatoire de la ville et du développement durable.

Makhloufi, L. (2009). Socio-economic issues in Constantine: which contexts for which consequences on the sustainable urban development? In S. Fortea & J. Al-Qawasmi (Ed.), Sustainable Architecture and Urban Development, Volume1/2, (pp. 367-381). Amman: The Center for the Study of Architecture in the Arab Region.

Modot, J. (1974). Constantine et ses environs. In Les guides bleus, Algérie (pp. 387-403). Paris: Hachette.

Regional Environmental Center for Central and Eastern Europe. (2009). What is a sustainable city? From http://www.rec.org/REC/Programs/ Sustainablecities/What.html

United Nations. (1987, December 11). Report of the World Commission on Environment and Development. General Assembly Resolution 42/187, from http://www.un.org/documents/ga/res/42/ares42-187.htm

Veschambre, V., & Ripoll, F. (2005). L'appropriation de l'espace comme problématique. Norois Journal : L'appropriation de l'espace, 195(2), 7-15.

Wikipedia, the free encyclopedia. (2010). Sustainable development and sustainability. From http://en.wikipedia.org/wiki/Urban_planning# Sustainable_development_and_sustainability

Urban Sustainability and Low Carbon Development

Thinking in the dimension of the city, this chapter explores ideas for the revitalization of the post-industrial urban landscape and sustainable city growth. While cities are in a constant state of transition, the development of large-scale complexes can be crucial for the future of any urban settlement. However, more than ever before, these developments need to be based on holistic thinking of low-to-no-carbon strategies, which include appropriate densities, compactness, renewable energy technologies, and support a strong focus on pedestrian-scaled public domain, with efficient public transport and mixed-use concepts for compact communities.

Rethinking the city itself: clearly, the design of districts and neighbourhoods is a very complex topic. The authors have given considerable thought to rethinking city design and to developing guidance for urban designers and architects, recommending a diversity of ideas for the urban transition towards more sustainable development and green urbanism. Sustainability on the urban scale is engaged in the transformation of entire districts into energy-efficient, close to zero-carbon neighbourhoods, designed for walking and cycling, with human-centred public space networks, future-proof green infrastructure, on-site energy generation and water collection. The `post-oil city' will have to be different, however, there still seems to be a lack of overview and data, which analyses and explains international best practice and the advantages of the various existing innovative models. Europe has been remarkably successful with the realization of a couple of demonstration projects, such as: Vauban Freiburg (Germany), Hammersby-Sjostad (Sweden), and BedZED (UK). But how do these models translate into other climatic zones, for instance to hot and arid or tropical environments? Much is still unknown and more research is necessary. The fundamental question is, of course: can urbanism ever be green, with its huge consumption of resources, energy and materials, and the vast creation of waste? The following four papers in the session on urban sustainability and low carbon development are offering valuable insights into this topic:

Mohataz Hossain (Bangladesh) has written a paper on Dhaka City: the relationship between electrical energy consumption and urban morphology.

In his paper on urban sustainability, Latifa Mohamed Wafa (Libya) describes strategies for the design of a high-performance city.

Jamie Halsall and Ian Cook (Liverpool, UK) report on the case study of Beijing and discuss the environmental impact of China's rapid urbanization.

Finally, Aaro Soederlund and Juha Kaaria (Finland) write about ideas for Tianjin Eco-City, which is currently under construction.

Steffen Lehmann
University of Newcastle, Australia

Towards Sustainable Urban Environment: An Investigation on the Relationship between Electrical Energy Consumption and Urban Morphology in Context of Dhaka City

Md Mohataz Hossain[1],
[1]*Bangladesh University of Engineering and Technology, Bangladesh*

Abstract

In a city, its morphological character and complex built environment mainly control its microclimate. The street pattern, orientations, the canyon shape, built density, available green space- all are the concerning features that should be properly cared for the a sustainable urban environment. The buildings that gain heat from solar radiation are responsible for increasing the heat of the densely populated area. The evaporative cooling, which is related to land use pattern, irrigation, wind speed and rainfall, also varies in urban environments. On the other hand, the microclimates as well as morphological character of a city have a great impact on its electrical energy consumption as both have a relationship with the outdoor and indoor comfort.

With the literature review for background study, this paper gives some observation and analysis based on the collected data and field study on a selected area to understand the relationships among the energy consumption and city morphology in context of Dhaka city. Analyzing with meteorological data, this study also gives some indications to understand the important factors of sustainable urban design to reduce energy consumption within the city.

Keywords: *Sustainable Urban Environment, Energy consumption, morphological characters, microclimate, meteorological data.*

1 Introduction

The Urban morphology which includes street pattern and its orientations, the canyon shape, built density, available green space is responsible enough in creating urban heat island effect within a city (Smith, C. & Levermore, G., 2008). With considering global warming, if the heat produced within any city is not reduced, the pressure will be created on the overall national energy demand, as more heat needs more electricity for cooling the indoor spaces of the buildings. Now-a-days Dhaka has become a densely populated city with high concentrations of various types of buildings and built spaces. This paper focuses on study of the electrical energy consumption in an area of Dhaka city and analyses the relationship with the climatic data as well as morphological characters of the same part of the city. Particular emphasis has been given on important findings which can be considered for reducing the electrical energy consumption of Dhaka city.

2 Objective and Scope

The objectives of the study are as follows:

a. To develop a relation of electrical energy consumption with climatic data of Dhaka city
b. To study the morphological characteristic of part of the city and to identify the dominant factors those affect the electrical energy consumption.

The study is conducted through analyzing the electrical energy consumption and morphological characters of specific area in the climatic context Dhaka city. This study is limited to evaluating the 'Segunbagicha' Division (a demarcated area among 32 divisions according to PDB) which includes three wards of Dhaka city (Figure 7) to limit the scope of work.

3 Methodology

Some literature reviews are done to gather general background knowledge about city morphology and the climatic context of Dhaka city within the research. The corresponding climate data are collected from the Met Office in Dhaka. Also all the energy consumption data are collected from the main office of the Power Distribution Board (PDB). For morphological analysis of the studied areas; GIS maps, photographs, measurements and other information are gathered from Dhaka City Corporation, URP Department of BUET, internet and extensive field surveys. Statistical Analysis is done to find the relationship among these issues. For statistical as well as software analysis of the collected data, Microsoft Excel 2007, Ecotect v5.2 and Rayman v1.2 software are used as Supporting tools. The research is conducted through analyzing the electrical energy consumption and morphological characters of specific 3 wards in context of Dhaka city.

4 Background of the Study

4.1 City morphology and its effect

Among the three levels of studies, distinguished as urban planning, urban morphology and building design (Goulding, Lewis and Steemers, 1986), urban morphology is the study of the form of human settlements and the process of their formation and transformation. The study seeks to understand the spatial structure and character of a metropolitan area, city, town or village by examining the patterns of its component parts and the process of its development. This can involve the analysis of physical structures at different scales as well as patterns of movement, land use, ownership or control and occupation. Typically, analysis of physical form focuses on street pattern, and building pattern, sometimes referred to collectively as urban grain. This urban morphology interacts with people behaviour and with the local climate. The development of cities parallels the growth in energy consumption with quite simple laws derived from physics and thermodynamics. At the neighbourhood scale, the heterogeneities of structures within the urban canopy (i.e., the layer between the surface and the tops of the buildings) exert a strong influence on the urban boundary layer wind and thermodynamic structure and a subsequent effect on the pollutant dispersion and resulting air quality predictions (Goulding, Lewis and Steemers, 1986).

An urban canyon is caused by streets cutting through dense blocks of structures, especially skyscrapers, which cause a canyon effect. The sky view factor of urban streets is also important because the proportion of the street and building geometry controls the solar heat gain and others factors Smith, C. & Levermore, G., 2008). Urban canyons have an impact on various local conditions:

- Wind speed, as moving air is channeled and accelerated
- Temperature, which can be elevated 5-10 degrees F (2-4 degrees C) and contributes to the urban heat island effect
- Air quality, where locally stagnant air concentrates pollutants near ground level.

So for any city the microclimate can be controlled through proper developing the morphological components which controls also the energy consumption.

4.2 The Context of Dhaka

Dhaka is located in the central position of Bangladesh at, on the eastern banks of the Buriganga River. The city lies on the lower reaches of the Ganges Delta and covers a total area of 59.40 sq miles. It consists of 7 principal thanas: Dhanmondi, Kotwali, Motijheel, Paltan, Ramna, Mohammadpur, Tejgaon, Sutrapur and 16 auxiliary thanas. In total, the city has 130 Wards and 725 Mohallas (http://en.wikipedia.org/wiki/Dhaka). Vegetation and moist soils characterize the land, which is flat and close to sea level. This leaves Dhaka vulnerable to flooding during the monsoon owing to heavy rainfall and cyclones.

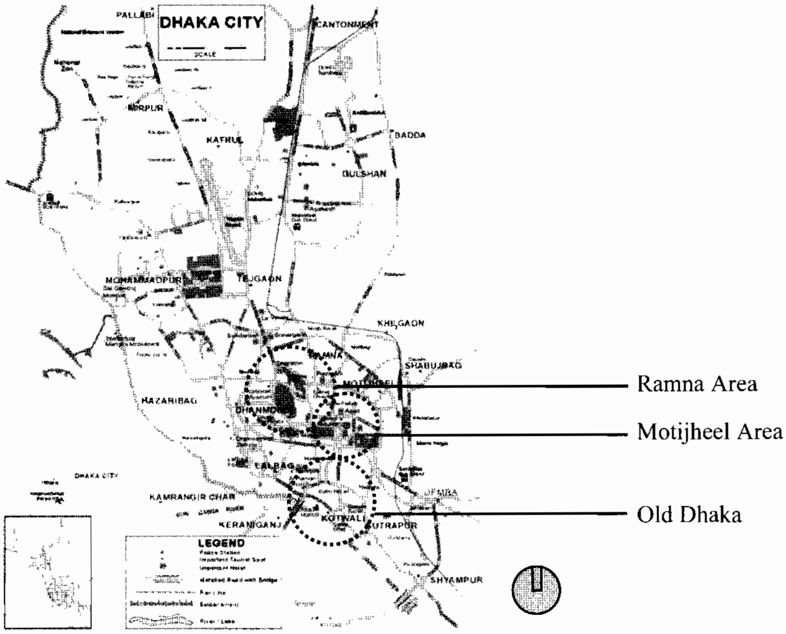


Figure 1: Map of Dhaka City (Source: www.dhakacity.com.bd/dhaka_city_map)

Dhaka experiences a hot, wet and humid tropical climate. The city is within the monsoon climate zone, with an annual average temperature of 25 °C (77 °F) and monthly means varying between 18 °C (64 °F) in January and 29 °C (84 °F) in August. Nearly 80% of the annual average rainfall of 1,854 millimetres (73 in) occurs between May and September. The Land use pattern (Figure 2) shows that among the built areas (without agricultural land) residential land is high in area. Commercial land use is low in respect to that. If the greater Dhaka is considered with its surroundings, it can be found that about 27% (figure: 2) of land are occupied by residential building. Also it is notable that the agricultural land is also high but they are all at outside of Dhaka metropolitan. Estimated number of housing plots in DCC is about 186,000 (plot size 4.5-7.5 decimals) out of which 80% plots (i.e., about 148,800 plots) are already used for housing. As a result there are very limited green open spaces in Dhaka city.

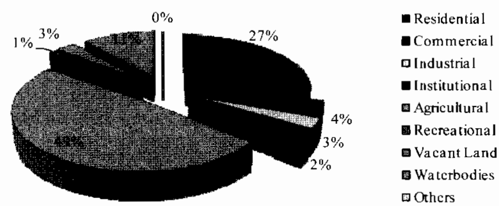


Figure 2: Land use pattern of Dhaka (Source: Dhaka City Corporation)

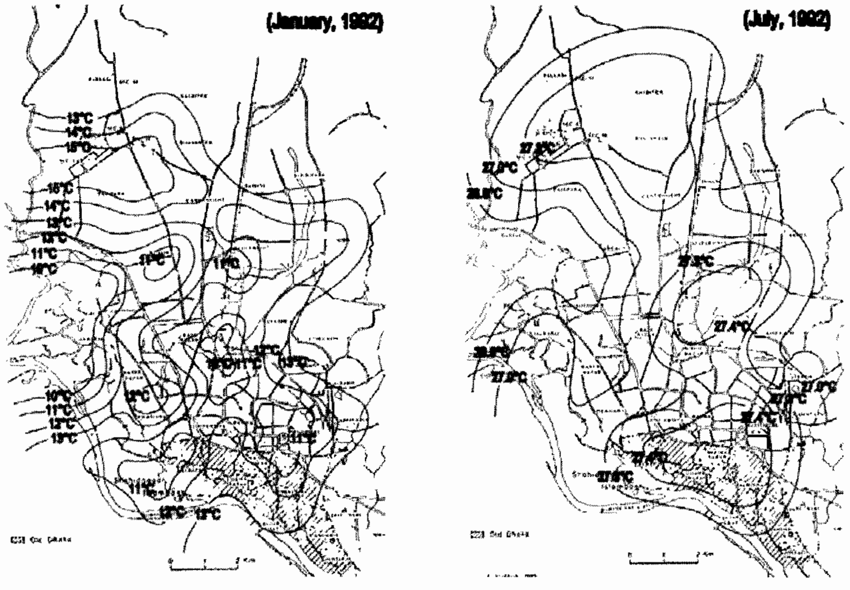


Figure 3: Effect of hard and green surfaces on Temperature distribution of Dhaka city (Source: Ahmed, K. A., 1996, newly drawn by the author)

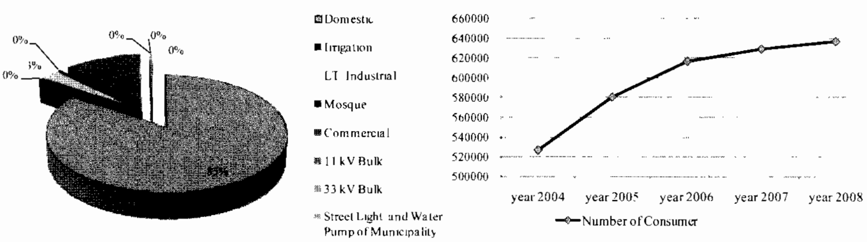


Figure 4: Energy consumption pattern of year 2005 and yearly consumer data of Dhaka city (Source: Data from Power Distribution board)

If the temperature distribution diagram (figure: 3) is analyzed, temperature of Dhaka varies with morphological (buildings, roads, green parks, water body and others) character of the city. The hard surfaces of roofs and roads gain more heat and are the cause of urban heat island effect

On the other hand, energy consumption Data (figure: 4) shows that domestic data is the highest in value. So the residential buildings as well as commercial buildings consume a lot of energy in Dhaka city. The numbers of consumers are increasing (Figure 4) as same as population, but the electrical energy import is limited. So, saving electrical energy of Dhaka city is very important for its sustainability.

4.3 Area of the investigation

In Dhaka city there are some circles (zones) according to the electricity coverage area of PDB. Each circle includes 4~ 5 divisions or demarcated areas. The area of Segunbagicha division is randomly selected from Ramna circle. This division (figure: 6) consists of Ward No 36, 56 and 57 (figure 7). Considering vegetation, this division has significance as primarily as numbers of studies have established the positive environmental impact of plants and vegetative surfaces in cities (Reza et al, 1991). The important characteristic of this area is its extensive vegetative surfaces (Figure: 5) and it has a distribution of large number of mature trees. On the other hand, it has also hard surfaces with multi storied buildings.

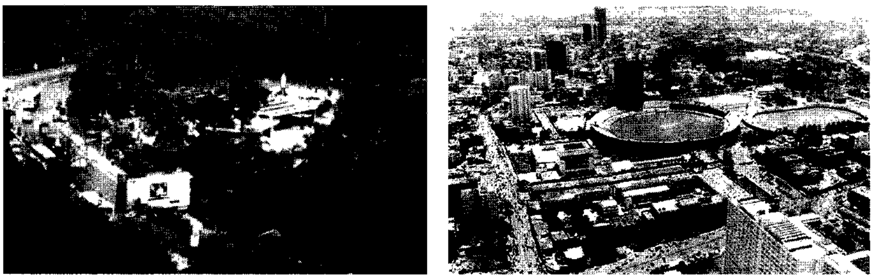


Figure 5: Green and Hard surface area in Segunbagicha division (Source: http://bsapk.tripod.com/id13)

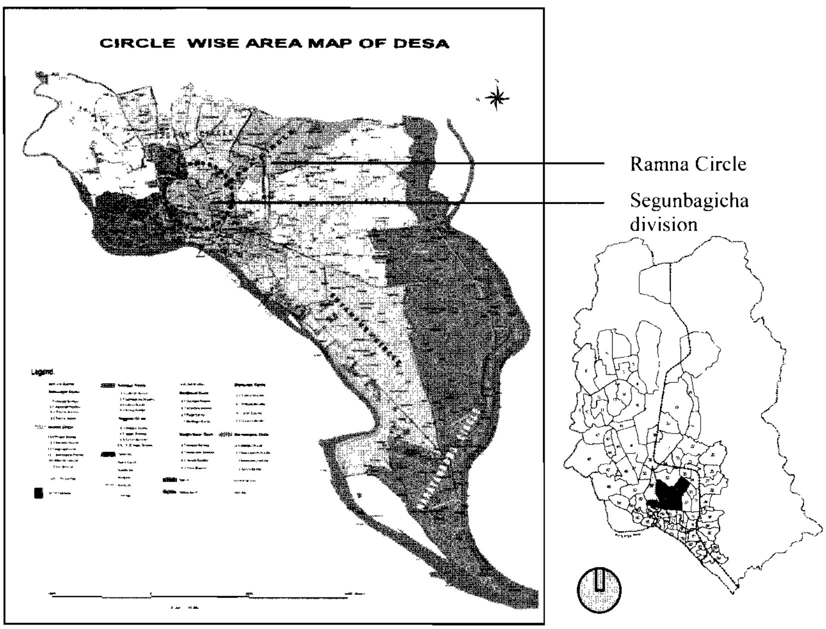


Figure 6: Circle wise area map of DESA (Source: Collected from Power distribution Board, Dhaka)

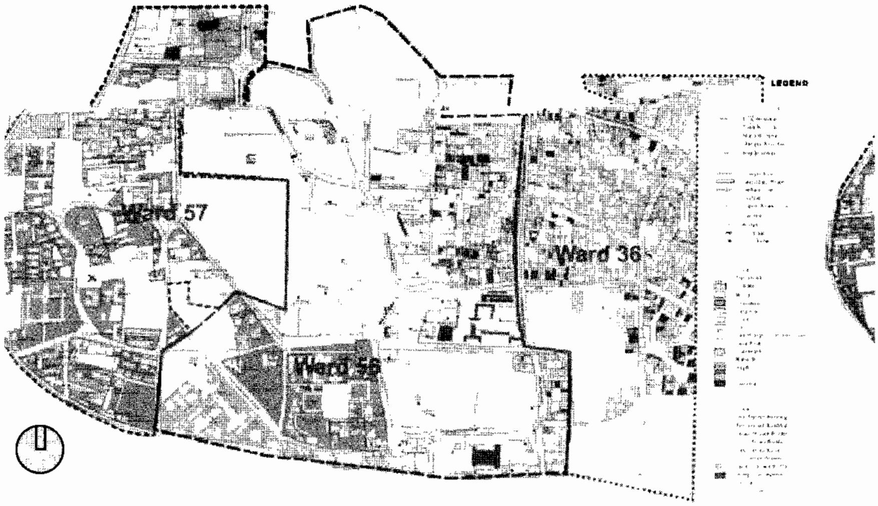


Figure 7: Map of Segunbagicha division including 3 Wards (Source: GIS MAP, Collected from Dhaka City Corporation)

5 Observations and Findings

The total area of Segunbagicha division is 46931031 sft (4.36 sq km) population is about 118,710 (figure 7). Among these three wards, the ward no 56 is larger in area and population is also high. Comparing the land use pattern it can be seen that the ward 36 which covers the Topkhana and Paltan area has higher density than the others. The ward 56 has greater green area (figure 8) which includes the Ramna Park, Sahrawardi Udyan, Osmani Udyan and other. And the ward 57 has mainly the educational and government institutes.

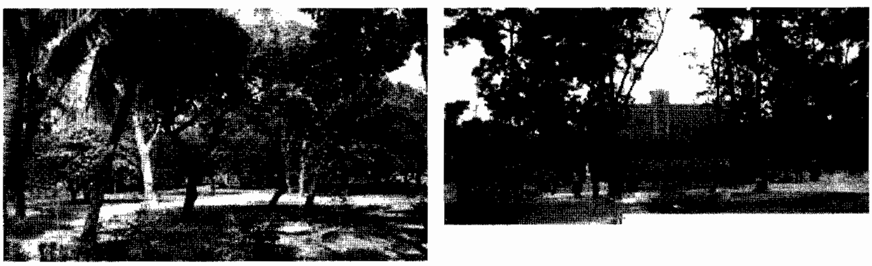


Figure 8: Sahrawardy and Osmani Udyan (Source: photography by author)

The green area creates a micro climate in the area through evaporative cooling. The water bodies are only covered in the ward 56 which includes Ramna Park Lake, Karjan Hall water body (figure 9), Osmani Udiyan's water body and others.

Figure 9: Water bodies: Karjan Hall and Ramna park lake (Source: photography by the author)

These water bodies have an impact on its local microclimate. Comparing with other wards it is clear that the ward 56 has some basic morphological difference with other area. These park areas can be considered as a northern most boundary of area with high distribution of vegetal covering. Large number of trees in this area had a considerably impact on the micro climate. Although, being surrounded by areas devoid of vegetation, the ambient temperature on this site is close to the values of meteorological station (Ahmed K.S., 1995, pp.164).

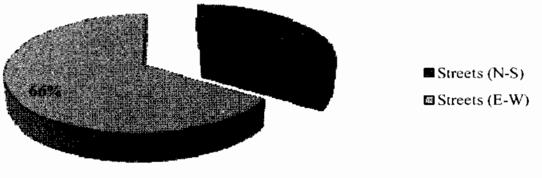


Figure 10: street orientation ratio (Source: DCC GIS map)

The E-W streets are high in number (figure 10) in Dhaka city and these streets gain more solar heat from sun especially on the months from April to July. The average canopy heights and sky view factors can be shown as follows:

Table 1: street orientation ratio (Source: DCC map)

	Commercial Zone	**Residential Zone**	**Educational use Zone**
Average road width (W)	50'	30'	60'
Average building height (H)	60'	40'	60'
Average sky view factor (H/W)	1.2	1.3	1.0

In table 2, the Abdul Gani road (figure 13) is E-W oriented and it is in the south-eastern perimeter. In this kind of wider canyon, there is considerably more radiation influx in comparison with a canyon of narrow section, resulting in a marked rise in canyon air temperature (Ahmed, 1994) (Salleh, 1994). The Edge of the Ramna Park is influenced by the cooling effect of the green vegetation and the water body (figure 9). The tree lined streets produces thermally agreeable climate and the air temperatures are close to meteorological data of Dhaka (Ahmed, K. S., 1995, p.170). Also, the Relative Humidity at this studied area is higher than the met data and the radiant temperature is found to be lower than the air temperature. (Ahmed, K.S., 1995, p. 264)

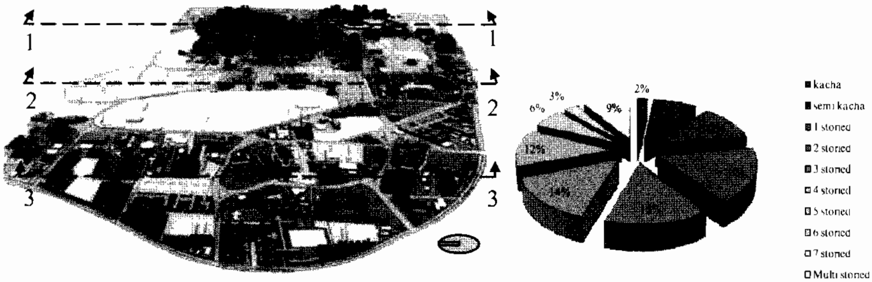


Figure 11: The morphology of the studied area (Source: Drawn by the author from the data Dhaka City Corporation GIS MAP)

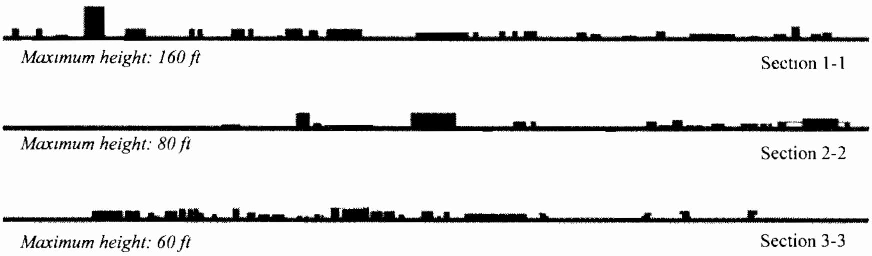


Figure 12: Morphology (Urban Canopy Height): Segunbagicha division (Source: Drawn by the author)

Table 2: Analysis of 6 Urban Canyons of Segunbagicha division (field survey and Ray man Software analysis)

Road Location	**Orientation**	**Road Width**	**Vegetation**	**Average SVF**	**Major Construction Materials**
Segunbagicha Road	N-S	50'-0"	Low	1.6	Plaster, Concrete
Suhrawardi Udyan Road	N-S	60'-0"	Moderate	0.17	Concrete
Bijay Nagar Avenue	N-S	60'-0"	No Vegetation	2.67	Glass, Plaster, Concrete
Abdul Gani Road	E-W	80'-0"	Moderate	0.4	Concrete
Pilkhana Road	E-W	60'-0"	High	0.12	Concrete
Topkhana Road	E-W	80'-0"	No Vegetation	1.87	Glass, Plaster, Concrete

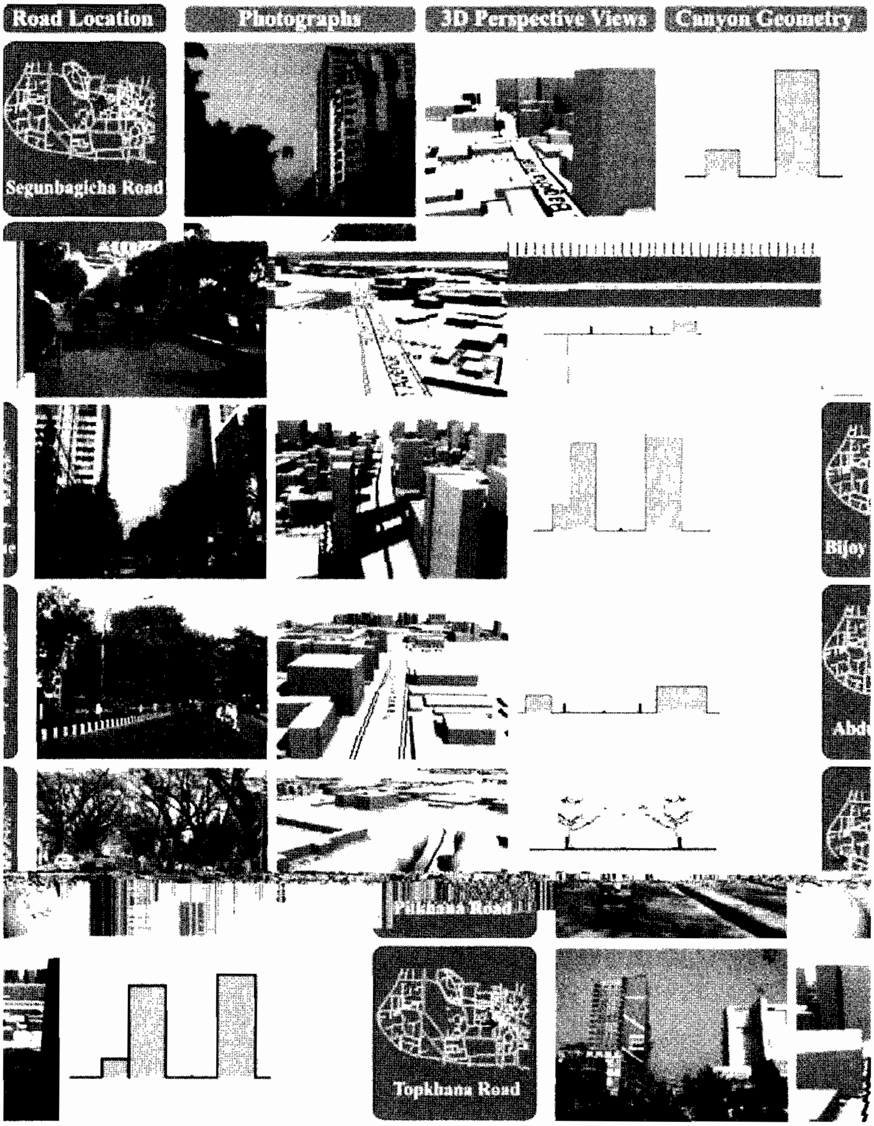


Figure 13: Graphical analysis of 6 Urban Canyons of Segunbagicha division (Source: Drawn by the author and field survey, use of Ray man Software)

Comparing all the data from table 2 with figure 11, 12 and 13, it is notable that both the width of the road and height of the buildings contribute to make urban canyon effective. As Orientation of the road also an important factor for gaining solar radiation in the canyon, the total morphological character of the canyon can be also responsible for extra electrical energy consumed by these buildings adjacent to the canyon.

6 Analysis and Findings

Firstly, analyzing only the meteorological data some relationships among each other can be found. In the figure 14, the average ranges of dry bulb temperature are found to be higher from March to August in the year of 2005. The second and third graph of this figure shows the relationship among average Relative Humidity, dry bulb temperature and average wind speed in the same year. But from May to October, there is an opposite relationship between sunshine hours and cloud in octa.

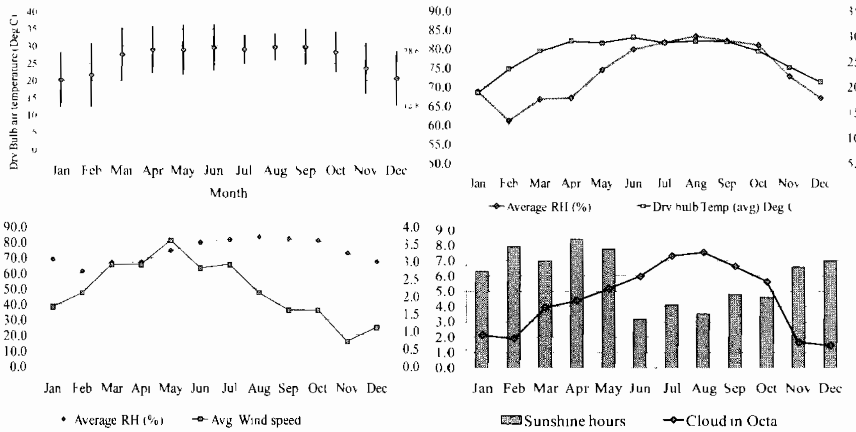


Figure 14: mean air temperature and Correlation among the met data 2005 (Source: Meteorological Data 2005)

Secondly, analyzing the energy consumption data (figure 15) it can be found that the electrical energy that is imported and sold from April to August is higher in value than the rest of the year. So there is an impact of climate on energy consumption during these months in Dhaka city, as we can see similar curves of average RH, dry bulb temperature and cloud in octa in figure 14.

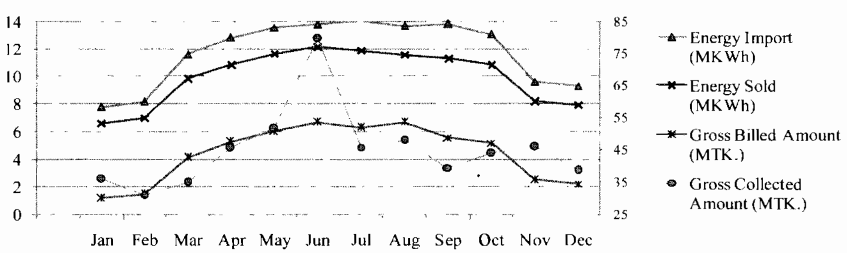


Figure 15: relations among the energy consumption data (Source: PDB)

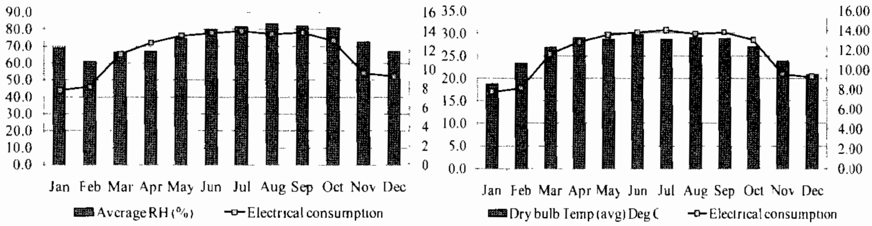


Figure 16: Relationship between Met data and energy consumption data, Year 2005 (Source: Met Data and PDB)

From comparative analysis among Meteorological data and electrical energy consumption data of the year 2005 in the charts (figure 16 and 17) it can be observed that electrical energy consumption of the Segunbagicha area has parallel relationships with Relative Humidity, Air temperatute, cloud cover and has inverse relationship with the Sunshine our, solar radiation and wind speed.

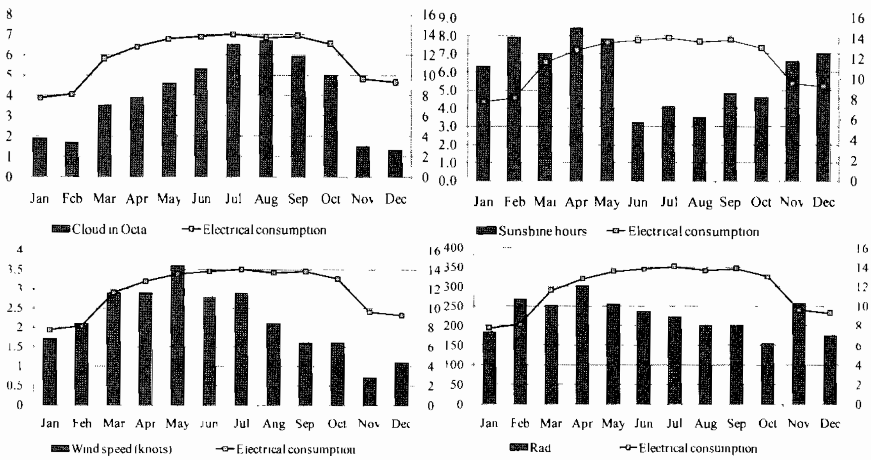


Figure 17: Relationship between Met data and energy consumption data, Year 2005 (Source: Met Data and PDB)

To justify the above comparative analysis with some definite numeric outcome, some statistical analyses like correlation, Ftest, Ttest and Linest (Table 3) is done among the detail monthly record of Meterological data and electrical energy consumption data of the studied area for the year 2005 with the help of 'Microsoft Excel' software. Here, 'Ftest' function is used to determine whether these two type of data have different variances. 'Ttest' is done to determine probability associated with these data, whereas 'Linest' is done to calculate some linear values that best fits these data. From correl statisitical Analysis (figure: 18) it can be shown that sunshine hour has inverse relationship (-0.51in value) with electrical energy consumption for Segunbagicha division. Through F-test probability analysis, it shows that only sunshine hour and cloud cover have probability relation with energy consumption. Again Through T-test it is found that probability associated with the Data are significant at all. LINEST analysis shows through value that it best fits with rain fall and solar radiation.

Table 3: Statistical Analysis of meteorological data and energy consumption and the results, Year 2005 (Source: Met Data and PDB, MS Excel)

Met. Data type	Correlation with Energy consumption	'F test' with Energy consumption	'T Test' with Energy consumption	Digression with Energy consumption (LINEST)
Dry bulb Temp (avg) Deg C	0.94	0.19	0	2.2
Average RH (%)	0.77	0	0	6.1
Rainfall in mm	0.9	0	0.03	16.7
Cloud in 'Octa'	0.92	0.55	0	0.35
Sunshine hours	-0.53	0.37	0	0.47
Solar Rad.	0.01	0	0	18.5
Wind speed (knots)	0.53	0.002	0	0.18

Now from the bar chart (Figure 19) it can be illustrated that the energy consumption of motijheel area (figure 1) is always high as from morphologial perspective, it has greater hard surfaces and no provision of cool micro climate. The studied area which is in the ramna circle have moderate energy consumption. The Energy consumption of old Dhaka (figure 1) is low as there is an effect of water body (Buriganga River) on its micro climate.

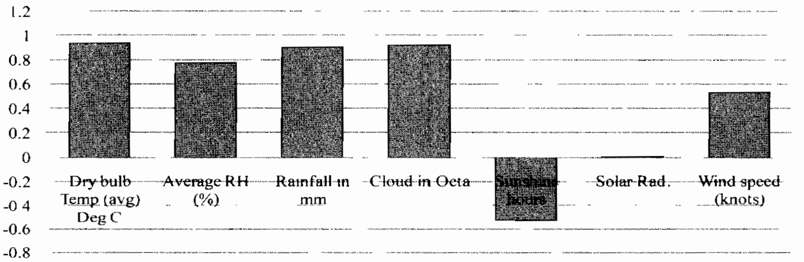


Figure 18: Results from 'Correl'Statistical Analysis of meterological data and energy consumption records, Year 2005 (Source: Met. Data and PDB, MS Excel)

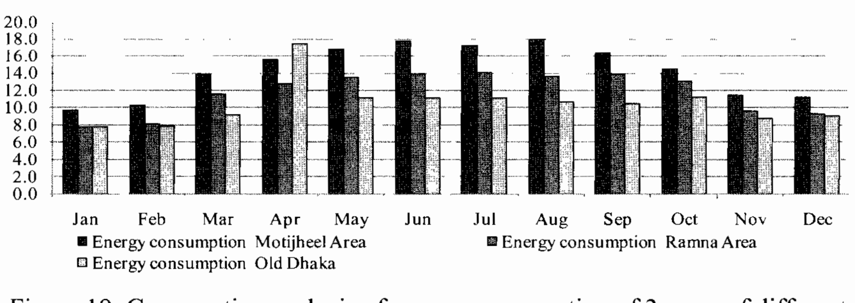
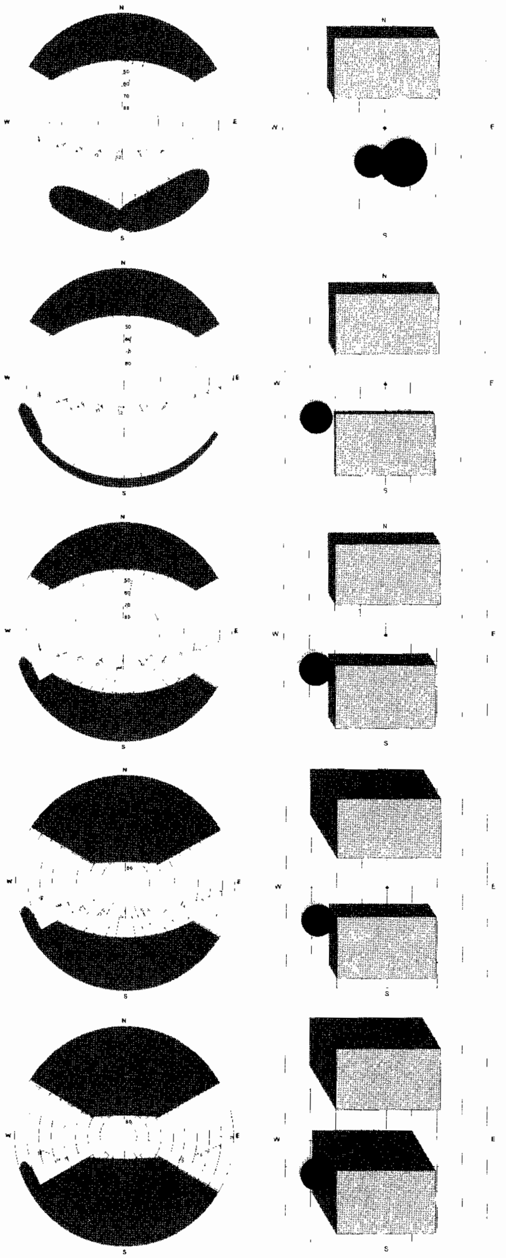


Figure 19: Comparative analysis of energy consumption of 3 areas of different morphological Character, Year 2005 (Source: PDB main office)



Canyon Type 1 (Suhrawardi Udyan Road):

Sky view factor: 0.695
Obstacle height: 40'
Deciduous tree1: 40',
Deciduous tree2: 20'

Canyon Type 2 (Katabon Road):

Sky view factor: 0.769
Obstacle height: 40'
Obstacle height: 20'
Deciduous tree: 20'

Canyon Type 3 (Elephant Road):

Sky view factor: 0.623
Obstacle height: 40'
Obstacle height: 40'
Deciduous tree: 20'

Canyon Type 4 Topkhana Road:

Sky view factor: 0.475
Obstacle height: 160'
Obstacle height: 40'
Deciduous tree: 20'.

Canyon Type 5 (Bijoy Nagar Avenue):

Sky view factor: 0.4375
Obstacle height: 160'
Obstacle height: 140'
Deciduous tree: 20'.

Figure 20: Analysis of various Canyons (Source: Rayman Software results)

The SVF variation in this urban areas and the importance of SVF in relation to other central parameters such as thermal admittance are also important. To limit the scope of the study on morphology a software analysis is done to find the relationships among the various canyons (Figure: 20) of this area with sky view factor and other climatic data found by the 'ray man' software. The spots are selected within Segunbagicha division to analyze the values of mean radiant temperature for the March, 2005. Five types of canyons are selected with constant road width of 80 feet assuming the other factors like construction materials, road orientations to be constant in order to limit the scope of the study. The objective of this software analysis was to observe the relationship between the sky view factor and the mean radiant temperature, as this temperature is one of main issues that have impact on electrical energy consumption of any area.

This software analysis (Figure 20) results that with increasing the height of the building in the canyons the sky view factors are decreasing and the mean radiant temperature decreases for the Canyon type 5. Further detail software analysis can be done in future with larger scope of work for accurate results.

7 Conclusion Remarks

According to the scope of study and its observations, analysis and results, it is clear that the urban morphology has a great impact in its microclimate. In relation to that it also directly controls the electrical energy consumption. So designing urban canyon, streets, buildings, urban open spaces- all are important to reduce the urban energy consumption and develop the quality of outdoor environment. Further detail and comparative studies can be conducted with larger scope of work to have recommended guidelines in this view.

Acknowledgement

Department of Architecture, Bangladesh University of Engineering and Technology, Dhaka, Bangladesh.

References

Ahmed, K.S. (1994). A Comparative analysis of the Outdoor Thermal Environment of the urban vernacular and the contemporary development: case studies in Dhaka. Proceeding of 11th PLEA International Conference- Architecture of the Extreams, Israel, 1994.

Ahmed, K. S. (1995). Approaches to Bioclimatic Urban Design for the Tropics with Special Reference to Dhaka, Bangladesh. Unpublished Doctoral Dissertation, Environment and Energy studies program, AA School of Architecture, London 1996. 33-105.

Bangladesh Students Association - Pakistan: About Bangladesh. (n.d.) Retrieved March 10, 2010 from http://bsapk.tripod.com/id13

Dhaka (n.d.) Retrieved May 1, 2010 from http://en.wikipedia.org/wiki/Dhaka.

Goulding, Lewis & Steemers (1986). Energy in Architecture: European Passive Solar Handbook, Commission of the European Communities.

Reza, S.H., Murthy, S.R., Lakhshmi,B. & Shylaja, G. (1991), Effects of Vegetation on Urban Climate and Healthy Urban Colonies, Energy and Buildings,Vol-15, 487-491.

Salleh, E.B. (1994). Tropical Urban Outdoor Environment and Human Thermal Comfort, EESP Architectural Association, PhD Thesis (unpublished).

Smith, C. & Levermore, G., (2008). Designing Urban Spaces and Buildings to Improve Sustainability and Quality of Life in a Warmer World, Energy Policy, 36, 45-58.

Urban Sustainability and the Move to Low Carbon Development: Developing a Strategy for a High Performance City

Latifa Mohamed Wafa
El Fateh University, Libya

Abstract

At the start of the twenty first century we are faced with human activities are having an enormous effect on the environment, ecological systems, and even on humans themselves. More than the result of any other human endeavour; the built environment has direct, complex, and long-lasting impacts on the biosphere. We are at a critical stage where we have to make some difficult decisions and choices. There are many issues that threaten the existence of the human species, perhaps none more than global climate change. Energy is a major cause of climate change due to the release of carbon dioxide in the combustion of fossil fuels. The distribution of the built environment in the world and the consequent need to rely on automobiles for movement between work, home, school, and shopping result in disproportionate generation of carbon dioxide. Building and Transportation consumes about 85% of primary energy in Libya, much of linked to the how we distribute the built environment across the landscape.

To tackle this serious global problem, a robust movement to rethink the built environment is rapidly emerging and affecting the planning, design, construction, and operation of new built environment; changing the renovation process for existing built environment; and reshaping cities and communities in many countries around the world.

This paper is part of the first phase of a study being undertaken by the author to convert Ras Lanuf New town in Libya from a conventional city into high performance city. Thus, the aim of the paper is to serve as a practical guide to the process of procuring and developing a strategy for high performance built environment at city scale, which uses whole-built environment design to achieve energy, economic, and environmental performance that is substantially better than standard practice. High Performance City planning is an opportunity to use our resources efficiently while creating healthier buildings that improve human health, build a better environment, and provide cost savings.

Keywords: *built environment, conventional city, high performance city, and sustainable development*

1 Introduction

Buildings account for 45% of worldwide energy use, 80% of potable water use, and 50% of the timber harvest in North America, (Gordon and Ode, 1997). Buildings also contribute nearly 40% of global warming emissions (Brand, 2010). For this reason, cities around the world are engaging in a number of strategies to make themselves more efficient. One strategy for accomplishing this is High Performance City.

Although a relatively new phenomenon, 'sustainable' or high performance built environment is rapidly becoming mainstream. All over the world, in both developed and developing countries, fairly robust movements have take root and are beginning a major process of transforming how built environment is procured, designed, built, and operated.

High performance cities planning emphasize efficient use of energy, water and materials, and focus on minimizing environmental degradation that is associated with buildings and infrastructure. High performance design also emphasizes the relationship between the building occupants and the workspace, to create an indoor environment that is safe, comfortable and fosters productivity.

2 Meanings and Concepts

Ecosystem planning, bio-regional planning, energy efficient design, sustainable design and a new term starting to appear on the surface at beginning of third millennium replacing sustainability; that is "High Performance Built environment"- Those who advocate the term claim that it covers more issues and that it is more inclusive of a wide variety of concerns (Salama, 2002) - are all concepts that place emphasis on resolving environmental problems caused by human activities. The main idea behind the notion of sustainability is to create an effective system of resource distribution and utilization with a long term perspective in mind, (Architects Council of Europe –ACE-, 1999).

High performance building is a structure that is planned, designed, built, renovated, operated, or reused in an ecological and resource-efficient manner. It is designed to meet certain objectives such as protecting occupant health; improving employee productivity; using energy, water, and other resources more efficiently; and reducing the overall impact to the environment.

The concept of sustainable development, with emphasis on environmental sensitivity, has presented a great challenge to both developed and developing countries. It has an essentially relative and normative character. In this kind of development, socio-economic objectives are balanced with the constraints that nature sets. A sustainable society in this domain is one that can persist over generations, one that is far sighted enough, flexible enough, and wise enough not to undermine either its physical or its social systems of support, (Economic Commission for Europe- ECE, 1996).

Thus, it is based on the principles of self reliance, fulfillment of basic needs and an emphasis on the quality of life. Based on the above definition, the objectives of implementing sustainable development concepts are:

- To encourage high quality designs reflecting proper layout and landscaping, density, safety and security.
- To promote the regeneration and enhancement of the city and the re-use of buildings and lands required for development within the existing built-up areas, thereby reducing or preventing urban sprawl.
- To protect and enhance the local character of built environment communities and the identity of towns and district centres.
- To manage the use of natural resources to avoid depletion and irreversible damage.
- To support the provision of sustainable and affordable housing solutions
- To protect and promote biodiversity and maintain and enhance the country ecosystem.

3 Conventional Versus High Performance Building Design

People spend over 80% to 90% of their lives in buildings, so that the impact of the built environment is pervasive (Lewis, 2009). The building sector accounts for some 60% of Libya, 45% of EU and 36% of United State of America primary energy consumption. As conventionally generated electricity costs continue to spiral upwards, homebuyers and building managers are looking for solutions to reduce their utility bills, through the adaptation of new approaches to how to plan, design and build our built environment. High performance buildings approach is one of answers to this dilemma. High performance buildings are succeeding in their rapid, exponential penetration of the world construction market for three basic reasons.

First, they are the ethical response to both global and local environmental and resource issues, the 'right' way to approach construction. A typical, code compliant building makes minimal efforts to address energy and water issues and totally ignores materials waste, impacts on the construction site and any other issue not specifically covered in the building codes. As has often been noted, if these buildings were built any cheaper, they would be against the law. High performance buildings take a far different approach. Environmental impacts and resource consumption are of primary importance in the design and construction process. The entire life cycle of the built environment and its constituent components are carefully considered. For materials, architects and other design professional consider the entire life of the product, from resource extraction to use in the built environment and disposal at the end of its useful life. What happens in the factory producing building products is considered to be as important as its performance in the built environment. Emphasis is on renewable resources for energy systems; recycling and reuse of water and materials; integration of native and adapted species for landscaping; passive heating, cooling, and ventilation; and a wide range of other approaches that minimize environmental impacts and resource consumption, (Figure 1).

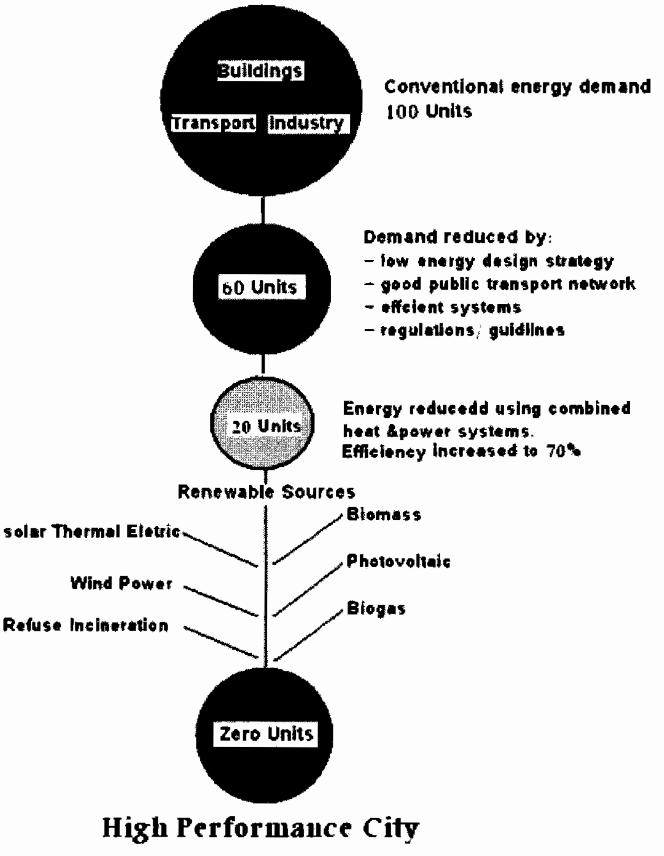


Figure 1: Conventional versus High Performance city

Second, high performance built environment make economic sense, not always on a capital or first cost basis, but virtually always on a life cycle basis. Sophisticated energy conserving lighting systems and air-conditioning systems with exceptional response to building and outdoor conditions will cost more than their conventional, minimal code-compliant counterparts. Rainwater harvesting systems that collect and store rainwater for non-potable purposes are an additional new system that will cost more money due to the need for additional piping, pumps, controls, storage tanks and filtration components. However most of the key features of a green built environment will provide a payback on their original investment within a relatively short time. As energy and water prices rise due to increasing demand and diminishing supply, the payback period will become much shorter. Life Cycle Costing (LCC) is an important evaluation technique that provides a consistent framework for evaluating alternative systems to determine their life cycle performance.

Third, high performance built environment squarely addresses the spotty performance of conventional built environment with respect to human health. There is ample evidence that on the order of 40% of all illnesses can be traced to building and homes where people live, work, or attend school, worship or sporting events. Conventional construction, unless forced to by lawsuits, generally ignores issues of Sick Building Syndrome (SBS) or Building Related Illness (BRI). High performance buildings meet the challenges of building health directly and provide several layers of consistent approaches that promote occupant health. The potential financial benefits of improving indoor environments exceed costs by a factor of 8 and 14 (Fisk and Rosenfeld, 1998).

3.1 The Benefits of High Performance Building Design

According to "Green Building Smart Market Report", (McGraw-Hill. 2006), high-performance buildings deliver measurable and significant environmental and fiscal benefits. When compared to structures built to conventional construction methods, green buildings:

- consume 26% less energy
- account for 33% fewer greenhouse gas emissions
- require 13% lower maintenance costs
- yield 27% higher occupant satisfaction

Building green doesn't have to cost a penny more (Langdon, 2007). Investments in green buildings pay dividends and reap rewards, on average resulting in:

- 6.6% improvement on return on investment
- 8%–9% reduction in operating costs
- 7.5% increase in building value
- 3.5% increase in occupancy ratio

Building green also creates quality jobs. A 2009 USGBC/Booz Allen Hamilton report found that, despite a challenging economic outlook, green building will support nearly 8 million jobs in the U.S. economy and contribute $554 billion to U.S. GDP between 2009 and 2013, many times its contribution to jobs and GDP over the last eight years.

4 Good Strategy Starts with Clear Vision

A good strategy starts with a clear vision of where we are now? (Situation assessment), where we should be in future? (Develop vision, mission, and goals) how do we get there? (Activity plan and implementation mechanism) How will we know when we get there? And how we ensure sustainability of results? (Monitoring, evaluation and planning) , (figure 2)

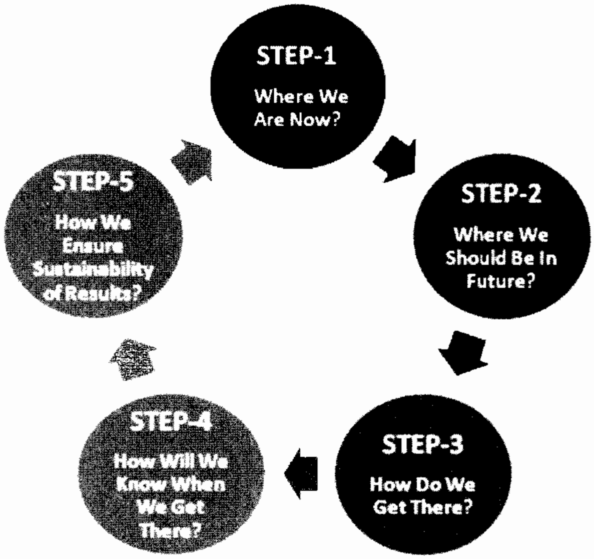


Figure 2: Five steps in form of questions to clarify the strategy's vision.

A clear vision provides a frame work for an integrated and comprehensive National Sustainable Development Plan approach rather than a sectoral approach. This plan serves three main purposes; first; it provides clear and flexible policies, strategies and programmes for guiding the nation's development. Second; it ensures that sustainable development principles are taken into consideration from an economic, environmental and social aspect. Third; it integrates development and capital infrastructure investment decisions to a spatial context. A successful high performance plan has four principles:

1. Flexibility – policies and strategies need to adapt to the dynamic nature of planning and changes in peoples demand.

2. Partnership- all stakeholders are required to participate in the way land is utilized, to assist in developing policies and strategies and to work towards common visions.

3. Sustainability – natural resources are limited sustainable principles need to be incorporated within the Plan.
4. Inclusion – everyone need to participate, regardless of sex, income class or age

The vision for high performance city should fulfill the needs and aspirations of its residents. It should be a place where:

- individual town and communities can thrive;
- all residents will have a place to call home; within which economic growth and prosperity are facilitated and maintained in a sustainable manner;
- high quality environment, which is safe and secure, protected from pollution;
- the physical resources are sustained and not compromised;
- Access to goods and services is provided in a manner which minimizes the need to travel and the impact of transport on the environment.

5 The Key Cycles of High Performance City

A city's metabolism is comprised of six cycles which each have their own individual patterns but in some way all affect one another: transportation; energy; water; waste; micro climate; materials. Naturally, many of the decisions to be made with respect to the above, are site specific and would necessarily take into account fundamental factors, such as: the climate (solar, temperature, humidity, precipitation, wind) ; geology (site conditions, .materials resources, topology); location; economics of country, etc. However, in many cases the general objectives remain the same. The key cycles of high performance city are:

5.1 Efficient Transportation

"Creating sustainable transport systems that meet people's needs equitably and foster a healthy environment requires putting the automobile back into its useful place as a servant. With a shift in priorities, cars can be part of a broad, balanced system in which public transport, cycling, and walking are all viable options." – (Lowe, 1990)

This can be defined as transport which aids the mobility of one generation without compromising the mobility of future generations (Brundtland, 1997). Clearly many of today's transportation modes are not in keeping with this definition: the private car -the first choice of many in many countries including Libya where it is the only choice because of unavailability of descent public transportation- is one of the major causes of the current high levels of pollution in our urban areas. The reliance extensively on automobiles has irredeemable damage to communities in terms of land-take, inner city deterioration, accident levels, air quality and noise. The challenge therefore is to prevent this foreseeable disaster from actually occurring without denying citizens of the developing world the indisputable benefits which increased personal mobility, facilitated by the car, can bring.

The key to a sustainable transportation system is the implementation of a transport hierarchy which gives priority to the pedestrian and public systems above the car. This does not necessarily imply positive discrimination against the private car: successful implementation of such a hierarchy can be achieved by merely creating an environment which does not cater for the car. This can be accomplished by limited parking spaces, traffic calming, cheap mass transit and by establishing a network of roads unsuitable for vehicular traffic: pedestrian; cycle based; mass transit (public); car. The hierarchy chosen will dictate which modes have 'design' priority over others. Successful implementation of such a structure will depend upon a segregated environment and will fundamentally effect design decisions, (figure 3). In order to encourage people to use public network and then walk (or cycle) it is important that the system must be of a high quality and provide similar or better service.

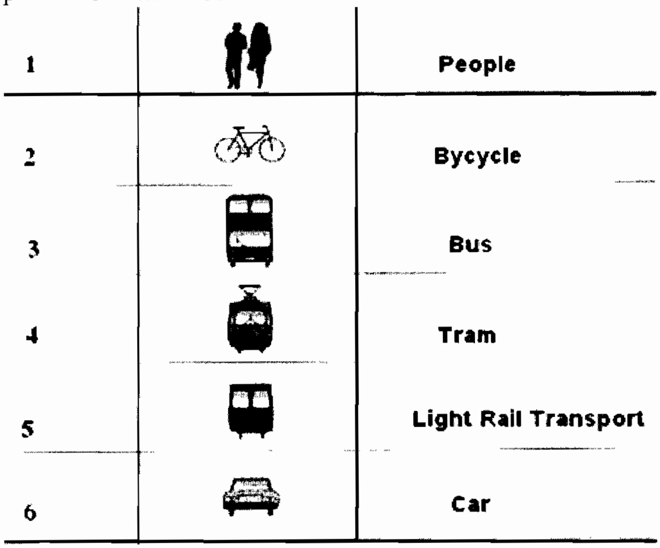


Figure 3: Sustainable transportation system hierarchy which gives priority to the pedestrian and public systems above the car.

5.2 Efficient Energy System

Energy in the form of electricity, gas, oil is used within three broad categories: buildings 50%; transport 25%; and industry 25%. The underlying principle of any energy strategy must be to firstly reduce the demand and secondly to provide the energy required from a renewable source thus creating a self sustaining (and in this case, even self sufficient) system. It is clear however that to achieve this, both the demand and supply must be tackled simultaneously and by the same strategic design body.

Building demand can be limited by producing design guidelines and energy targets for given plots of land. Typically, this will influence decision making with respect to both the building systems and architectural response. Importantly, it will place greater emphasis on the architect to develop a building type that is environmentally responsive (or selective) rather than being environment rejecting. Thus buildings will need to be: naturally ventilated wherever feasible; day lit; limit use of air conditioning; utilize solar energy for heating, cooling and ventilation efficient systems; careful orientation and planning; appropriate materials choice. By adopting these principles, it may be possible to reduce the actual energy demand by up to 70%. Renewable sources include: biomass, solar energy, and winds. Most buildings can reach energy efficiency levels. Computer modelling is an extremely useful tool in optimizing design of electrical and mechanical systems and the building shell.

There are a wide range of actions necessary to change the way in which a city is wired and powered from the traditional centralized grid model run from large power plants. In order to achieve this scale of change in as short a time as possible a wide range of policies, strategies and mechanisms need to be applied to the challenge including (Gupta and Roaf):

1. Changing legislation and standards
2. Provision of incentives and disincentives
3. Institutional reform and improved strategic and general planning practices
4. community action development, industry alliances, information and education and
5. Re-education program for related professionals.

5.3 Water Efficiency

In most countries including Libya, water is a valuable and scarce resource. It is thus important that a specific strategy is adapted that sets, as its prime objective, the achievement of a self- sufficient system; reduce demand; collect and store water over days or months to ensure that it is available all year round; treat and distribute water to areas of need efficiently; recycle waste water where possible for use in WCs or landscape. In any site specific area, it is necessary to carefully examine the precipitation and evaporation data. In many areas of the world, although there are long dry periods of little rainfall, there is often enough rainfall over the wet periods of the year to satisfy the yearly demand.

However, essential to this strategy is an efficient collection and storage system. The city should be designed around the need to collect and store water in underground areas, tanks and lakes. The tanks form central squares and act as a significant thermal heat sink - creating a cool micro climate within their immediate vicinity, whilst the above ground water surfaces (lakes and canals) not only provide visual amenity but also a degree of evaporative cooling. In addition the canals from primary routes along which the landscape can be integrated to form pedestrian walkways and wildlife corridors (Figure 4).

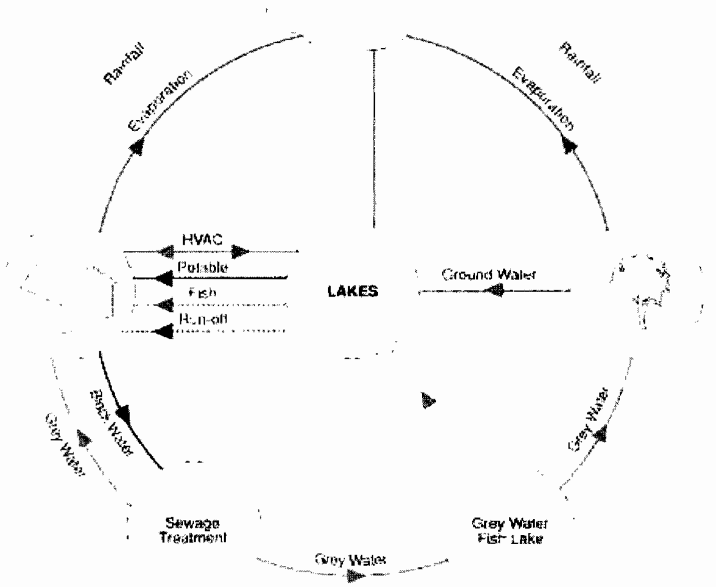


Figure 4: Energy strategy, the natural water and waste cycle

(Battle & McCarthy, 1994)

5.4 Efficient Waste Management

Waste from a typical city can be broadly categorized into four forms: human effluent; bio-degradable/combustible waste (paper, vegetable materials); non-combustible waste (metals, glass etc); toxic waste. It is essential that the waste strategy is set to carefully deal with these four categories and that the 'waste' is not necessarily seen as something to be disposed of but as a resource to be cycled-and re-used, (Figure 4). Human effluent produces gas for heating\cooling power, sludge for composting and water for landscaping. Biodegradable\ combustible waste can be cleanly combusted to provide power and heat, can provide compost and ash, and can be used for road construction / aggregate. Non-combustible metals {metals, concrete, glass, etc) -can be recycled or sold on to other areas. Toxic waste must be reprocessed by specialist offsite plant. The simplest means of dealing with this is to ensure that all industrial processes are environmentally friendly and their waste can be easily dealt with.

5.5 The Creation of a 'Comfortable' Urban Micro-Climate

The creation of a 'comfortable' urban micro-climate is essential to the successful operation of the urban transportation strategy of the sustainable city. This will fundamentally affect the planning and layout of the urban environment. The response however will be site specific, primarily / responding to the prevailing climate. The climatic elements within the urban area that can be modified by a sensitive urban design include: air temperature and humilities; radiant temperatures (surface) to which occupants are exposed wind speeds in streets and around buildings; concentration of air pollution within traffic arteries; potential for natural ventilation; shading, and potential for daylight; solar exposure and potential for daylight; solar energy utilization. The urban factors that the urban designers have control over and that will effect these aspects are topographical features of the city; density (land cover) of buildings; distances between buildings; orientation and width of street urban parks, landscape; colour of buildings and streets; material-choice (heavy weight versus light weight).

The aim of adapting such an approach is not to create an even level of comfort throughout the city, which would place too many restrictions on the design, but to create a changing thermal, air quality, acoustic and light 'topography' that recognizes the need for varying landscapes. Thus streets may have a combination of fixed and variable shading systems. Bus stops and public squares may have a concentration of evaporative cooling systems (in hot/dry climates) or permit good solar penetration (typical northern climate). Landscaping and green areas will play a vital role in the creation of the urban-scape and have a marked influence on the urban environment: provide outdoor shading, protection from hot or cold winds; provide evaporative cooling; absorption of solar radiation; reduction in natural dust and air pollution particles; rainwater absorption; can impede or redirect wind to improve natural ventilation to buildings or surrounding areas. The landscape will also play a vital role in allowing fauna, flora and wildlife a - natural path into and through the city. So that the - city rather than merely destroying existing habitats can in some cases improve them or - introduce new habitats and create opportunities - for human and of wildlife interaction.

5.6 Materials (Green building materials)

The choice of construction materials will play an important part in the sustainability of a high performance city. The primary objectives being that the materials should be: appropriate to the climate and the climatic response required; of local origin; low embodied energy; utilize local skills for construction; can be recycled; appropriate for the chosen structural regime.

Green building materials are composed of renewable, rather than non renewable resource and environmentally responsible because impacts are considered over the life of the product (Spiegel and Meadows, 1999). Depending upon project-specific goals, an assessment of green materials may involve an evaluation of the following criteria resource efficiency, indoor air quality, energy efficiency, water conservation and affordability. Product selection can begin after the establishment of project-specific environmental goals. The environmental assessment process for building products involves three basic steps research, evaluation and selection (Froeschle, 1999) .

1. Research. This step involves gathering all technical information to be evaluated, including manufacturers' information such as Material Safety Data Sheets (MSDS), Indoor Air Quality (IAQ) test data, product warranties, source material characteristics, recycled content data, environmental statements, and durability information. In addition, this step may involve researching other environmental issues, building codes, government regulations, building industry articles, model green building product specifications, and other sources of product data. Research helps identify the full range of the project's building material options.

2. Evaluation. This step involves confirmation of the technical information, as well as filling in information gaps. For example, the evaluator may request product certifications from manufacturers to help sort out possible exaggerated environmental product claims. Evaluation and assessment is relatively simple when comparing similar types of building materials using the environmental criteria. However, the evaluation process is more complex when comparing different products with the same function. Then it may become necessary to process both descriptive and quantitative forms of data. A life cycle assessment (LCA) is an evaluation of the relative "greenness" of building materials and products. LCA addresses the impacts of a product through all of its life stages. Although rather simple in principle, this approach has been difficult and expensive in actual practice (although that appears to be changing).

3. Selection. This step often involves the use of an evaluation matrix for scoring the project-specific environmental criteria. The total score of each product evaluation will indicate the product with the highest environmental attributes.

The concept of high performance buildings incorporates and integrates a variety of strategies during the design, construction and operation of building projects. The use of green building materials and products represents one important strategy in the design of a building (Spiegel and Meadows, 1999)

6 Design Strategy for High Performance City

The very nature of this approach means that at first, each of these cycles should be analyzed independently of each other and the urban plan in order to idealize their operation. It is then possible to create a multilayered design which is made up of all the individual components including the urban objectives. They can then be moulded together to create a working metabolism. This design process will involve highlighting the areas of both positive and negative interaction, leading to an emphasis of certain areas, that will inform the urban an architectural design: Thus, the plan for water may highlight a need for open lakes or canals, which can then be utilized as part of the landscape plan, and form an important element of the urban streetscape, or the transport requirements for drop off points every 300 m could form a module upon which the urban centres are clustered, which in turn may tie in with the requirement for water storage, etc.

In this manner, the urban planner, the architect and the engineers can work together with the various specialists to create an integrated plan and strategy based upon informed decision making. This approach to urban design is, however, more involved and more complex than the traditional methodologies for it involves examining the problem in not merely two or three dimensions, but in seven or eight dimensions.

All towns and cities have metabolisms that ultimately form part of the global eco-system. These metabolic cycles must respond to the demands for increased efficiency interaction so that they-become sustainable Urban Environmental Design separates idealizes and the recombines these component cycles or metabolism creating an environment and ecological topography that better satisfies today's demands for cleaner-and better cities- towards a sustainable future. Successful High Performance City can be achieved if we conceder the following steps:

- Establish a vision that embraces sustainable principles and an integrated design approach.
- Develop a clear statement of the project's vision, goals, design criteria, and priorities.
- Develop a project budget that covers sustainable built environment measures. Allocate contingencies for additional research and analysis of specific options.
- Seek advice of a design professional with sustainable built environment experience.

If we do succeed in developing a Strategy for a High Performance City, it is likely that it will have the following characteristics:

- All material processes will be designed to be cyclical. There will be no such thing as waste or pollution, only outputs from one system serving as assimilatable inputs to another.
- The driving physical energy used by society will be renewable solar energy, either directly or in forms such as wind, hydropower, and biomass.
- The human population and the quantity of material goods will be stable in size (or gradually declining). This does not imply a static society, for changes in quality can continue unabated; indeed they may accelerate.
- It helps to preserve our natural resources and can significantly reduce a building's impact on the environment (Salama, and Abdou, 1999).

7 Concluding Remarks

Essentially, this paper has argued that there should be a new manner in which we approach the planning and design of our cities. Business-as-usual is not the only path open to us. Humanity could have a bright future if the whole world:

- Made use of currently proven technologies and techniques. The same technology that has been employed to subdue and conquer nature needs to be employed for the benefits of nature, and, in turn, for the long-term benefit of the human race (Salama, 1999).

- Improve greatly the efficiency of our resource use, and to greatly reduce our waste-stream going into the environment.
- Maintain and conserve renewable resource systems, like topsoil, fisheries, forests, and water supplies.
- Stabilized overall consumption of resources through switching, especially in industrialized countries, to a focus on "better" and "enough" (quality) rather than "more" (quantity).

All four of these steps are within our human capability. This new path necessitates revision of building laws regulations, architectural programs, curricula and their implementation. Architectural education and building industries and the general public should become more responsive to sustainability and sustainable development realms, which demands a change in culture and behaviours toward our built environment

References

Battle, Guy & McCarthy, Christopher, 1994. Multi-Source synthesis The Design of sustainable New towns, Architectural design Magazine, London.

Brand, Glen, (2010), Green Buildings for Cool Cities,

Brundtland, R. (1987), *World Commission on Environment & Development Our Common Future.* Oxford: Oxford University Press.

City of New York. The Department of Design and Construction,1999, *High Performance Building Guidelines* project, New York City.

Davies J. et al. (Eds.), (1994). Sustainable Urban Projects: Principles of Implementation. Torino, Italy: European Academy for the Urban Environment.

ECE, Economic Commission for Europe (1996). Guidelines on Sustainable Human.

Energy Information Administration, (2008). Assumptions to the Annual Energy Outlook". USA.

Gordon, Kate and Ode, Susan. High Performance Cities A Guide to Energy-Saving Policies for Urban Areas, ICLEI Local Governments for Sustainability.

GSA Public Buildings Service. (2008). "Assessing green building performance: A post occupancy evaluation of 12 GSA buildings", USA.

Froeschle, L. (1999). Environmental Assessment and Specification of Green Building Materials. The Construction Specifier.

Langdon. Davis, (2007). "The Cost of Green Revisited: Re-examining the Feasibility and Cost Impact of Sustainable Design in the Light of Increased Market Adoption". USA.

Lewis, Owen J., Developing a Low Energy Architecture for Europe,-research paper. Energy Research Group, School of Architecture, University College Dublin, Ireland.

Lowe, M. (1990) Alternatives to the Automobile: Transport for Liveable Cities, World watch Paper 98.

Ode, Susan. High Performance Cities A Guide to Energy-Saving Policies for Urban Areas, ICLEI Local Governments for Sustainability

Roodman, D.M and Lenssen, N. A. (1995). Building Revolution: How Ecology and Health Concerns are Transforming Construction, World watch Paper 124, World watch Institute, Washington, DC.

Salama, A. (1999). Planning and Architectural Pedagogy in a Time of Paradigm Change: A Responsive Argument for Future Professional Practice. Proceedings of the 2nd International Symposium on Planning Education for the 21st Century. Faculty of Urban and Regional Planning, Cairo University, Cairo

Salama, A. and Abdou, O. (1999). Designing for Sustainable Future: Reflections on Architectural Education in Africa and the Middle East. Proceedings of the 2nd. International Conference on Sustainability in Desert Regions, SDR 99, United Arab Emirates University, Al-Ain, UAE.

Salama, A. (2002). A Critical Thought on Sustainability. IAPS-Bulletin of People Environment Studies. Netherlands: Technical University of Eindhoven

Spiegel, R. and Meadows, D. (1999). Green Building Materials: A Guide to Product Selection and Specification, John Wiley & Sons, Inc., New York.

U.S. Green Building Council and Hamilton, Booz Allen, (2009). Green Jobs Study.

World Congress of Architects (1993A) AIA/UIA Declaration of Interdependence for a Sustainable Future. AIA Press, Washington, D.C., USA.

World Congress of Architects (1993B) The Architect's Handbook of Professional Practice. 1st Ed. AIA Press, Washington, D.C., USA.

The Environmental Impact of China's Rapid Urbanization: A Case Study of Beijing

Jamie Halsall and Ian Cook
Liverpool John Moores University, UK

Abstract
The impact on the global environment in recent years has caused much political discourse. Over the years there have been many global conferences from Stockholm (1972) to Copenhagen (2009) that have raised environmental concerns with regard to tackling these problems in a cohesive way. However these conferences have created political tension. China has had its fair say on the environment and has been an influential player in making crucial decisions on the World's approach to the environment. It is argued in this paper that China's massive economic and social upheaval has impacted on the environment. The purpose of this paper is to explore the environmental challenges facing China within an urban context, utilising Beijing as a specific case study.

Keywords: *Beijing, China, environment, urbanisation*

1 Introduction

In December 2009 major world leaders attended the Copenhagen Climate Change Conference to discuss the challenges facing the world in environmental terms. The world media portrayed this event as fourteen days to save the world or as the British Guardian newspaper headline read on 7^{th} December 2009 'Fourteen Days to Seal History's Judgement on this Generation.' Some commentators (see Porter, 2009; CNN 2010) have argued that Copenhagen was a failure because the conference was unable to come up with realistic solutions in tackling climate change. Even political leaders such as President Obama argued that this conference was not a success, to quote, 'This progress is not enough...We have come a long way, but we have much further to go' (Mackenzie, 2009). The conference also caused political tensions in terms of the developed and the developing countries. At this time it was well documented that there were political struggles between United States of America and China because both countries were duly concerned that they had 'something to lose' (United Nations, 2009a). At the end of the conference the 115 world leaders devised the Copenhagen Accord Global Agreement, as a means of recognizing 'the scientific case for keeping temperature rises to no more than 2C but does not contain commitments to emissions reductions to achieve that goal' (Vidal, 2009). Basing its analysis on a case study of Beijing in China the paper develops a conceptual understanding of sustainability and urbanization. It involves a historical discussion on the sustainability and urbanisation, in order to contextualise and help explain the environmental issues in Beijing. The paper then discusses the sustainability issues in the context of urban Beijing.

2 Environment, Sustainable Development and Climate Change

Since the 1970s there has been a continual shift on terminology related to the environment. In the 1970s the phrase of 'environment' was at the forefront of the world's agenda. However by the 1980s a new phrase was being used, that of 'sustainable development' and by the millennium we saw the new contemporary term, which is used by all, 'climate change.' The reasoning behind these terminology changes is due to various international environmental conferences. The first key conference on the environment was the Stockholm Conference in 1972. This conference has been seen as a turning point in the development of international environmental law when countries around the world debated the environment. Moreover, the Stockholm Conference was perceived as a high point with regard to public interest in the environment and as Elliott, (2004, p.12) notes 'Scientific knowledge expanded, the activities and expertise of environmental Non Governmental Organisations increased and there was a greater recognition that environmental problems required not just scientific and technical solutions but attention to the complexity of social, economic and political causes and consequences.' By the 1980s the term sustainable development was introduced. The Brundtland Commission (1987) established the conceptual framework of sustainable development. This Commission provided a definition of what sustainable development actually means stating that it 'meets the needs of the present without compromising the ability of future generations to meet their own needs' (World Commission on Environment and Development, 1987, p.8). Furthermore, Reed (1996) has stated that the concept of sustainable development set a standard of international development. This was established in three ways: (1) 'the World Commission on Environment and Development effectively established the present generation's responsibility for safeguarding future generation;' (2) 'it placed the alleviation of poverty in developing countries as the central axis around which global sustainability world revolved;' and (3) 'it recast the pursuit of sustainability in the context of the international economy by recognizing the need to reorder patterns of international trade and flows of capital and to ensure greater developing world influences in these economic relations' (Reed, 1996, pp.29-30).

Many scholars have argued that sustainable development has caused political connotations from an economic and social context (see Lele, 1991; Reid, 1995; Welford, 1995; Driver and Chapman, 1996; Macnaghten and Jacobs, 1997; Hopwood et al, 2005). For example Redclift (1987, p.2) who has been a critic of sustainable development argues that the concept has 'moral convictions as a substitute for thought.' Furthermore the main critical scepticism of sustainable development is that it is mainly economically driven from developments and primarily ignores the social element (Lafferty, 1996). By the 1990s sustainable development was aggressively promoted at the UN Rio Earth Conference in 1992. According to Shakur et al (2001) this conference provided the impetus to turn the concept of sustainable development into a policy framework. Countries from around the world went to Rio to implement policies that would tackle the environment and development concerns facing the world. Overall this conference was perceived to be a limited success by the fact the only binary agreement that was seen to be successful was Local Agenda 21. Ten years on from the Rio Summit was the 2002 Earth Summit in Johannesburg. This conference was also deemed by many to be a limited success. At Johannesburg all the agreements reached were seen to be watered down as notes (Frantzius, 2004, p.470) the Earth Summit caused "a lot of talk about the poor and sustainable development, but when it came to targets, timetables and money, no commitment was made."

3 China's Urbanization

There is much evidence of the long term documentation of China's urbanization. According to Friedman (2003) historians have undertaken a remarkable amount of work on China's cities. In the past the main focus on China's cities has tended to concentrate on coastal, geographical locations because cities, such as Shanghai and Zhanjiang have experienced exceptional economic growth. Blecher (1988) has argued that the urbanization in China is unprecedented, due to the transformation brought about by a society's shift from a rural to an urban society. This fundamental shift of populations moving from rural to urban centres can primarily be attributed to economic globalization. Scholars, such as, Yusuf and Wu (2002), Nolan (2004) and Wu (2006) have noted that this economic globalization has had a profound effect on China's urbanization. When analysing China's urbanization there are four distinct phases of expansion. Lin (2002) has identified these stages as: (1) initial growth of cities and urbanization (1949-1961); (2) reduction of cities and de-urbanization (1962-1965); (3) stagnation and under-urbanization (1966 -1977) and (4) accelerated growth and rapid urbanization (1978 - to present).

Table 1: China's Urban Population, 1958-2008

Year	Urban Population %	Urban Population Millions
1953	13.3	77.3
1964	18.3	127.1
1978	17.9	172.5
1980	19.4	191.4
1985	23.7	250.9
1990	26.4	302.0
1995	29.0	351.7
2000	36.2	459.1
2004	41.2	542.8
2006	42.0	559.2
2008	44.9	593.8

Source: Adapted from: Cook, 2008, p.134; National Bureau of Statistics of China, 2009

The last 40 years has provided fascinating trends in Chinese urbanization (see Table 1). Fenggan (2000, p.167) has calculated that in this time China's urbanization level has grown from 10% and increased to 30%. However, the yearly rate of increase of urban population is double that of total population (4.2% to 1.8%). Hence, this progress of urbanization has become rapid and this growth, according to Fenggan (2000) can be identified in different historic periods. Prior to the Great Leap Forward of 1958 China's urbanization was experiencing a steady yearly increase of urban population. The reason why there was a normal population increase in this time was because political campaigns only had a slight impact on economic development and population migration. When the Great Leap Forward policy was introduced and implemented in

January 1958 the period from 1958 to 1963 saw the urbanization population process rise and fall sharply. As Fenggan (2000, p. 168) notes in this period 'the percentage of urban population went from 16+ per cent to – 20 per cent and back to 16+ per cent again.' The cause for this fluctuation in population can be attributed to the Great Leap Forward policy because this strategy promoted rural-urban migration and thus created a vast influx of people to cities over a short period of time. The Great Leap Forward approach engineered an introduction of control methods to limit rural to urban migration because by 1963 authorities were alarmed at the rate of rural migration to the urban regions due to the expansion of economic development occurring in urban areas (Yang, 2008).

Between 1965 and 1978 the urbanization process remained stable. In this period the urban population in China was at 17% and this trend can be explained according to Fenggan (2000, p. 170) for two reasons. Firsly, in this period there 'was simultanoueous rural-urban and urban-migrations, the latter outweighing the former.' Secondly, there was 'a disguised urbanization process caused by relatively fast demographic growth in urban areas.' By the introduction of reform policies in the late 1970s and China opening trade to the outside world, population in urban areas in China showed a steady increase.

China's urbanization data shows that from 1978 to present day an accelerated growth in urbanization. This rapid change has come about due to market reforms and globalization and as Lin (2002, p. 306) confirms:
"The transition of power from Maoist plan ideological, into the post-Mao market-regulatory regime, has ushered in a new development strategy that values efficiency over equity, individual creativty over collectivism, and regional comparative advantages over decades or ideological considerations."

These reforms directed the Chinese government in 1979 to create Special Economic Zones. Primarily this reform certified foreign investment and throughout the 1980s and 1990s the reform snowballed. For example in 1980 four Special Economic Zones were established in Shenzhen, Zhuhai, Shantou, Xiamen and in 1984 Development Zones were opened up in 14 coastal cities: Beihai, Dalian, Fuzhou, Guangzhou, Lianyungang, Nangtong, Ningbo, Qingdao, Qinhuangdao, Shanghai, Tianjin, Wenzhou, Yantai and Zhanjiang to overseas investment. According to Lin (2002, p. 306) from 1978 to 1984 the Chinese government commissioned 78 new cities and redeveloped 32 cities. The figure of cities increased from 193 in 1978 to 668 in 1998 and as Lin (2002, p. 306) calculated this was an increase of 47 new cities in 20 years. The urbanization in China surged from 79.8million in 1978 to 217.7 million in 1998 and the share of the total population increased from 8.3% to 18%. This acceleration in population growth and urbanization can only be described as dramatic and this period has created new environmental and social challenges (Pannell, 2002). However, this rapid growth of China's urbanization, due to the changing economic system, has caused urban wealth but also urban poverty. Longan (2008) has noted that the last two decades have created a culture of 'haves' and 'have nots' and there is a growing awareness of social inequalities. For example research undertaken by

Liu and Wu (2006) has discovered that since the 1990s urban poverty has been a cause for concern. Liu and Wu (2006) have revealed that urban poverty occurs in specific locations. It has been suggested by Wu (2007) that the reason why urban poverty is seen to be problematic in urban China is directly linked to three major challenges which are: (1) deindustrialisation (redundancy of state employment); (2) the change in the labour market and (3) public policies (housing privatisation and minimum income support). This paper now moves on to discuss the wider issues of environmental and social challenges that are facing China's cities today.

4 China's Environmental Challenges

In 2007 it was reported that China was the world's biggest polluter in terms of carbon dioxide (Vidal and Adam, 2007). The ever increasing urbanization of China has created environmental challenges. These environmental challenges in China's cities are addressed by what is termed as environmental justice. Particular studies in the past have focused on the environmental justice element surrounding the effects on the environment that can be attributed to China's rapid growth as a consumer (Gao *et al*, 2001; Liu *et al*, 2003; Cook and Dummer, 2004). This environmental justice, in China's case, relates to three key areas which are, tackling the pollution of air, water and land. The rapid rise of environmental consequences relates to the increased rise of industrial development. In comtemporary urban China today these environmental challenges affect many millions of people in urban areas and affect mainly the poorest and most marginal groups (Liu and Diamond, 2005). In October 2005 Beijing was recognized by the European Space Agency Satellite as the most polluted city on earth while the World Bank states that 16 out of the world's most polluted cities are in China (Cook, 2007). This rise in poor air quality in Beijing can pose a threat to people in the city by producing the condition 'Beijing Throat.' Beijing Throat is developed through a mixture of dust, vehicle pollution, industrial pollution and cloudy conditions. It has been estimated that 100 million people are living in cities where air quality conditions are perceived to be 'very dangerous' and 411,000 people have died prematurely from respiratory problems and heart disease. Walker (2006) has said that the biggest contributor to air pollution is coal burning and currently coal burning is at one tonne per head of population, at 1.3 billion tonnes, but future predictions suggest that this will increase to 2 billion tonnes by 2020.With this increase in coal burning in many Chinese cities acid rain has become a major problem.

The second environmental challenge is water pollution. Research by Cook (2007, p.32) has argued that water pollution is attracting a major concern and he warns:

"Seventy per cent of China's rivers and lakes are polluted so apart from the problem of rural water quality, even in the capital Beijing visitors are advised not to drink the tap water, and as in other countries there is a tremendous trade in bottled water in Beijing's supermarkets. This situation is found in many other cities too, while nearly two-thirds of China's cities, 420, are estimated to have water shortage problems, with 100 having 'acute shortage' including Beijing itself."

The reason why water is a problem is largely due to the Maoist period's encouragement of heavy industry. After Mao's death in 1976 the continued drive on China's industrial and export-based economic growth created a disregard for the environmental impact, thus having an effect on the quality of water in many urban cities. An example of this concern is the ecological problem of the Yangtze River. However by 1998 the Chinese government decided to address this problem by building the first waste disposal plant in Chongqing (Cook and Murray, 2001). The ever-increasing growth of cities has also placed pressure on water and created shortages. Cities expanding across China have placed a demand for greater amounts of water for industrial and personal use (e.g. toilets, showers and cooking).

Finally, land pollution is the last major environmental challenge to Chinese cities. Again the reason why land pollution is deemed to be a threat is due to the heavy production industries such as chemical and steel. Steel and iron works such as Panzhihua have caused high levels of land pollution and as Shapiro (2001, p.155) notes the Panzhihua plant has 'enduring soil pollution by toxic metals is not surprising in an environment in which chemicals and metals were so heavily and carelessly used.' This level of land pollution has created deforestation around the prefecture level city located in Sichuan Province. Moreover, the post-reform era land pollution still continues but has relatively improved. Murray and Cook (2004) have noted that China produces 9 millions tons of waste every year but only manages disposal of a third of that amount safely. The Chinese government recognise that waste disposal has become a problem and realise that action needs to be taken to minimise urban environment threats, thus creating a better quality of life.

5 Sustainability Issues in Beijing

As an example of sustainability issues in China's cities we focus on Beijing, capital of China's socialist enterprise and, increasingly, a new world city (Gu and Cook, 2010; (Zhang and Zhao, 2009). Historically, China's cities were primarily in symbiosis with their rural hinterlands, with the city providing security, goods and religious meaning for the peasantry outside the city, while the latter in turn provided the food and surplus labour and wealth on which the city could be developed. At times, however, especially in times of periodic flood or famine, the city could be parasitic on the rural society, with the greed and power of the urban leaders squeezing the peasantry until they became impoverished at the expense of the urban dwellers. The ecological footprint of the city could be extensive, and during the reign of Kublai Khan in the Yuan dynasty for example, goods were transported over hundreds or even thousands of miles over the renewed Silk Road across Asia, or South to North via the Grand Canal from the Yangtze delta, a process that has been termed 'embryonic ensure that the city would be ready for the Games. US$15 billion was to be spent on anti-pollution efforts through to 2008 and:

"From 1998-2007, the plan envisaged such features as:

- total expenditure of $12.2 billion on protection and enhancement of the ecological environment;
- 14 new wastewater treatment plants to be built to improve the sewage treatment rates to 90 per cent from 42 per cent;
- 240 square kilometres of trees and grass to be planted around Beijing to create a 'green coverage' area of more than 50 per cent;
- 200 industrial enterprises to change production or be shifted out of the downtown area altogether to reduce pollution levels;
- completion of the fourth and fifth ring roads, five new subway lines, 90 per cent of buses and 70% of taxis to use natural gas' (Cook, 2007b; Cook and Miles, 2010)."

In the event, many of the targets were realised and efforts continue to sustain the progress that was made, for example the continuation of the policy to restrict car use on different days depending on number plate registration means that one-fifth of private cars and one-third of official vehicles are off the roads on any one day, ensuring that emissions are reduced by 10% (Watts, 2009). There were setbacks, however, in part because the regional aspect of sustainability issues affected the city. For example, despite the huge scale of tree-planting on 16th April 2006 a massive sandstorm hit Beijing, estimated to have deposited 330,000 tons of dust on the city, while the next day 'saw most of North and Northwest China enveloped in sandstorms' (Cook, 2007b; Cook and Miles 2010). This issue is a reflection of the desertification of the North and Northwest regions of China, a desertification that began over 2,000 years ago during the building of the Great Wall (Cook, 2007a). Today, despite many techniques employed to combat the spread of the deserts, including afforestation in the Three Norths Shelter Belt, or Great Green Wall, and the afforestation programme in Beijing itself, it is extremely difficult indeed to prevent the sands locating further and further to the east.

There are also question marks concerning just how successful the Olympics were in promoting green issues (Cook and Miles, 2010). For example, on the positive side the United Nations Environment Programme (UNEP) gave the city a 'big tick' for such improvements as increased awareness of environmental issues among residents and businesses, introduction of Euro IV emission standards for cars instead of the Euro II planned, creation of 8,800 hectares of green space, including more than 30 million trees and rose bushes, and a rise in blue sky days (a key policy target) from less than 180 in 2000 to 274 in 2008 (United Nations, 2009b). In contrast, an analysis involving US and Chinese scientists (though the Chinese author later backtracked on the findings) found that the level of particulate pollution during the Beijing Olympics was double that of the Olympics in Athens, three times that of Atlanta and 3.5 times that of Sydney (US News, 2009).

One area of pressure that has been on the increase as a result of the huge expansion and modernisation of Beijing has been water shortage. For some years now, hotels have, as in many other parts of the globe, exhorted guests to have their towels and sheets changed only when necessary, not to waste tap water, while urinals increasingly have automated flushing systems via sensors, flushing only when needed. Despite such initiatives, the combination of water loss from major rivers in North China, for agriculture and industry, and from local artesian wells for example means that the water table has sunk drastically and water shortages are acute. In order to deal with this, the South-North Water Diversion Project has been mooted, to transfer water from the Yangtze River to Beijing and its environs (Water Technology, 2010). First proposed by Mao Zedong in the 1950s the project has 3 phases, costing $62 billion in all, twice that of the Yangtze Dam, and designed to transfer 44.8 billion m3 by the end date of 2050. There are concerns about this project, however, not least because the Yangtze River is no longer such a water surplus river as it once was, due to the Yangtze Dam itself as well as regional industrialisation of the Yangtze Valley and Delta (ibid.).

Air pollution has had a negative impact on health, as it has across China generally. China now suffers from 'diseases of affluence' as well as the continuation of 'diseases of poverty' (Cook and Dummer, 2004), and although it is in China's rural areas that the most negative aspects are evident (Dummer and Cook, 2007), nevertheless people in Beijing are at risk of respiratory disease and heart problems linked to poor air quality. By 2005, it was claimed that Beijing was the most polluted city on earth, and despite sterling efforts to increase the proportion of blue sky days, reduce vehicle emissions and to curtail industrial pollution, as noted above the visitor and residents alike are likely to suffer at the least from 'Beijing Throat' as a result of a cocktail of vehicle particulates, low air quality and dust in the atmosphere, while it has been claimed that exposure to such pollution over a few weeks can increase the risk of heart attacks and strokes (Science Daily, 2008). Further, wider dietary changes associated with modernisation/ westernisation are linked to a rise in obesity, and it is now 16 years since the first 'fat camp' was opened to treat overweight children in the city (Cook and Dummer, 2004).

To conclude this analysis, there is the situation of the floating population (*liudong renkou*) to consider, in terms of people-centred sustainability issues. During the Maoist era a *hukou* system of registration was introduced whereby residents required formal registration before they could gain access to food rations, health provision, housing and employment. This system was used to limit, control and direct migration into China's cities, including Beijing. Since the reform era, begun under Deng Xiaoping from 1978 onwards, the authorities have relaxed their stance on migration, not the least because they believe that urbanisation is essential to the development of a modern economy (Cook, 2006).

Gu and colleagues have conducted a number of studies of this floating population in Beijing, and have shown for example that there were more than 1 million in the city by 1989 and nearly 4 million by 2004 (Gu et al, 2006, p.275). These are the people that 'through their visibility...disturb the modernization project and question Beijing's alleged modernity' (Broudehoux, 2004, p.136), people that live in crowded urban enclaves or villages (Gu et al, 2006), face the regular threat of demolition of their dwelling places as the land is required for grand projects, and find it difficult to access health and education provision for example. They, especially if they are male, which they most often are, are also at risk of sexual disease, alcoholism and tobacco-related disease as they spend their hard-won leisure time in such activities (Cook, 2008). Today, with the current recession many have returned to their home villages, risking taking STDs and other conditions home to spread among their family and fellow villagers.

6 Conclusion

Chinese urbanisation has brought many advantages to China in terms of increased material wealth. The beneficiaries of this are China's new middle class and many of China's working class. As a consequence China has experienced an increase in the modernisation of its economy and this has assisted in forming linkages with the global economy. However, as we have shown, there is a cost to this urban economic growth, as in other countries, due to the increased pressure on social and environmental resources. The impact of the 2008 Olympic Games in Beijing has brought a new emphasis on sustainability. As a consequence the Chinese government has strengthened environmental legislation. This legislation has provided a new framework on environmental protection thus giving new guidance to Chinese local authorities. However, China has urbanized rapidly in the last few decades. Sustaining this high level of urban development poses many problems for planners, architects, developers and those concerned with China's future urban society. As we have discussed in our case study, Beijing has made great strides in tackling such sustainability issues, yet many questions of environmental and social sustainability remain unanswered (Zhu, 2009). It is essential, in our view, that these issues are kept high on China's urban agenda in order to ensure that China maintains a high quality of urban life.

References

Blecher, M. (1988). Rural contract labour in urban Chinese industry: migration control, urban-rural balance and class relations. In Gugler, J, (Ed.), *The Urbanization of the Third World* (pp. 109-123).Oxford, England: Oxford University Press.

Broudehoux, A, M. (2004). *The Making and Selling of Post-Mao Beijing*, London, England: Routledge.

Cook, I, G. (2000). Pressures of development on China's cities and regions. Cannon, T. (Ed.), *China's Economic Growth: The Impact on Regions, Migration and the Environment* (pp.33-55). London, England: Macmillan.

Cook, I. G. (2006). Beijing as an 'Internationalized Metropolis'. In Wu, F. (Ed.), *Globalization and China's Cities* (pp.63-84). London, England: Routledge.

Cook, I.G. (2007a). Environment, health and sustainability in twenty-first century China. In Chen Y. and Sanders, R. (Eds.) *China's Post-Reform Economy: Achieving Harmony, Sustaining Growth* (pp.30-43). London, England: Routledge.

Cook, I.G. (2007b). Beijing 2008. In Gold, J.R. and Gold, M.M. (Eds.) *Olympic Cities: City Agendas, Planning and the World's Games, 1896-2012* (pp.286-297). London, England: Routledge.

Cook, I.G. (2008). 21st Century issues and challenges in Chinese urbanization. In Wagner, L.N. (ed.) *Urbanization: 21st Century Issues and Challenges* (pp.133-153). New York, America: Nova Science Press.

Cook, I.G. and Dummer, T. J.B. (2004). Changing health in China: re-evaluating the epidemiological transition model. *Health Policy*, 67(3), 329-43.

Cook, I.G. and Miles, S. (2010). Beijing 2008. In Gold, J.R. and Gold, M.M. (Eds.) *Olympic Cities: City Agendas, Planning and the World's Games, 1896-2016* (Second edition, no pagination yet, in press). London, England: Routledge.

CNN. (2010, January 5). After Copenhagen: Hope for the future. Retrieved January 8, 2010, from

http://www.cnn.com/2010/TECH/science/01/04/climate.mark.lynas /index.html

Dong, L. (1985). Beijing: The development of a socialist capital. V.F.S. (Ed.) *Chinese Cities: The Growth of the Metropolis Since 1949* (pp. 67–93). Oxford, England: Oxford University Press.

Driver, T., S., and Chapman, G., P. (1996). *Time-Scale and Environmental Change.* London, England Routledge.

Elliott, L. (2004). *The Global Politics of the Environment.* Basingstoke, England: Macmillian.

Fenggan, Z, (2000). Urbanization. In Xizhe, P, and Guo, Z, editors, *The Changing Population of China* (pp. 167-178). Oxford, England: Blackwell.

Frantzuis, I., V. (2004). World summit on sustainable development Johannesburg 2002: A critical analysis and assessment of the outcomes. *Environmental Politics*. 13(2), 467-473.

Gao, J., Tang., S., Tolhurst, R., and Rao, K. (2001). Changing access to health services in urban China: implications for equity. *Health Policy and Planning,* 16(3), 302-312.

Gaubatz, P.R. (1995). Urban transformation in Post-Mao China: Impacts of the reform era on China's urban form. In Davis, D., S., Kraus, R., Naughton, B. and Perry, E., J. (Eds), *Urban Spaces in Contemporary China: The Potential for Autonomy and Community in Post-Mao China*, (pp. 79-96). New York, America: Woodrow Wilson Center Press.

Gu, C., Chan, R., C., K., Liu, J., and Kesteloot, C. (2006). Beijing's socio-spatial restructuring: immigration and social transformation in the epoch of national economic reformation, *Progress in Planning*, 66(4), 242-310.

Gu, C. and Cook, I.G. (2010). Beijing: Socialist Chinese Capital and New World City. In Forbes, D., and Hamnett, S. (Eds.) *Asian Cities: Risk and Resilience* (in press). London, England: Routledge.

Hopwood, B., Mellor, M., and O'Brien, G. (2005). Sustainable development: mapping different approaches. *Sustainable Development,* Vol 13(1), 38-52.

Lafferty, W., M. (1996). The politics of sustainable development: global norms for national implementation. *Environmental Politics,* Vol 5(2), 185-208.

Lele, S. (1991). Sustainable development: a critical review. *World Development,* 19(6), 607-621.

Lin, G. C. S. (2002). The growth and structural change of Chinese cities: a contextual and geographical analysis, *Cities,* 19(5), 299-316.

Liu, G., G., Wu, X., and Peng, C. (2003). Urbanization and health care in rural. *Contemporary Economic Policy,* 21(1), 11-24.

Liu, J., and Diamond, J. (2005). China's environment in a globalizing world. *Nature,* 435(30), 1179-1186.

Liu, Y., and Wu, Fulong, W., (2006). Urban poverty neighbourhoods: typology and spatial concentration under China's market transition, a case study of Nanjing, *Geoforum,* 37(4), 610-626.

Logan, J. R. (2008). *Urban China in Transition.* Oxford, England: Blackwell.

National Bureau of Statistics of China. (2009). *China Statistical Yearbook.* Beijing, China: China Statistics Press.

Nolan, P. (2004). Transforming China: Globalization, Transition and Development. London, England: Anthem Press.

Mackenzie, K. (2009, December 18). Copenhagen: Full text of Obama's Statement and Press Conference. Retrieved January 7, 2010, from

http://blogs.ft.com/energy-source/2009/12/18/copenhagen-full-text-of-obamas-statement-and-press-conference/

Murray, G., and Cook, I., G. (2004). *The Greening of China.* Beijing, China: Intercontinental Press.

Science Daily. (2008, July 22). Beijing pollution may trigger heart attacks, strokes. Retrieved January 5 2010 from

http://www.sciencedaily.com/releases/2008/07/080721102807.htm

Pannell, C. W. (2002). China's continuing urban transition, *Environment and Planning A,* 34(9), 1571-1589.

Porter, A. (2009, December 21). China and America to blame for Copenhagen failure, says Brown. Retrieved January 8 2010 from

http://www.telegraph.co.uk/news/newstopics/politics/6859567/Gordon-Brown-Copenhagen-China.html

Reed, D. (1996). *Structural Adjustment, the Environment, and Sustainable Development.* London, England: Earth Scan.

Redclift, M. (1987). *Sustainable Development: Exploring Contradictions.* London, England: Methuen.

Reid, D. (1995). *Sustainable Development: An Introductory Guide.* London, England: Earthscan.

Shakur, T., Dasgupta, N., and Treloar, D. (2001). *Unsustainable Environment and the Cities of the Developing World.* Liverpool, England: Hegemon Press.

Sit, V.F.S. (1996). Soviet influence on urban planning in Beijing 1949-1991. *Town Planning Review,* 67(4) 457-484.

The Guardian. (2009). Fourteen Days to Seal History's Judgment on the Generation. Retrieved January 8 2010 from

http://www.guardian.co.uk/commentisfree/2009/dec/06/copenhagen-editorial

United Nations. (2009a, December 20). Copenhagen was more than the Accord. Retrieved January 7 2010 from

http://en.cop15.dk/news/view+news?newsid=3089

United Nations. (2009b, February 20). Beijing Olympics Get Big Green Tick. Retrieved January 31, 2010, from

http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=562&ArticleID=6086&l=en,%20Beijing%20Olympics%20Get%20Big%20Green%20Tick,%20February%202009,%20accessed%2010%20July%202009.

US News. (2009, July 10). Study: Beijing's Air Worse Than at Past Olympics. Retrieved January 31 2010 from http://www.usnews.com/science/articles/2009/06/21/study-beijings-air-worse-than-at-past-olympics.html

Vidal, J., and Adam, D. (2007, July 19). China Overtakes US as World's Biggest CO2 Emitter. Retrieved January 8 2010 from

http://www.guardian.co.uk/environment/2007/jun/19/china.usnews

Walker, M. (2006). A National Struggling to Catch it Breath. *Newscientist,* 2549, 8-9.

Water Technology. (2010, January 5) South-to-North Water Diversion Project, China.Retrieved January 8 2010 from

http://www.water-technology.net/projects/south_north/

Watts, J. (2009, April 6). Beijing Keeps Olympic Restrictions on Cars After Air Quality Improves. Retrieved January 8 2010 from

http://www.guardian.co.uk/environment/2009/apr/06/beijing-pollution-carbon-cars

Welford, P. (1995). *Environmental Strategy and Sustainable Development.* London, England: Routledge.

World Commission on Environment and Development. (1987). *Our Common Future.* Oxford, England: Oxford University Press.

Wu, F. (2002). China's changing urban governance in the transition towards a more market-oriented economy, *Urban Studies,* Vol 39(7), 1071-1093.

Wu, F. (2006). *Globalization and the Chinese City.* London, England: Routledge.

Yang, D. T. (2008). China's agricultural crisis and famine of 1959–1961: a survey and comparison to Soviet famines. *Comparative Economic Studies*, 50(1), 1-29.

Yusuf, S., and Wu, W. (2002). Pathways to a world city: Shanghai rising in an era of globalisation. *Urban Studies,* Vol 39(7), 1213-1240.

Zhang, L., and Zhao, S., X. (2009). City branding and the Olymic effect: A Case study of Beijing. *Cities,* 26(5), 245-254.

Zhu, J. (2009). *Architecture of Modern China: A Historical Critique,* London, England Rutledge.

Case Floating EcoCity Tianjin China

Aaro Söderlund [1,2], Juha Kääriä [1]
[1]*Turku University of Applied Sciences, Finland*
[2]*Architect Office Aaro Söderlund Ltd, Finland*

Abstract

In 2007, China and Singapore decided to build an EcoCity in Tianjin, North China, as an example of sustainable development to be reproduced around China and the world. Tianjin is the third centre of development in China, after Hong Kong (1980's) and Shanghai regions (1990's), and an excellent test site for the struggle with tough environmental challenges in the 21st century.

In 2009, the Finns were challenged to consider building their share of Tianjin EcoCity. The resulted Floating EcoCity-concept (FEC ©ASOY 2009) will be treated on this paper. It consists of hexagonal platforms and EcoFlo Vessels. six caissons offer maximal stability to the hexagonal platform. The lower deck has technical facilities in the middle, services on the edges, and traffic between, while the upper deck has prefabricated modular housing on the edges, Central Park in the middle, and the whole is covered by a megatent. The platforms are assembled into larger hexagons.

EcoFlo Vessels are equipped similarly in new tankers and container ships that were left unused due to recession. They surround the platforms creating an even larger hexagonal quarter, to be replicated in fractals.

Each unit is an energy positive and CO_2 negative biosphere, where plants shade, purify air, water and soil, balance humidity and produce oxygen, food and recreation. Local services and working opportunities minimize traffic. FEC offers secure, practical, clean, healthy, and exciting sea life.

Keywords: *EcoCity, Mega-Float, Mega tent, Green Architecture, Climate Change, Rising Sea level*

1 Introduction

China has the world's largest construction market. Over the next decade, half of the world's new buildings will be built in China, adding 2 billion square meters of floor space annually. According to China's "Green Building Evaluation Standard," (Standard 2006) a designated Green Building reduces pollution emitted, maximally protects the environment and reduces the consumption of natural resources such as water, land, and non-renewable energy throughout its lifecycle. Therefore, any technologies, products or services that help buildings to achieve this, have a potential market in China (Shujuan, 2009).Tianjin, the Harbor City of Beijing on the Delta of Huang He, offers an excellent test bench for sustainability in architecture and urban design concerning both human and natural challenges (Fig.1).

Springtime sandstorms cover the area with 1-2 cm of Gobi sand. Typhoons hit the area once a decade. Summer monsoons overfill the narrowed, uplifted and shortcut, concrete-canalized rivers, causing severe flooding (e.g. June 25, 2008). At the Tianjin EcoCity there are four such rivers adjoined, causing a focused risk.

Huang He carries over 1000 million tons of loess silt (Keller & Prior, 1986, p. 63) from Ordos Desert, filling the Bohai Gulf with up to 660 m a year at its mouth. This 'Mother of Rivers' tends to fill its old courses, of which some 40 are known, and break new ones, as last time in 1854. A major avulsion took place as late as in 1976 (Keller & Prior, 1986, p. 63). The river has run at least 3 times over Tianjin.

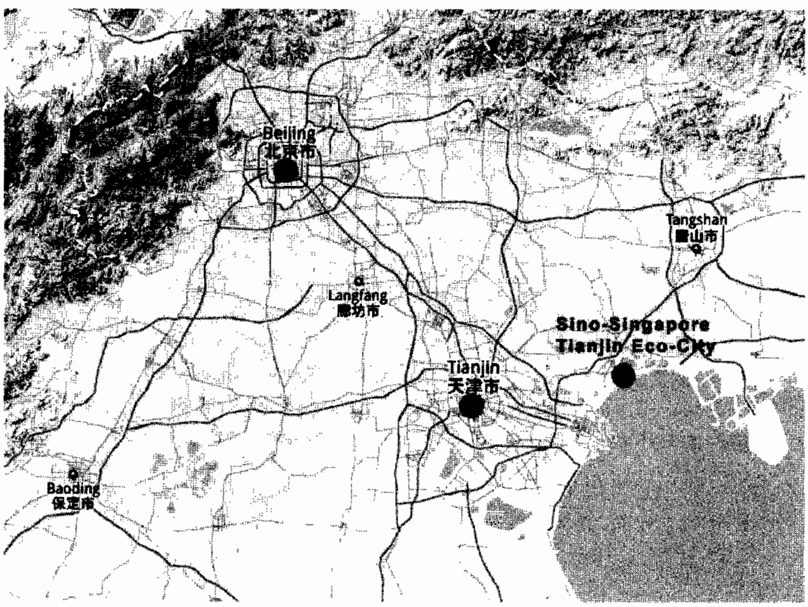


Figure 1: Study area in Tianjin Eco-City. ©Google

Huang He –delta is one of the most densely populated areas in China. Huge water consumption dries the rivers, sinks the groundwater, and causes the delta soil to recede into the sea. This phenomenon is known from other highly populated deltas as well.

On the other hand, the Climate Change may raise the sea level. Thus water would submerge parts of the North China Plain, Shanghai, Hong Kong, and other low elevation coastal zones (LECZ) in the World. The risk is focused on Asian lands, population, and economy (McGranahan et al. GB. 2007).

The local earthquakes reach up to R8. E.g. that of Tangshan killed 0.3 million people in 1976. Tsunamis from Bohai may occur twice a decade and reach far inland, as the 2 m contour runs some 50 km inland.

Tianjin belongs to the fastest developing industrial regions on the Globe, with +15% economic growth in 2009. The extensive burning of coal results in the smog entering interiors. Poisonous ozone hovers over the land and sea. Acid rain and extensive nitrate fertilizing acidify the soil. The fields are also saline and polluted. Ground-, surface- and rainwater are likewise polluted e.g. by industrial heavy metals. Human waste flows into Bohai.

Condensed urbanization causes intensifying lack of land – and the land prices rocket. In Tianjin, more than a half of a skyscraper investment goes into its lot alone. Thus the investors are getting interested to build in radically new ways, like into the sea.

Artificial islands produced by land reclamation, in the style of Netherlands, Japan and Singapore, are good for 20 m deep or shallower water (Andrianov, 2005). The mean depth of Bohai is 18 m, with the deepest point of 70 m at the Bohai Strait (Tao, 2006). In that sense, the bay offers suitable conditions for landfill islands. Unfortunately, they are expensive (Andrianov, 2005). The landfills cover the bottom and marine life, breaking the sensitive sea currents and thus affecting the coastlines, and alter the sea chemistry. What more, tremors will liquidize the landfills with dramatic consequences: when shaken the fill may swallow the buildings on top (ref. R8 San Francisco 1906).

China has strengthened the means to protect their biggest inner sea, Bohai, by an Eco-compensation Mechanism, which aims at directing development into environmentally less harmful directions, making unwanted actions even more expensive (Jun et al. 2008).

Floating artificial islands have the benefits of land fill islands without their weaknesses. E.g. when the floating platforms are anchored flexibly to the bottom, they harm the marine life very little, mostly by shadowing it.

Tianjin's location and role as the focus of economic growth is significant and the economic utilization rate of the marine shoreline ranks among the highest in China. According to Tianjin Oceanic Administration, at present the use of Tianjin area is characterized by the use of sea area, high development costs and long capital recovery cycle. In this area, the development enterprises generally face greater financial pressure. To help businesses break the financing problems with the sea, and promote financial innovation, Tianjin and Tianjin Oceanic Administration, and Banking Bureau of extensive consultation with relevant financial institutions, established a relatively perfect right to use the mortgage waters institutional system. The initial construction of the right to use the waters of Tianjin mortgage loan system was announced in December 4, 2009 in Tianjin. (Wei & Yuan 2009)

Based on the above discussion, the paper deals with the Floating EcoCity-concept (FEC), which aims at answering all of the abovementioned challenges.

2 Floating EcoCity Concept

Architect Kenzo Tange opened the discussion about floating cities by his 1960 plan to expand Tokyo into the sea. Very large floating structures have been used for different purposes in Japan, Canada, Norway, the USA, the UK, Brazil, Saudi Arabia, and Vietnam. China, Korea, Israel, the Netherlands, Germany, New Zealand, and Singapore are going to do so in the near future (Andrianov, 2005, p. 5). Japan is leading the development in this field, under intensive research and development (e.g. Suzuki, 2005), because of their 80% mountainous land. There are proposals/projects of the Japanese Society of Steel Construction, of the Nishimatsu and Shimizu corporations (Watanabe et al. 2004). Moreover, there is the Seasteading Project in the USA (Andrianov, 2005, p. 8). Several thousand meters long 'very large floating structures' (VLFS) are under studies (Fujikubo & Yao, 2001). Also the affects of super waves on VLFS have been studied in Japan (Talavera et al. 2001).

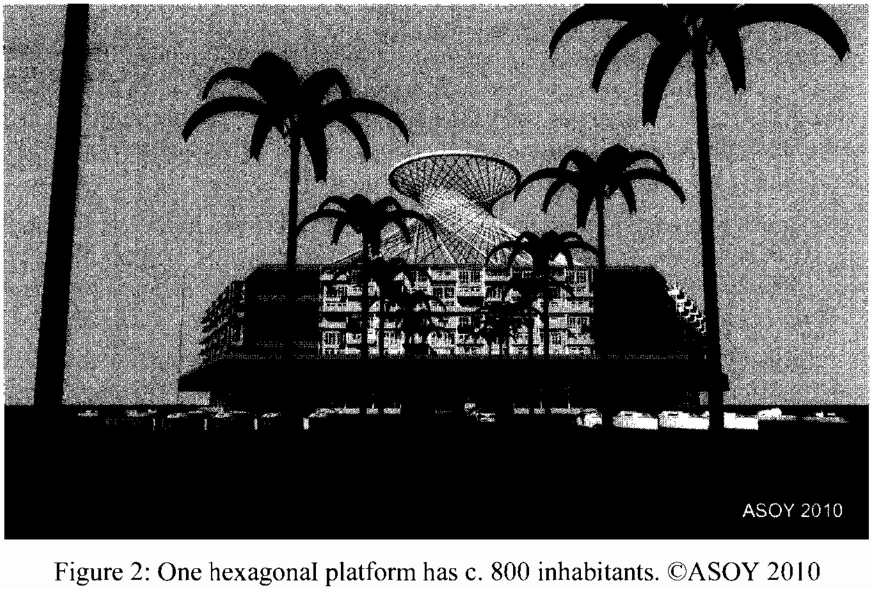


Figure 2: One hexagonal platform has c. 800 inhabitants. ©ASOY 2010

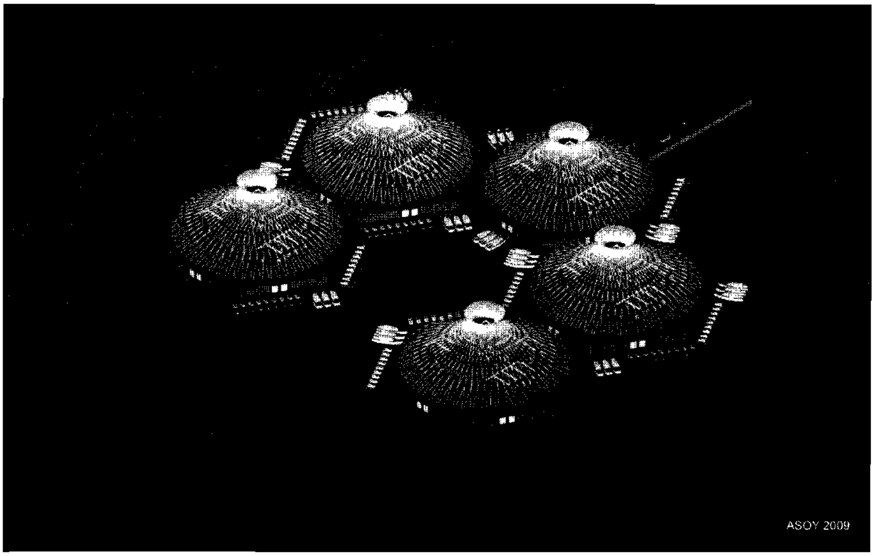


Figure 3: Five hexagonal platforms

FEC-concept for Tianjin has been inspired by the Great Navy of the Ming Emperor Yongle, (1402 - 1424). His loftiest 'Treasure Ships', all built and based in Tianjin, were 140 by 55 m in size, and had up to nine masts: they were equipped like floating biospheres. Other sources for inspiration have been the 2 m tide of Bohai Gulf twice a day (Mobile Geographics LLC, 2010) offering enormously kinetic energy; the local earthquakes of up to R8; the Climate Change rising the sea level; the Chinese tent roof tradition; the regional building wisdom FengShui ('WindWater'), as well as the Confucian teachings by Mengtse about how to form successful societies. Thus the social life on the platforms is based on the long Chinese tradition of living in rather closed autonomous urban subunits. Also the present Global recession has been taken into account.

FEC-concept consists of two main elements, the hexagonal platforms (Fig. 2, 3) and the EcoFlo Vessels (Fig. 4, 5). Used together they form a new type of urban texture, protective against a range of natural and human threats (Fig. 6). The FEC achieves its high environmental goals by leaving dry land for other uses. Moreover it aims to be energy-positive by using a wide range of green energy sources (see: Green Energy Sources below), and is a biosphere (see below), with vegetation, which shades and cools the buildings, purifies air, water and soil, and balances humidity, produces oxygen and gives CO_2 negative results – as well as food and recreation. Local services and working opportunities minimize the need for traffic. When transportation is needed, waterborne transport consumes the least energy.

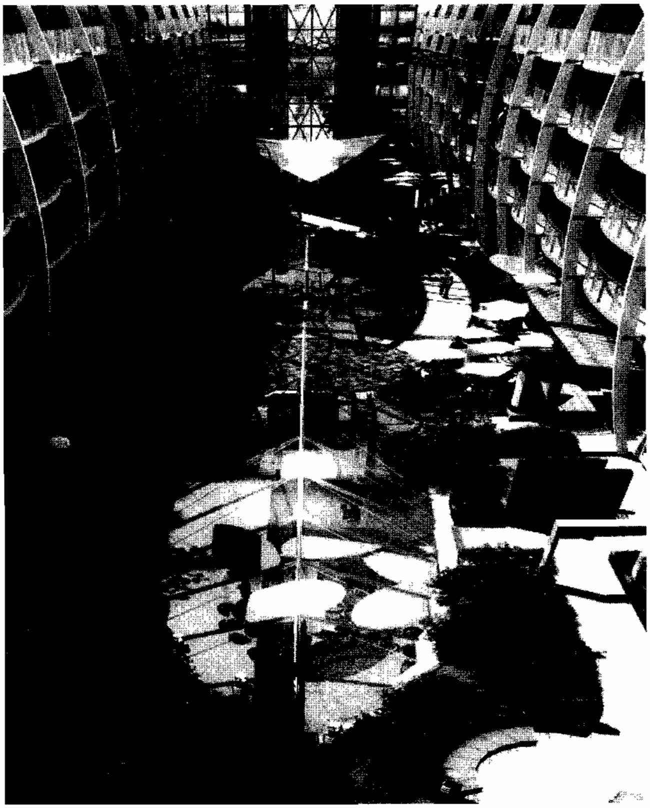


Figure 4: EcoFlo Vessel: Central Park built in a ship Oasis of the Seas © Royal Caribbean International

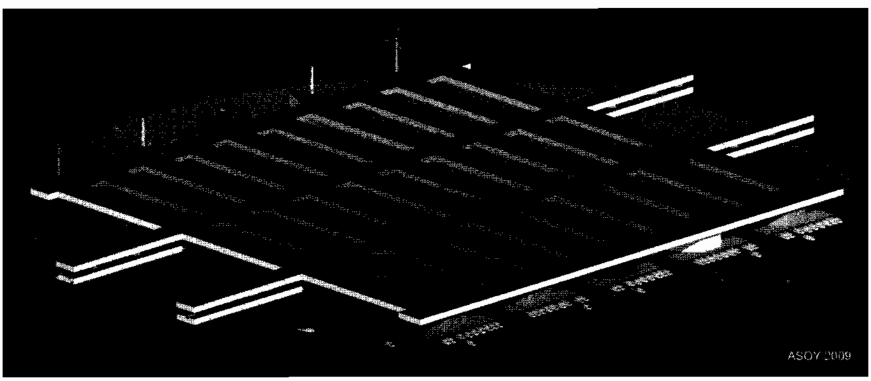


Figure 5: Five ships joined into a float of 20'000 inhabitants ©ASOY 2009

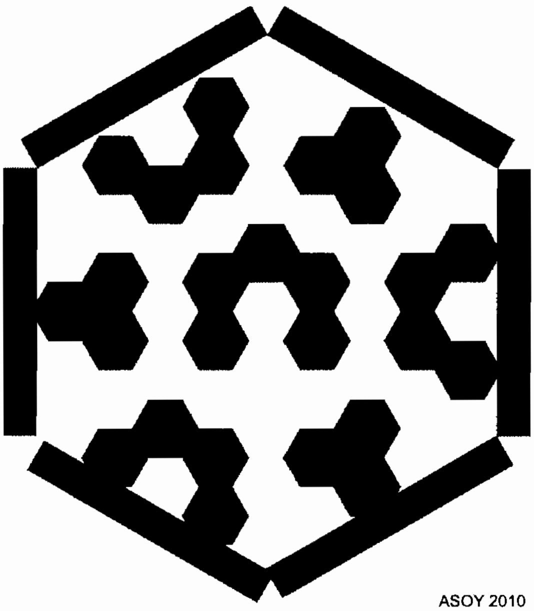


Figure 6: EcoFlo Quarter: 6 vessels and 26 hexagons, Ø 1km.

The hexagonal design of the platforms is based on the local Feng-Shui tradition. Similar planning can be found e.g. from the Forbidden City of Beijing (fire altars, beam heads, door grilles) or the international airport of Beijing. The form is also ideal for the attachable floating units. In principle circular shape offers maximal stability against winds and quakes. However, the waves may cause a hydroelastic problem with rounded structures (Andrianov, 2005, ch. 5; Hamamoto, 1995). This is why six diamond-shaped caissons support each hexagonal platform with the best balancing results under all conditions.

Floating structures in general are well protected from seismic shocks (Andrianov, 2005 p. 7) contrary to the landfill islands (ref. San Francisco 1906). FEC offers green energy surplus, an opportunity to live and work in secure, clean, healthy and exciting sea environment - notwithstanding the most demanding environmental conditions. As a result, the FEC offers an investment alternative without the environmental stresses harming the over-priced shores and landfill islands.

If one wants to find a parallel for FEC built on land, the Masdar Headquarters at Masdar City, Abu Dhabi, United Arab Emirates shows a rather similar attitude and vision (Smith & Gill, 2010).

In the following, the FEC is treated in more detail.

2.1 The Floating EcoCity

The FEC is based on two basic units, the hexagonal platforms, and the EcoFlo Vessels, both of which have central parks, framed by the buildings and roofed by the megatent. The vessels are rebuilt (new but due to the recession unused) Malaccamax –size ships (470x65x20 m). In the following description, the hexagonal floating platforms are referred to. However all this is mutatis mutandis applicable to the EcoFlo Vessels as well.

There are three ways to form FEC-units:

1) for rougher seas EcoFlo Vessels can be used without the EcoFlo Platforms, joining them side by side, leaving a channel between every parallel hull, into the form of an EcoFloat (Fig. 5).

2) for medial seas EcoFlo Platforms and Vessels can be combined to form hexagonal EcoFlo Quarters, where the Vessels surround and protect the Platforms in their midst (Fig. 6).

3) for quieter seas EcoFlo Platfoms can be used without the Vessels (Fig. 3).

Moreover, it is well possible to attach additional elements, such as under-sea traffic tunnels, floating traffic pontoons, and normal seaborne traffic, joining the units together and with the coast. However, these are not treated on this paper.

2.2 Caissons

Six 'Duck-foot-shaped' caissons (60x70x6 m) carry one hexagonal platform (Ø 150 m). Several caissons balance the hexagonal platform well against tremors, waves and tsunamis. The caissons contain a storage and reservoir deck.

The caissons carry one Ø 5 m column each, standing on their weight point. The column contains a staircase, elevator and technical channels, all in line with the upper columns supporting the tent right above them. The caisson columns have a plug-in joint with the upper deck. Thus the caissons can be taken out, replaced or docked one by one without affecting the life on the Platform.

'BufferFlexes' between the caissons prevent their collisions and catch their kinetic energy.

The management of water quality can be implemented with aquatic macrophyte farms (Srivastava et al. 2008). In FEC, the Marine farms are located under the 5 m wide pontoons, surrounding the caissons. The back of these farms hides their sides effectively from sunlight, preventing boat bottom fauna or 'biofouling', and the erosion they cause on the caissons.

2.3 Lower Deck

The hexagonal lower deck is Ø 150 m and +1.5 m above the sea level. It hangs from the upper deck. Its free height of 6 m allows 2 floors, including roads, car parks and winter storage of small boats. This deck is surrounded by services and work spaces, the technical apparatus being centered in their plug-in space units in the middle, while traffic lane circulates between them.

2.4 Upper Deck

The upper deck is a 3 m high Ø 150 m structure. It has a Central Park with a receding 360° amphitheatre with pool in the middle, right above the technical spaces of the lower deck.

Upper deck is surrounded by six 6-floor high buildings (see below), as well as 6 tent-supporting columns (20 m). They are set in line with six caisson columns under them. Also these columns contain a staircase, an elevator and channeling.

2.5 Modular Buildings

The homes and commercial properties will be developed according to the Tianjin Eco-City's Green Building Evaluation Standard (Standard, 2006) and Green Mark Gold standard of the Building and Construction Authority of Singapore (Green Mark, 2005). The buildings of FEC are compiled of prefabricated spatial modules. Each apartment, office, storage, purification or energy plant, forms its own plug-in module. There are no structural seams within a module. Their structure is very light but stern, allowing over 40 floor high buildings. However, in order to resist the earthquakes and typhoons only 6 floor high buildings are utilized (ref. patent by Neapo Oy).

The design of the apartments is based on the simple, steel structured prefabricated space units. Each apartment has a high loft and glazed balconies on both sides. These glass-covered areas can be used as conservatories and green houses. All in all, one apartment of 65 m^2 can be 'expanded inwards' by up to 45 m^2 simply by using the capacity hidden into its loft and balconies.

The 'pistol-shaped' section of the apartment modules allows corridors on every 3rd floor (2nd, 5th), saving floor space for the apartments.

Modularity allows effective building production by numerous parallel subcontractors, an exceptional transportability and rapid assembly on site. Weather-sensitive building work takes place under the roof and the execution period on site is cut into minimum. The modules are fitted for transport by ships and wide lorries, world-wide.

The space modules have sanitary services in their middle axis. The 2-floor loft-room in one end is to be used as a living room or customer area. If required, this can be divided into two rooms by an additional floor. More private 1-floor bedrooms, stores and offices are located in the other end of the module. Each module has visibility to the exterior as well as to the Central Park in the middle.

The lower deck has 70 offices, shops, restaurants, and manufactures. They are fed by traffic from inside and used by pedestrians from outside. The FEC is self-sufficient with working places, thus minimizing the need for transportation.

The upper deck has 6 floors of altogether 264 apartments. With 3 inhabitants in each apartment, one hexagon platform would have 800 inhabitants. They need their nursery, school and leisure-spa located by the pool in the Central Park.

Plant-covered walls (Kontoleon & Eumorfopoulou, 2010, p. 1287) and roofs (Eumorfopoulou & Aravantinos 1998) are used for the better thermal performance of the buildings (Papadakis et al. 2001, pp. 831-36).

2.6 Tent

The need for having an 'oxygen tent' rises from the coolness of the snowy winters, sand rains in the springs, very hot summers with monsoon rains, and possible typhoons in the autumns. Moreover, acid rain, ozone and poisonous smog are a continual detriment for soil, plants, animals as well as human beings, and thus to be averted. The tent creates a closed biosphere, allowing a longer growth period and healthier living conditions.

The design of the beautifully curved parabolic tent joins the regional tent roof tradition with modern megatents. The form is based on simple bambu-like straight beams, which form a stern 3D-grill structure. The form of the tent is optional against high winds. Moreover, it refines wind into a laminar form, to be utilised in propelling effective laminar windmills. The mesh structure is supported by a circular main beam, carried further by the six stairwell towers.

The tent can function also like a Middle Eastern wind tower. 'Pipe effect' is used for creating low pressure, utilized for drawing the polluted exterior air in through the air filters. The tent has three layers of cloth, with two air pockets between them. These are used for ventilation, in order to balance the extremes of light, temperature and humidity. The tent also collects condensed water (interior), rainwater and raining sand for further use.

The tip of the tent, above its neck, is reserved for photovoltaic plates.

2.7 Biosphere

The air and rain of Tianjin are polluted. Hence they cannot be allowed in a healthy Eco-environment. In FEC there are two types of biospheres. Firstly the whole platform can be a biosphere, enveloped by the upper deck, surrounding buildings and the mega-tent for occasional environmental threats, or as a constant solution. An interesting detail is how these floating biospheres require domesticated bees for pollination. Secondly an apartment can be transformed into a biosphere, with air, water, energy, heat and biowaste circulation, based on extensive purifying plantations on its glazed balconies.

Over 70% humidity causes rust and mold. The plants result in 35 – 65% healthy or 40 – 60% optimal humidity, preventing the structures and inhabitants from damages. (Wolverton, 1996, p. 9-10)

On the other hand, also humans discharge over 150 bio-excretes, like CO_2, hydrogen, methane, alcohols, phenols, methylindol, aldehyde, ammonia, hydrogen sulfide, fatty acids, indol, mercaptan - and most importantly acetone, ethanol, methanol and ethyl-acetate. Some of the previous are poisonous in high concentrations. Especially in the vacuum-tight Eco-houses these substances can cause severe risks for health. By the extensive use of plants, substances can be substantially eliminated, while the number of mold spores and microbes lessens remarkably in the air, respectively. (Wolverton, 1996, p. 11; Fujii et al. 2005). The use of plants for air purification has received deserved attention also in China (Liu et al. 2007).

Moreover, the plants are themselves a significant emission source for short-chained alcohols, aldehydes and ketones and they are not able to purify everything. The adverse effects of airborne volatile organic compounds (e.g. VOCs; toluene, acetone, xylene, ethylene, formaldehyde, methanol, propylene, etc.) on urban plants are under study, species by species. E.g. beans are known to be especially vulnerable (Cape, 2003, p.145).

One adult requires 0.9 kg oxygen and produces 1.1 kg CO_2 in 24 hours. On the other hand 1.0 kg new plant biomass releases 1.3 kg oxygen and binds 1.6 kg of CO_2. Thus we need 0.6 kg new dry plant mass to fulfill the breathing need of one adult inhabitant a day. (Wolverton, 1996, p. 15).

The interior plants are chosen according to their ability to flourish in shadow, purify the air, water and soil, and produce food, spices, drugs - and taste and beauty.

Exterior vegetation can adjust the urban microclimate and improve the thermal behavior of buildings. Plant-cover provides cooling within the buildings. Plants absorb solar radiation for their growth and biological functions, such as photosynthesis, respiration, transpiration and foliage evaporation (Krushe et al., 1982). In addition, the plant-cover is functioning as a solar barrier due to the reflective properties of plants. The absorption coefficient value for a plant-covered wall is about 1/3 of that for a conventional wall. The peak temperatures and variations are lower while the unwanted heat flow to indoor is reduced. Plant-cover reduces wind effect and is beneficial to the controlling of the humidity within the buildings (Kontoleon & Eumorfopoulou, 2010, p. 1287). 25 cm thick modular trellises ease the plants to colonize building surfaces, producing 'Green Facades' with 'bio-shaders' (Ibid et al. 2010. p. 1289, fig. 4; Ip, et al. 2009, p. 81), à la Botanist Patric Blanc, who has been bringing the wilds of the rainforests to Parisian walls for over 30 years (Blanc, 2010).

2.8 Green Energy Production

The FEC achieves its high energy goals by utilizing a wide range of ordinary green energy sources, such as the heat of wastewater, exhausted air, and biowaste, biogas, wind energy, solar energy, etc. Some more exotic energy sources are utilized as well, like water current energy, tidal energy, kinetic energy taken from between the platforms, and ocean thermal energy. The heat capacity of the sea is multifold when compared with that of the earth.

Tidal currents are formed by the energy dissipated by the tides. Tidal power has good potential to play part in a sustainable future. It is a predictable energy source, depending only on the gravitational pull of the moon and the sun, and the centrifugal forces created by the rotation of the earth–moon system. After the first tidal powerplant at La Rance, France in 1966 the research has concentrated on turbines and the horizontal element of tide (Rourke et al. 2010; Bryden, Grinsted & Melville, 2005). The horizontal force of the sea can be utilized by anchoring and propellers (Charlier, 2003; Finkl & Charlier, 2009). However, in the FEC the vertical axis is central. The 3 m semidiurnal tidal range (Mobile Geographics LLC, 2010) is transformed into electricity (Hartono, 2000). The anchor drillings are used for geothermal energy as well.

The kinetic energy offered by the waves, moving the circulating pier pontoons up and down, as well as the caissons against and apart from each other, can be transformed into electricity (Falcão, 2010). The kinetic energy of the wind can also be utilized by several ways. The anchoring transforms forces into energy. The lateral wind generator, located on the exterior of the tent is more effective than the ordinary mills using turbulent wind. Smaller private wind generators can be located on the exterior balconies of each apartment. Methane is gathered from the biodegradable waste. Dry waste is burned by very efficient floating sand bed technology. The heat transformers take back the heat of the exhaled air and wastewater.

Solar energy is used to move air within the ventilated double surfaces of the buildings, triple windows and the triple-clothed tent, and collected by the solar collectors, not to forget the plants transforming solar energy into biomass.

All in all, the FEC will go beyond zero net energy. It would be one of the world's first large scale positive energy buildings. The FEC utilizes pioneering, never-before-seen green energy technologies in the creation of the aesthetically astounding, functionally proficient environment.

3 Discussion

In a critical analysis, the FEC is expensive, work and material intensive solution, as the 'land to live on' must be produced artificially in the ship yards. However, it is suggested only for such areas where natural land is extremely polluted or costly already, and new visions are searched for.

The emergency scenarios of FEC cover earthquakes, tsunamis, rising sea level, receding coastal soil, high tide floods, river floods, the breakaway of Huang He, and the resulting massive silting, collapsing ground water level, the salination of ground, the high pollution of air, polluted soil, and polluted water. The tent protects also against high typhoon winds, monsoon rain, acid rain, heavy snowing and sand rains. In all these emergency scenarios, the platform is planned to offer protection to its inhabitants.

When it comes to the collisions, the platform quarters are surrounded and protected by large EcoFloVessels. The platforms are also surrounded by a protective belt of pontoons. Moreover, their anchorage is flexible – the platforms can move sideways. . Finally, some of the six caissons can be eliminated by a collision or taken out for maintenance without harming the whole. The fire exhaustion can be powered by the local energy sources, without exterior energy or water sources. Only 6-floor high buildings allow fast evacuation by both land and sea vehicles.

And finally, at the end of the life cycle, all the materials of the FEC can be recycled.

4 Conclusion

The planning of the Floating EcoCity joins the Nordic Green know-how with the Chinese legislation, tradition and practices, while its execution involves the high-end EcoCity building and Ocean Cruiser shipyard industries., in order to create a new flexible and environmentally secure living biosphere. The radical idea offers interesting new planning and execution tasks, and most possibly it seminates numerous new inventions. As it is based on plug-in subunits, its execution can be spread widely from local small to international big industry.

The consistency of a single platform can vary greatly from a heliport to a super secure jail, from a barrack to an autonomous sea purification or energy plant. It can be transformed into a sea-side resort or high-end living quarters, a shopping centre or a marine farm, a research centre of scenic offices or gardens.

The FEC-concept is more ecological than the artificial landfill islands. If the platforms are fit for the raw conditions of Tianjin, they can be well adjusted to other similar over-populated coastal areas of the World, like Nile Delta, Shatt al Arab and Arab Emirates, Indus, Bangladesh, S Burma, Bangkok, Mekong Delta, Haifong, Hongkong, Shanghai, as well as the urbanizations of Singapore and Japan, likewise New Orleans, Florida, N Carolina, New York, London, Holland and St Petersburg.

Acknowledgements

The paper is financed by EU's South Finland ERDF Programme (Rocket project), Architect Office Aaro Söderlund Ltd and Turku University of Applied Sciences. We like to thank Rina Bao, Jussi Hattara and Sirpa Lehti-Koivunen their practical help during writing process of paper. We also like to thank Royal Caribbean International for allowing us to use their figure.

References

Andrianov, A (2005). Hydroelastic Analysis of very large floating structures, 172 p, Doctoral Thesis in Delft University of Technology, The Netherlands.

Bryden, I.G., Grinsted, T. & Melville G.T. (2005). Assessing the potential of a simple tidal channel to deliver useful energy. Applied Ocean Research 26: 198-204.

Cape, J.N. (2003). Effects of airborne volatile organic compounds on plants. Environmental pollution 122: 145-157.

Charlier, R.H. (2003). A "sleeper" awakes: tidal current power. Renewable & Sustainable Energy Reviews 7: 515-529.

Eumorfopoulou E.A. & Aravantinos D. (1998). The contribution of a planted roof to the thermal protection of buildings in Greece. Energy and Buildings 27(1): 29-36.

Falcão, A. F. de O. (2010). Wave energy utilization: A review of the technologies. Renewable and Sustainable Energy Reviews 14: 899-918.

Finkl, C.W. & Charlier, R. (2009). Electrical power generation from ocean currents in the Straits of Florida: Some environmental considerations. Renewable and Sustainable Energy Reviews 13: 2597-2604.

Fujikubo, M. & Yao, T. (2001). Structural modelling for global response analysis of VLFS. Marine Structures 14: 295-310.

Fujii S., Cha H., Kagi N., Miyamura H. & Kim Y-S. (2005). Effects on air pollutant removal by plant absorption and adsorption. Building and Environment 40: 105-112.

Hartono, W. (2000). A floating tied platform for generating energy from ocean current. Renewable Energy 25: 15-20.

Hamamoto, T. (1995). Stochastic fluid-structure interaction of large circular floating islands during wind waves and seaquakes. Probabilistic Engineering Mechanics 10: 209-224.

Ip, K., Lam, M. & Miller, A. (2009). Shading performance of a vertical dedicuous climbing plant canopy. Building and Environment 45: 81-88.

Jun, Q., Rongzi, L., Jingzhu, Z. & Hongbing, D. (2008). Establishing Eco-compensation Mechanism in Bohai Sea Waters under Framework of Ecosystem Appropach. China Population, Resources and Environment 18(2): 60-64.

Keller, G.H. & Prior, D.B (1986) Sediment Dynamics of the Huanghe (Yellow River) Delta and Neighboring Gulf of Bohai, People's Republic of China: Project Overview. Geo-Marine Letters 6:63-66.

Kontoleon, K.J. & Eumorfopoulou, E.A. (2010). The effect of the orientation and proportion of a plant-covered wall layer on the thermal performance of a building zone. Building and Environment 45: 1287-1303.

Krusche P, Krusche M, Althaus D & Gabriel I. (1982). Öekologisches Bauen,Herausgegeben vom Unweltbundesamt. Wiesbaden und Berlin: Bauverlag.

Liu, Y-J., Mu, Y-J., Zhu, Y-G., Ding, H., Arens, N.C. (2007). Which ornamental plant species effectively remove benzene from indoor air? Athmospheric Environment 41: 650-654.

McGranahan, G., Balk, D. & Andersson, B. (2007) The rising tide: assessing the risk of climate change and human settlements in low elevation coastal zones. Environment and Urbanization 19(1): 17-39.

Maps available in: http://sedac.ciesin.columbia.edu/gpw/lecz

Papadakis, G., Tsamis, P. & Kyritsis, S. (2001). An experimental investigation of the effect of shading with plants for solar control of buildings. Energy and Buildings 33:831-836 .

Rourke, F.O., Boyle, F. & Reynolds A. (2010). Tidal energy update 2009. Applied Energy 87: 398-409 .

Shujuan, C. (2009). China: Green Building Opportunity. World Watch Institute, US Commercial Service .

Srivastava, J., Gupta, A. & Chandra, H. (2008). Managing water quality with aquatic macrophytes. Rev Environ Sci Biotechnol 7: 255-266.

Suzuki, H. (2005). Overview of Megafloat: Concept, design criteria, analysis, and design. Marine Structures 18: 111-132.

Talavera, A.L., Masaoka, K., Tsubogo, T., Okada, H. & Murotsu, Y. (2001) A study on reliability-based design systems of very large floating structures under extreme wave loads. Marine Structures 14: 259-272.

Tao, J-H. (2006). Numerical simulation of aquatic Eco-environment of Bohai bay. Journal of Hydrodynamics, Ser B,18.3.1: 34-42.

Watanabe E., Wang C.M., Utsunomiya T. & Moan T. (2004). Very Large Floating Structures: Applications, Analysis and Design. CORE Report 2004-02, Singapore, 30p.

Wei, Z. & Yuan, D. (2009). The initial construction of the right to use the waters of Tianjin mortgage loan system. Taiwan Network, Tianjin, December 4 (Xinhuanet).

Wolverton, B.C. (1996). Eco-Friendly House Plants, New York.

Electronic references

Blanc, P. (2010). Vertical Garden –Web Page:

http://www.verticalgardenpatrickblanc.com/mainen.php

Green Mark Standard, Singapore Government, Building and Construction Authority BCA (2005):

http://www.bca.gov.sg/GreenMark/green_mark_buildings.html

Mobile Geographics LLC (2010) –website:

http://www.mobilegeographics.com:81/locations/6455.html

Smith, A. & Gill, G. (2010). Masdar Headquarters, Abu Dhabi - website: http://www.smithgill.com/#/work/by_name/masdar_headquarters

Standard by People's Republic of China (2006) - Evaluation Standard for Green Buildings GB/T 50378-2006. http://docs.google.com/Doc?id=ddfqxmx9_29hs74dhgv

Participants

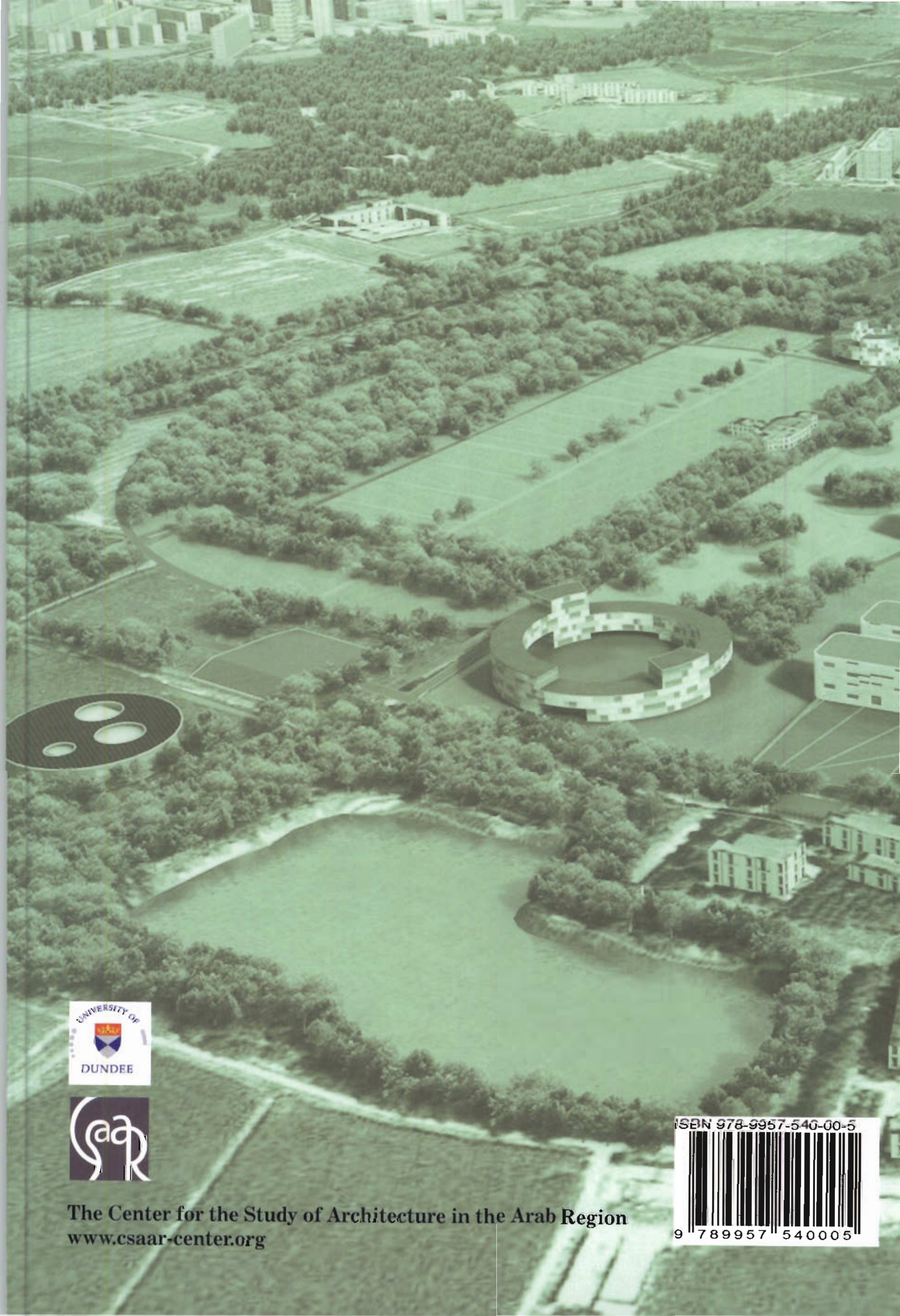
Scientific Committee Co-Chairs

Steffen Lehmann, University of Newcastle, Australia
Husam Al Waer, The University of Dundee, UK
Jamal Al-Qawasmi, CSAAR, Jordan

International Scientific Committee

Abas Elmualim, University of Reading, UK
Ahmed Yehia Rashed, The British University in Egypt, Egypt
Aikaterini Tsikaloudaki, Aristotle University of Thessaloniki, Greece
Akkelies van Nes, TU Delft, The NetherlandsK
Amar Bennadji, Robert Gordon University, UK
Amira Elnokaly, University of Lincoln, UK
Amira Osman, CSIR, South Africa
Amjad Al-musaed, Archcrea institute, Denmark
Ammar Kaka, Heriot-Watt University, UAE
Antony Radford, University of Adelaide, Australia
Arjan van Timmeren, Heriot-Watt University, UAE
Assem Al-Hajj, TU-Delft, The Netherlands
Aylin Orbasli, Oxford Brooks University, UK
Ayman Othman, The British University in Egypt, Egypt
Behzad Sodagar, University of Lincoln, UK
Blaine Brownell, University of Minnesota USA
Ceridwen Owen, University of Tasmania, Australia
Chrisna Du Plessis, CSIR, South Africa
Dalila ElKerdany, Cairo University, Egypt
Deepak Gopinath, University of Dundee, UK
Derek Clements-Croome, The University of Reading, UK
Dirk Donath, Bauhaus-Universität Weimar, Germany
Doris Kowaltowski, UNICAMP, Brazil
Ettore Maria Mazzola, The University of Notre Dame, Italy
Firas Sharaf, The University of Jordan, Jordan
Fodil Fadli, University of Liverpool, UK
Francisco Serdoura, FAUTL, Portugal

Author Index



The Center for the Study of Architecture in the Arab Region
www.csaar-center.org

ISBN 978-9957-540-00-5