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W116 - SMART AND SUSTAINABLE BUILT ENVIRONMENTS

PAPERS AND POSTGRADUATE PAPERS FROM THE SPECIAL TRACK

CIB W116 has a mission to promote the best practices of integrated development of smart and sustainable built environment with knowledge transfer and benefits to all stakeholders. It focuses on the integrated approaches to developing intelligent systems, methods, and practices for sustainable products and outcomes of the built environments. Its objectives are to encourage global networking, foster awareness and promote understanding of smart technologies and sustainability issues in built environment, to identify, collect, create, discuss, evaluate and disseminate information and knowledge on strategies and best practices for developing smart and sustainable buildings and infrastructure, to analyse, develop and apply appropriate knowledge and transfer this to stakeholders and to promote and facilitate international collaborative research, consultancy and professional education in this field.

W115 - CONSTRUCTION MATERIALS STEWARDSHIP

PAPER AND POSTGRADUATE PAPER FROM THE SPECIAL TRACK

This Commission aims to: drastically reduce the deployment and consumption of new non-renewable construction materials, to replace non-renewable materials with renewable ones whenever possible, to achieve equilibrium in the demand and supply of renewable materials and ultimately to restore the renewable resource base and to carry out these tasks in ways to maximize positive financial, social and environmental and ecological sustainability effects, impacts and outcomes. Commission subgroups have been established with a focus on the following topics/objectives and with the indicated leader/information contact per subgroup: to develop systems to mitigate and ultimately avoid construction materials waste, to develop ways of using material wastes as raw material for making construction materials, to develop methodologies for designing for closed loop materials use and for the effective recovery of materials and components from exisiting buildings and to develop design and construction methodologies for transformable and adaptable buildings and spaces to extend service life and so reduce overall construction material resource use.

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Sustainable Construction Strategies – Case study in Architecture Project Conception

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Abstract

This paper proposes a study of project strategies for sustainable construction. A case study was made about an architectural project under development, in order to implement already at project conception, sustainable practices and thus contribute in fact for architectural result and better environmental performance of the set. However, were found difficulties in reconciling issue aesthetics and technology, but in the end, project has achieved a good compliance level, considering aspects such as maintenance and building infrastructure.

Keywords: sustainable construction, project strategies, sustainability

1. Methodology

This paper proposes an architectural project that utilizes technology and building systems for low environmental impact; efficient use on energy, water and natural resources; and that fosters comfort to users. The methodology constitutes a case study because it investigates a contemporary phenomenon within a context that approximates to reality. This work is structured based on: literature review about sustainability and construction; presenting programs for energy efficiency in Brazil; studying technologies and building systems and their applicability; architectural project development; and final result analysis.

2. Sustainability and civil construction

The sustainable development concept resulted from concerns' evolution arising in the 70's with energy crisis. This term was defined in 1987 at Our Common Future Report of The Brundtland Commission as a development that meets present needs without compromising future generations' ability to meet their own needs. Sustainable development does not exhaust resources for the future. This concept applied in civil construction gives rise to terms such as sustainable construction, eco-efficiency and sustainable architecture.

Sustainable buildings must include efficient natural resources use at the same time it provides comfort to users. Some features are desired in such projects, like: energy efficiency; hygrothermal, light, visual and acoustic comfort; concerns about surrounding environment and existing buildings renovation; use flexibility; low environmental impact materials; energy consumption control systems; renewable energy; water reuse; and low maintenance.

From the 1990's, many countries have developed mechanisms for assessing environmental buildings performance through a voluntary certification process, but emphasizing aspects which represent the most challenging environmental conditions. Nowadays, each European country, besides United States, Canada, Australia, Japan and Hong Kong, has a building assessment certification system. Most of them are based on performance indicators which assign a technical score according to service level requirements for building, climate and environment, focusing on building inside, its surrounding and its relation with the city. However, according to Silva (2003), the main international assessment systems focus exclusively on sustainability environmental dimension. In Brazil's case it must go from environmental assessment to buildings sustainability assessment and also address social and economic aspects related to production, operation and change on built environment. However, concepts about building environmental performance are not disseminated throughout Brazilian society. Although some specific sectors are mobilized to this end, the demand for environmental certification properties is now relate to specific kind of consumers, especially high standard and commercial buildings. Despite Brazil presents several initiatives on regulations and laws about this subject, the country is at the beginning of pursuit for better building environmental performance.

Nowadays, it is evident how important it is to include sustainable measures in new buildings and make adjustments on existing ones. When sustainable alternatives are thought since project conception, it is expected that building performance be better than traditional ones, bringing benefits to users and reducing environmental impacts.

3. Energy efficiency programs in Brazil

3.1 ABNT NBR 15220:1998 Part 3

The NBR 15220:1998 is a set of rules on Thermal Buildings Performance made by the ABNT - *Associação Brasileira de Normas Técnicas* (Brazilian Association of Technical Standards). This paper discusses part three of the standard, which study provides a Brazilian Bioclimatic Zoning (Figure 1) presents an applicable methodology on project phase and brings constructive recommendations and strategies for passive thermal conditioning (Associação Brasileira de Normas Técnicas (ABNT) 1998). One of the goals of NBR 15220:1998 Part 3 is to provide a satisfactory building comfort standard to low income population and for this, settle project minimum requirements. These requirements are the same as those to obtain comfort in other residential constructions located on zones established by the standard.

The Brazilian Bioclimatic Zoning divides the territory in eight areas relatively homogeneous on climate. For each area, the ABNT proposes constructive recommendations that optimize thermal buildings performance, according to climate adaptation.

According to the standard, the thermal performance evaluation can be held either in project phase, through computer simulations or construction guidelines compliance verification, as after building construction, through measurements on site of variables representing performance. However, the standard does not present procedures for evaluating thermal buildings performance, but announce its further development.

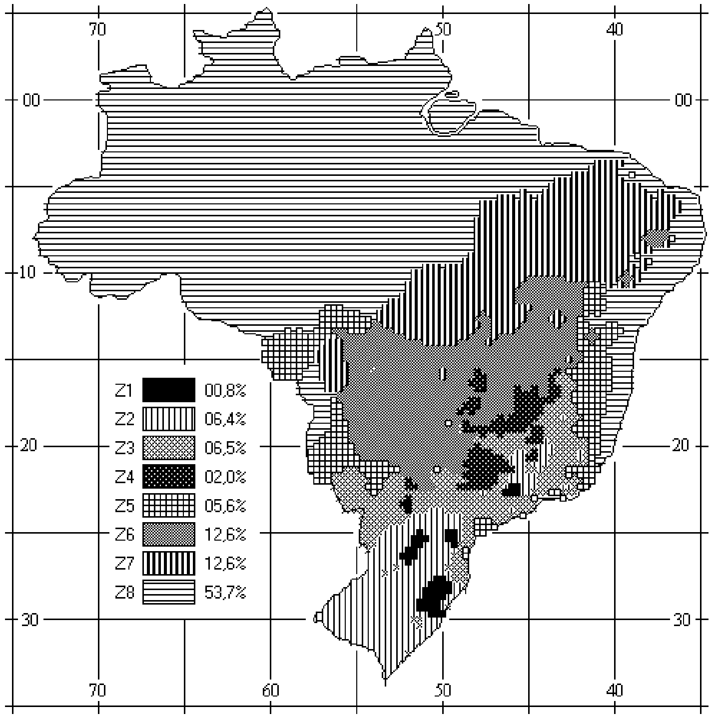

Figure 1: Brazilian Bioclimatic Zoning (Associação Brasileira de Normas Técnicas (ABNT) 1998)

3.2 PROCEL EDIFICA

The PROCEL – *Programa Nacional de Conservação de Energia Elétrica* (National Program for Electricity Conservation) – is a Brazilian government program, whose mission is to promote energy efficiency, helping to improve life quality and efficiency on goods and services, reducing environmental impacts. It covers different power consumption segments with specific programs, such as PROCEL EDIFICA – *Eficiência Energética em Edificações* (Energy Efficiency in Buildings) – approached in this paper. PROCEL EDIFICA proposes labeling energy efficiency level in commercial and public buildings. Next step, scheduled to become operate in 2010, will classify residential buildings through regulation of Law. 10.291/01.

This program exists since 2003, but its operation was limited to promote and disseminate energy efficient practices and develop new technologies. The regulation is still voluntary and will be compulsory by 2012, when the initiative will evolve from label (consumption analysis) to seal (quality certificate). During this period the system will be tested and the market will be able to adjust to changes.

The labeling program will be governed by a regulation which allows to classify efficiency level (A to E, with the letter A more efficient) to buildings with total useful area of at least 500 m² and/or supply voltage exceeds 2.3 kV, and includes additional incentives for adoption of systems such as water rational use, solar heating, renewable energy, cogeneration and innovations that promote energy efficiency. Although it was developed for new buildings classification, it can also be used in existing ones.

The label will have three main requirements: efficiency and installed power lighting system; air conditioning efficiency; and building envelope thermal performance (coverage, windows, doorways and openings analysis). Each one of these elements is certified separately, by pre-set calculations and parameters or computer simulations that assess built environment behavior related to environmental comfort parameters – temperature, humidity, lighting and acoustics. This program intends to compare the building project presented with an efficient version. The certification process occurs in construction phase and after enterprise delivery.

3.3 Legislation

About legal issues, the country focuses its attention on reducing costs, especially on electricity energy, and on rational energy resources use for environment preservation. Energy efficiency in buildings is an ongoing discussion point, but treated as future plan performance, as it is a relatively new topic in Brazilian experience.

The main energy efficiency legislation is the Federal Law. 10.291 from 17/10/2001, which provides maximum specific consumption energy levels or minimum energy efficiency levels for machines and appliances marketed in the country. It also provides mechanisms development to promote energy efficiency in constructions built in Brazil (República Federativa do Brasil, 2001).

4. Strategies for sustainable construction

4.1 Architectural recommendations from Mahoney's Tables

Mahoney's Tables are a simple method for analyzing climate that has been used for nearly 30 years in many countries as an important project aid tool. Based on climatological data from the city used as reference for the project, Mahoney's Tables were filled and then the architectural recommendations were generated, as described below. In order to reduce sun exposure, it is recommended that buildings should be oriented along the east-west axis. To support wind permeation it is important to keep large spacing between buildings, but with proper protection from hot or cold wind. Windows should have a simple orientation, should have dimensions from 25% to 40% of walls surface; allow permanently air circulation; be protected from direct sunlight and rain and be positioned in north and south walls, at human body height, on side exposed to wind. Roof should be lightweight and well insulated and both walls and floors should have thermal transmission time greater than 8 hours, indicating a massive construction. Outdoor areas must have appropriate rain drainage and protection from violent rains.

4.2 Guidelines constructive from NBR 15220:1998, Part 3

As quoted in this paper, the NBR 15220:1998 Part 3 proposes constructive guidelines according to the city used as reference for the project. The passive conditioning strategies are: cross-ventilation in summer and solar heating and use of heavy internal walls (thermal inertia) in winter.

On the subject of ventilation and shading, openings shall be sized according to the floor area in a 15% to 25% ratio, and also shall contain provisions which allow shading flexibility in order to provide comfort conditions during winter.

4.3 Outdoor environment quality

Caution about surrounding environment and building impact upon the city are factors worth considering. Concentration of tall buildings is common in urban areas, due to high population density. This factor not only represents a drawback for urban life quality, but it is also accountable for blocking light and ventilation. A blend of tall and short buildings maximizes natural light and wind. The creation of free spaces, opposed to maximum land occupancy, is a strategy that provides public spaces in the city and grants a relief to urban chaos.

Constructions must be projected in a way as to contribute to a larger diversity of uses, to the socialization of public space, urban infrastructure efficiency and built environment quality (Duarte & Gonçalves, 2006). Improvements to enterprise's neighborhood are also important, such as street and urban equipments rehabilitation and forestation.

4.4 Indoor environment quality

Indoor environmental quality is directly linked to the issue of energy efficiency, which in turn is linked to users' environmental comfort and building location issue, setting favorable conditions to natural lighting and ventilation use. Through the use of techniques and specific materials it is possible to achieve low energy consumption. In order to obtain good results, studies must be made about solar orientation, prevailing wind direction, space use, type of opening and available materials.

To optimize natural ventilation, Corbella & Yannas (2003) suggest dissipating heat from building interior and removing excess moisture by way of: promoting higher ventilation levels when outdoor temperature is lower than indoor's; combining night ventilation with thermal inertia; transferring heat to areas with lower temperatures than inhabited ones, such as deposits and basements; and promoting air movement and renewal at periods when people are present.

There are high thermal levels in a building resulting from: solar radiation; occupation; lighting and equipment. That happens because internal temperatures tend to be higher than projected ones and air conditioning sometimes cannot be waived. However, the adoption of mechanical systems must have secondary importance in building project and environmental comfort should be achieved initially through passive cooling strategies.

Indoor building comfort depends on heat gain control, which can be done through: thermal insulation in areas heavily affected by the sun (walls or ceiling); internal and external solar protections (curtains, blinds and *brise-soleils*); and balconies projected to shade indoor areas and to standardize natural light distribution. Also, walls can be painted in clear colors to reduce solar heat absorption by surfaces.

Natural light is very important to human being and has great impact on physical welfare and mental health. Besides its health benefits, it gives a psychological time sense – chronological and climatic. Therefore, it is important to pursue harmonic integration of natural and artificial lighting in environments through devices such as occupancy sensors, photoelectric control systems and time programming systems.

In architecture the lighting goal is to create a visual environment more suited to planned activities. Thus, there is no need to provide high lighting level for any environment, whenever you can focus it on visual tasks. Therefore, a good part of the indoor area can have its illumination level reduced, also reducing power consumption (Dutra *et al*, 1997).

4.5 Energy production and water treatment

Renewable energy is an alternative for energy production. Since it uses non exhaustible sources, it can be used with success in buildings. Solar energy can produce thermal and electrical energy in building through solar collectors and photovoltaic cells, respectively.

Reused rainwater and wastewater systems are important to reduce potable water consumption, and are increasingly being used in construction. Thanks to available technologies, such water, when properly treated, can be fully reused in a non-drinking form, or even as drinking water, for different uses.

4.6 Materials and constructive systems

Sustainable construction aims to rationalize traditional materials use and to avoid adoption of products whose production and use result in environmental problems and are suspected to affect human health. Therefore, it is recommended to use materials which: are compatible with environmental deployment area; have extended useful life; are climatic factors resistant; demand low energy on production, use, transportation and maintenance; contribute to saving energy and building comfort; and are non-toxic, standardized, renewable and recyclable, or whose residues can be reused.

5. Case study

5.1 Sustainable strategies application on the project

The project was created to reduce environmental impacts, while providing user comfort. Outdoor and indoor environment qualities have been taken into consideration, as well as energy production, low impacts materials, and water reuse. The construction was here addressed as a global product, and its components life cycle were not evaluated, which would be subject of a deeper analysis. In this way, the project includes some strategies for sustainable construction, as described below.

This architectural project is composed of two towers, one residential and one commercial, whose access is given by a common tower for vertical circulation, connected to them by walkways (Figure 2 and Figure 3).

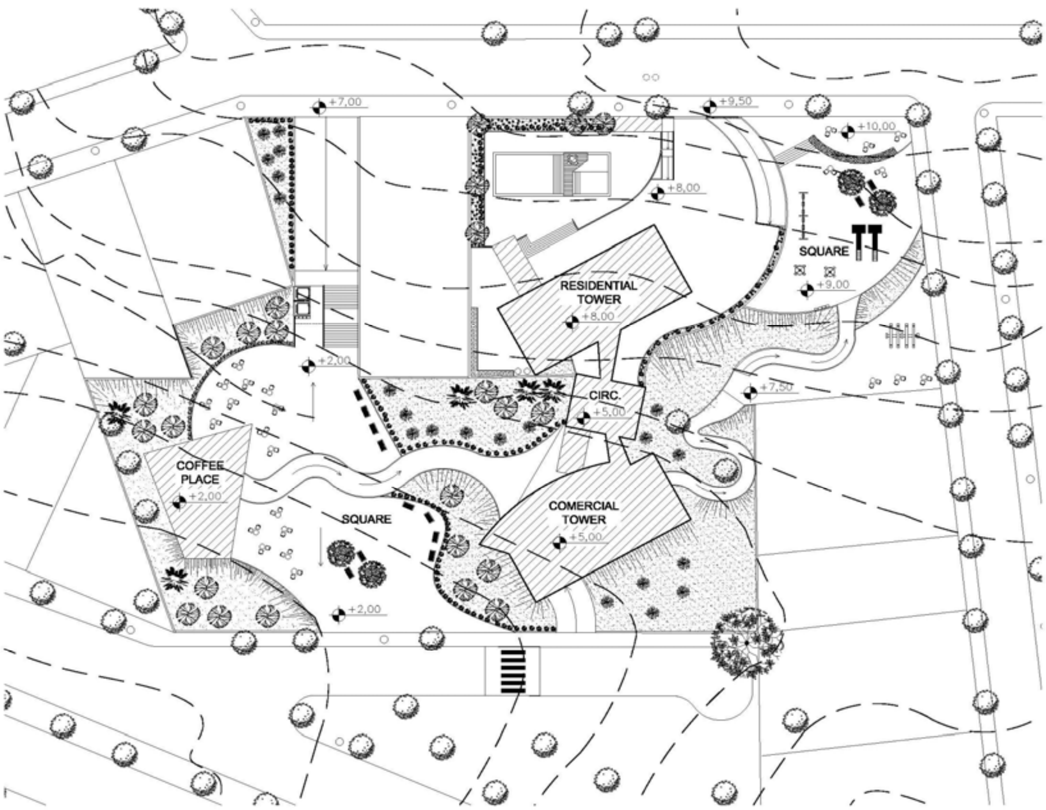

Figure 2: Building plan.

The commercial tower has 14 open floors for offices that can include one to five rooms each, which allows the acquisition by different size companies. The concentration of water installations and the structure – with steel pillars and beams and concrete slab – were both developed to release space on the floor and allow flexibility to user.

The residential tower has the same structure as the commercial (concrete and steel), with 16 floors of apartments, two per floor. The indoor apartment layout is created according to the solar orientation aiming greater environmental comfort. Wet areas, mostly, are facing north and west, to receive more sunlight during the day, which facilitates clothes drying and prevents high heat load from reaching intimate and social areas. Rooms and bedrooms are oriented to east and south, in order to provide greater comfort to users.

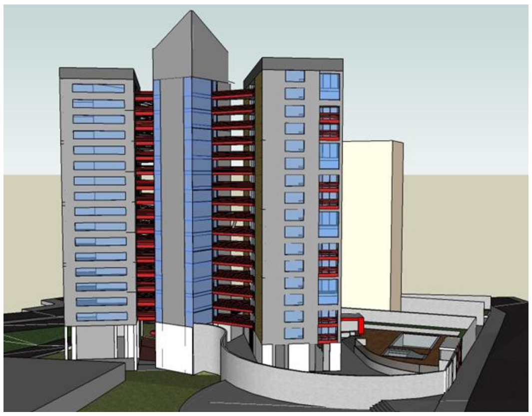

Figure 3a: South view.

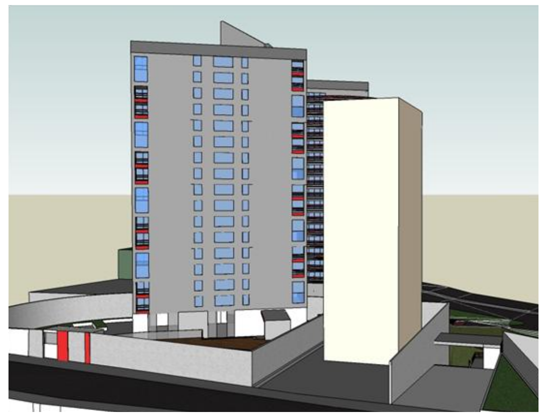

Figure 3b: East view.

Figure 3c: West view.

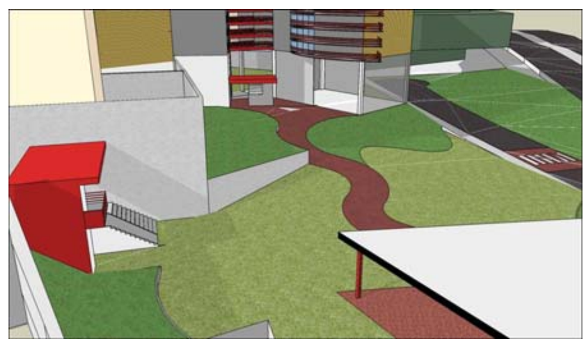

Figure 3d: North view.

Figure 3: Buildings' views

In order to improve urban surrounding environment quality, the project has a square which encompasses almost all land. The access to the towers and the connection with surrounding streets are made through this square. Also in the square, there is a coffee place, which attends the community, allows use at night, prevents public spaces degradation and gives security to neighborhood.

On the commercial building's first floor there is an art gallery as a multiuse space. It intends to integrate those spaces, in a public and permeable place. All over the field, there are gardens, linking indoor and outdoor areas. The large permeable area facilitates rain drainage, as recommended in

Mahoney's tables. This factor is even more important due to a slope of 10m from one street to the other. So, it does not overload the public system in heavy rain situations.

The project proposes fruit trees in square vegetation to attract birds and improve local fauna. The use of native species is recommended, as they require less irrigation, because they are already adapted to local rainfall and sunlight. The large green area helps to maintain temperature pleasant, reducing heat islands, extending leisure and rainwater drainage areas. Besides that, the trees make shadow, reducing people exposure to solar radiation for an extended period of time, avoiding visual and thermal discomfort.

There is space between buildings to allow wind permeation. Cross ventilation is possible thanks to openings located in opposite facades and a duct, inside residential tower, works as a chimney effect for ventilation, drawing foul air from apartments and ventilating circulation area in walkways.

For deployment solution, factors such as solar orientation, prevailing winds direction and space between buildings were decisive. After architectural recommendations' review from NBR 15220:1998 Part 3 and Mahoney's tables, it was concluded that building orientation according to long axis east-west would be recommended to reduce sun exposure. However, this approach hampers indoor's efficient ventilation, because in project reference city the prevailing winds direction is east. If the building had its major axis parallel to predominant direction, it would not be possible to renew air by ventilation. Thus, it was decided to place building in order to take advantage of natural ventilation, while excessive sunlight issues were resolved with solar protections as *brise-soleil*. So, it is possible to obtain a good level of lighting and ventilation, reducing dependence on artificial systems.

The conditioning system provided in this project allows good control and power saving, since the control system is independent for each room, allowing natural ventilation use and option for mechanical system when the first one is insufficient. In the residential tower, natural ventilation will be enough to resolve environmental comfort issue. Pivoting frames are installed on East and South facades (where wind pressure is positive) with panels open in parallel direction to the wind in order to direct flow into the building and promote its permeation. Within spaces the vertical ventilation takes place through openings at different levels, one at human body height and another close to ceiling, removing hot air from environments.

The heating of the building, as a whole, is prevented through wooden mobile *brise-soleils*, horizontal in north orientation and vertical in west orientation. East and south facades have walls made of precast concrete panel and windows on glass frames. This panel presents good thermal performance, ensures flexibility in implementation and produces little waste, due to their industrialization. Besides that, it does not require coating and facade maintenance, with good resistance to degradation by pollution – an important factor to consider on projects made for central areas, where there is a heavy traffic of cars and buses. The east facade on the office tower also has balconies linked to access walkways, which promote shadow to indoor, and create living space for users.

The project has natural and artificial light integrated through photoelectric sensors connected to lighting fixtures. Besides, presence sensors trigger lights along circulation areas.

The office tower dimensions can accommodate layout, while enabling efficiency of natural lighting and ventilation. The workstations are well lit, even when located in inner rooms, where they are 4.8m from openings. As offices operate generally during the day, it is possible to save significant energy for lighting.

The buildings have photovoltaic cells to produce electric power and a boiler system to generate thermal energy to showers. Electricity is generated from solar energy by photovoltaic cells located to the north in 418m² of roof in the towers. The water heating for showers is produced by burning organic waste in the boiler located at the underground park. This system is associated with garbage collecting, since organic waste is burned to produce thermal energy. After being separated by users, the garbage is placed in rooms located on all floors from circulation tower.

Materials and construction techniques were chosen to reduce environmental impacts and to provide health quality. Beams and pillars are metallic due to: recyclable potential at the end of its useful life, speed on execution and less wastage on production. Slabs are in reinforced concrete, due to the ability to overcome distance in project at competitive cost. External walls are coated with precast concrete cell panels for good thermal and acoustic behavior, lightness, flexibility in assembly and low waste. Internal walls are made of ecological brick masonry. Walkways, window frames and covering on the balconies have recycled low-power embedded aluminum railings. For finishing, paints made with green natural oil free raw materials, with no smell and no volatile organic compounds emission, which are aggressive to living organisms' health and the ozone layer. The liner ceiling used in commercial building is metallic and movable to facilitate layout changes and maintenance activities without need to break and reconstruct any part of it.

For water conservation, residential and commercial towers were equipped with water saving devices such as basins with usage control, taps and urinals with sensor and installed meters per apartment and per office floor so that its users know how much they are consuming and paying accordingly. The hydraulic installation and sanitary sewer are enclosed by shafts, in order to facilitate maintenance.

At the basement level there is a rainwater cistern able to partially meet the demand, for commercial supply on tower basins and for residential supply on showers, restrooms, service areas and swimming pools. Furthermore, the water from showers and sinks is treated and directed to urinal supply. To this end, there is a Sewage Treatment Plant located in building underground, where treatment is performed. This measure, while reducing drinking water consumption for non-drinking water, also contributes to sewage discharge reduction in public collect.

6. Conclusion

A good architectural project must introduce sustainability issues since its conception. However, project creation for sustainable construction has proven to be a challenge for designers as it demands more investigation and dedication in project first stages. Moreover, in Brazil the cost related to materials with less environmental impact and technology, still regarded as alternatives, is an obstacle. Even though the cost is compensated during building lifetime, often the constructor does not analyze this matter, and opts for construction conventional method, in which practices and project choices are repeated.

There is a lack in the literature about sustainability concepts application in housing policies, mainly studies that go beyond a vision focused in product or process. Today, Brazil has a shortage of 6 million new houses, and is aware of natural resource scarcity and degradation caused by civil construction, which indicates the need of housing eco-efficient projects for all social classes. There is, however, certain neglect for planning and designing low-income houses, and a lack of studies for better use of environmental conditions and consequent comfort to its users, due mainly to cost reducing concerns. In this context, the research for strategies in pursuit of sustainable construction focused to these dwellings is necessary.

Some difficulties were found in the architectural project discussed in this work. Conciliating the technology and aesthetic performance was a challenge. The formal resolution issues of architectural typology in face of solar orientation and prevailing winds demanded studies and reconsiderations about the project goals. In this case, strategies for environmental performance were preferred.

The adoption of strategies for sustainable construction may be considered successful. There was good project coordination and questions of maintenance and infrastructure were resolved. At times, however, choosing among different technologies was required, for instance, in the option of coverage for solar energy capitation instead of a green roof.

The low environmental impact project adds to building program some factors that hinder the word of the architect and his team. This can be crucial to the withdrawal of project creations of this type. However, once the project is created, it serves as a basis for the next one, increasing knowledge and facilitating resolution of problems. At the end of this work, it was possible to manage good knowledge about technologies and sustainable materials that can serve as a basis for future works, both academic and professional.

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Climate Change Related Environmental Risks to Construction Projects: An ASEAN Perspective

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Abstract

Environmental considerations play a significant role when planning and implementing national and regional policies to ensure that the use of natural resources for development is done equitably and sustainably. With the ever increasing focus at all levels of policy and planning on climate change mitigation and adaptation, construction sector has been identified as one of the key industries that should be pro-active in engaging in sustainable development. It is therefore not surprising that those involved in construction projects now have to overcome not only strict regulatory regimes, but also public opposition and scrutiny. This paper examines some of the key climate change related environment risks that could threaten the progress of the construction industry in ASEAN countries and the relevant national and regional responses required to mitigate such risks. This paper argues that environmental law and policy are essential tools for the governance and management of the environment and natural resources and to promote sustainable development within the construction industry. However, due to the level of integration in the construction sector in the ASEAN region and certain environmental risks faced by the entire region due to its geographical location, in addition to providing an effective legal and policy frameworks at the national level, measures will have to be taken to harmonize laws, policies, and the relevant industry practices to mitigate such risks.

Keywords: environmental risks, construction industry, ASEAN, sustainable development, climate change

1. Introduction

Risks are unavoidable in almost every construction project. Thus, managing risks is considered compulsory for project success. However, even the most proficient managers would find it difficult to avoid and or mitigate all risks associated with construction projects. Despite the various methods such as, decision milestones to anticipate outcomes, risk management to prevent disasters and sequential iteration to ensure goods and services delivery by those responsible, construction projects may still end up with cost overruns, delays, and at times, with compromised specifications (De Meyer et al., 2000).

Environmental risks to construction projects are particularly challenging because some of them are low-probability events that can produce severe consequences. For example, natural hazards such as earthquakes, hurricanes, floods and landslides could cause massive destruction. It should be noted that, although some authors (for example, Mimura et al., 1998) note that disaster rehabilitation and countermeasures against natural calamities could expand the market for the construction industry and thus environmental risks could potentially contribute to the growth of the construction industry, the flip side is that sea level rise, flooding and other extreme climate related events could damage existing buildings and infrastructure costing countries billions of dollars to replace the damage. This would require diversion of precious funds earmarked for other development activities. In addition, some of the damages to the existing living environments could be irreplaceable. The Tsunami that struck Asia in December 2004, killing approximately 230,000 people and inundating coastal communities is a good example (Pearce, 2005).

Due to its geographic location, ASEAN region has been identified as one of the most vulnerable areas to environmental risks associated with climate change. This is because millions of people in this region rely on the great rivers such as the Mekong, Irrawaddy, Red River, and Salween, which flow from the Himalayas. The rapidly melting Himalayan glaciers could cause these rivers to floods, followed probably by seasonal drought (SDC, 2008). Further, the rising sea levels and the consequent flooding from the sea may also adversely affect the coastal areas in this region (IPCC, 2007). In the circumstances, it is important that the countries in the ASEAN region identify the climate change related environmental risks to the construction industry and take both national level, and regional level initiatives to mitigate such risks.

The following sections of this paper are organized as follows: section 2 deals with the regional integration in ASEAN and the status of the construction industry in the region. Section 3 deals with the key environmental risks that threaten the progress of the construction industry in the region. Section 4 deals with the necessary mitigation measures for such risks. Section 5 deals with the current national and regional initiatives for dealing with climate change related environmental risks and the scope for further initiatives. Section 6 concludes and makes recommendations.

2. Construction industry in the ASEAN region

2.1 Regional integration in ASEAN

South East Asia is a region that has come a long way since its regional association; the Association of South East Asian Nations (ASEAN) was established on 8 August 1967 in Bangkok by the five original Member Countries, namely, Indonesia, Malaysia, Philippines, Singapore, and Thailand. Today, ASEAN consist of 10 Member Countries, Brunei Darussalam, Vietnam, Lao PDR, Myanmar, and Cambodia being the new additions between 1984 and 1999. Since its creation, ASEAN has evolved from a more security oriented organization towards an ASEAN Free Trade Area (AFTA), which was agreed upon on 28 January 1992 in Singapore (Chan and Gunawansa, 2008).

Since the articulation of the ASEAN Vision 2020 in 1997, and the adoption of the Hanoi Plan of Action (HPA) in 1998, as a first step in an intended series of “road maps” charting the region’s journey to ASEAN Vision 2020, ASEAN has focused on a systematic process of development through cooperation planning, programme implementation and adopting region wide standards. The signing of the ASEAN Economic Community Blueprint (AECB) on 20 November 2007 indicates the region’s desire to transforming ASEAN into a single market and production base.

2.2 Construction industry in the ASEAN region

As far as the construction industry in the region is concerned, except for the ripple effect of the current global economic recession, it could be said that the ASEAN region has been experiencing a construction boom during the last decade, having gone through a lean period during the 1997 Asian financial crisis followed by the terrorism threat in the region and the SARS outbreak. The decline of trade restrictions and the harmonization of standards, among other things, have facilitated the free movement of construction-related goods, services, knowledge, investments, experts and workers between member countries. As a result, construction is taking place in all sectors of the economy. Projects range from domestic housing and office towers through to sophisticated petrochemical plants, power stations, dams, pipelines, road and rail projects, and even the development of eco-cities (Chan and Gunawansa, 2008). The AECB shows scope for further development of regional infrastructure and technical cooperation.

According to the Singapore government, the construction experts of BIS Shrapnel have claimed that, of the countries in ASEAN, the boom market will benefit mostly countries such as Singapore and Vietnam, due to the rising activity in each of their domestic residential building sectors (EOS, 2007). The rising property prices in Singapore serve as a proxy of investors’ confidence in the business conditions in Singapore. As for Vietnam, its economy has been growing at an average of eight percent a year over the past decade, which is one of the fastest rates in Asia. Accompanying its robust growth is the expanded needs for infrastructure development and new construction projects. For example, Vietnam is currently building about six deep-sea ports in joint ventures with leading port and shipping companies. It also plans to construct an international airport for 5 million tonnes of cargo and 80 million passengers (EOS, 2007).

Despite its economic and trade development, as mentioned above, due to geographic location, some member countries of the ASEAN are among the most vulnerable in the world to natural disasters and environmental risks associated with climate change. Thus, despite the growth in the construction sector, there are key concerns relating to the stability and sustainability of the construction industry in ASEAN countries that needs consideration. If the current growth in the construction sector in the region is to be sustained, initiatives are needed to identify and mitigate the environmental risks.

3. Climate change related environmental risks and the construction industry in ASEAN

3.1 Mitigation related risks

Now there is overwhelming scientific consensus that since pre-industrial times increasing emissions of greenhouse gases (GHG) have led to a marked increase in atmospheric GHG concentrations causing global warming (IPCC, 2007). Of the industries that are responsible for GHG emissions, the construction industry is said to be one of the main. According to the American Institute of Architects (AIA, 2000), the biggest source of emissions and energy consumption both in the U.S. and around the globe is the construction industry. According to a briefing note prepared for the International Investors Group on Climate Change (Kruse, 2004), the cement sector alone is said to account for 5% of global man-made CO2 emissions. Further, mining and manufacturing of raw materials used in construction and the transportation of heavy building materials contribute significantly to climate change.

To give an example from South East Asia, in heavily urbanized Singapore, where half the total land area is built up, the buildings sector is said to account for approximately 16% of national emissions of carbon dioxide (MEWR, 2008). This figure however includes emissions resulting from primary and secondary energy consumption by buildings and excludes the emissions from the industrial process involved in the construction industry. Hence the total of direct and indirect emissions resulting from the construction industry itself could be much higher.

According to a list prepared by the World Resources Institute (2009) showing GHG emissions per capita of 185 countries, four of the ASEAN members are ranked among the top 50. Indonesia is the highest ranked at 16th, followed by Thailand (25th), Malaysia (35th) and Philippines (38th). Singapore is ranked 79th.

In the circumstances, it is important that the ASEAN members take initiatives to mitigate their GHG emissions, although they are currently not in the list of Annex 1 countries that have to meet emission reduction targets under the *Kyoto Protocol*[1] during the commitment period of 2008 to 2012 (Article 3). This is because, irrespective of the lack of current obligations to reduce GHG emissions, these countries have a moral responsibility to contribute to the global efforts to deal with climate change mitigation. Further, one of the key criticisms against the Kyoto Protocol is that it is flawed as imposes obligations of GHG reductions only on a handful of developed countries. Thus, once the Kyoto Protocol ends in 2012, any post Kyoto mechanism the UNFCC members might agree on might have mandatory emission reduction targets for non Annex 1 Countries.

However, the initiatives that may be taken by governments to mitigate the emission of GHGs from the construction industry might have direct or indirect impact on construction activities. For example, the legislative and policy instruments may influence new building designs, technologies and construction standards, and drive up the cost of construction.

The International Investors Group on Climate Change (IIGCC) has identified the key impacts of climate change on construction. According to them, weather related impacts such as flooding, coastal erosion, and subsidence will require new building techniques and materials to withstand adverse weather conditions. In addition, it may influence the choice of site. Further, when the insurance sector begins to factor impacts of climate change into premiums, the cost of construction will go up (IIGCC, 2004). A British study of possible effects of climate changes on buildings and construction shows that an increase in average wind speed of 6% could damage roughly a million buildings in Great Britain, with repairs costing around GBP 1–2 billion (Graves and Philipson, 2000).

The Building Control (Environmental Sustainability) Regulations 2008 of Singapore, which has introduced a new minimum environmental standard for buildings, is a good example of a specific legislative action that has been taken to deal with climate change. These regulations which apply to the following types of buildings have resulted in a construction cost increase, as the contractors and developers now have to install various green features into the construction (Gunawansa, 2008):

- All new building works with gross floor area of 2000 m2 or more;
- Additions or extensions to existing buildings which involve increasing gross floor area of the existing buildings by 2000 m2 or more;
- Building works which involve major retrofitting to existing buildings with existing gross floor area of 2000 m2 or more.

The Green Building Mission that has been launched in Malaysia, in March 2007, with the aim to discuss sustainability and environmental issues in construction and to recommend possible solutions for sustainable building policies in Malaysia, is a good example of a non-statutory voluntary action.

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[1] The Kyoto Protocol is an international agreement linked to the United Nations Framework Convention on Climate Change (UNFCC). It sets binding targets for 37 industrialized countries and the European community for reducing GHG emissions .These amount to an average of 5 percent against 1990 levels over the five-year period 2008-2012.

Another aspect needs consideration. Ongoing construction work may be destroyed or delayed due to events such as hurricanes, flooding, coastal erosion, and other unpredictable extreme weather conditions resulting from climate change. Such incidents are likely to frustrate the parties to construction projects and sometimes even lead to abandonment of projects. For example, the Bangkok-Chonburi Highway Construction Project was considerably delayed as a result of 1995 flooding which submerged all construction sectors, requiring some construction work to be redone (Mitsubishi UFJ, 2006). When Cyclone Nargis struck Myanmar on 2 and 3 May 2008, moving across Ayeyarwady and Yangon Divisions in the south of the country, devastating a 23,500 square metre region and affecting 2.4 million people, most of the ongoing construction work in the country had to be abandoned. The cyclone left approximately 140,000 people dead or missing and destroyed already fragile infrastructure (ASEAN Secretariat, 2009).

3.2 Adaptation related risks to the construction industry in ASEAN

According to some current predictions, as a result of such sea level rise, the number of people affected annually due to floods in coastal populations in Southeast Asia could increase by about 16 million, with Thailand, Vietnam, Indonesia and the Philippines likely to be the worst affected (WWF, 2007). According to the Minister of Environment of Indonesia, of the approximately 17,000 islands of Indonesia, about 2,000 islands may be submerged by 2030 due to sea-level rise if the current trend of global warming continues unchecked (Reuters, January 29, 2007). The Philippines, with approximately 7,100 islands and rocks, might not fair any better. Vietnam which has approximately 3000 islands with total area of more than 1600 square kilometers and more than one million square kilometers of sea surface is another country that is likely to be affected (World Bank, 2004).

In the circumstances, several hundred million people in densely populated coastal regions, particularly river deltas in the ASEAN region are threatened by rising sea levels and the increasing risk of flooding. Further, more than one-sixth of the world’s population lives in this region likely to be affected by water sources from glaciers and snow pack that will “very likely” disappear (IPCC, 2007). Thus, the South East Asian region is one of the most vulnerable to the adverse impacts of climate change.

In the circumstances, the construction industry in the ASEAN region should take the necessary initiatives to deal with adverse impacts of climate change. To mitigate the impact of hurricanes, flooding, coastal erosion, and other unpredictable extreme weather conditions, and to improve the adaptive capacity to such events, the use of new building techniques and materials that could withstand adverse weather conditions should be considered. Further, the threats of such events should also influence the choice of building sites for construction projects. In the worst case scenario, countries may even have to consider permanent relocation of people. This might be problematic to countries such as Singapore suffering from land scarcity.

Such moves for permanent relocation of people might also have adverse economic and social impacts. For example, the fishing communities in the coastal areas might have to develop new vocational skills causing the governments to take on the responsibility of looking after the economic interests of such communities in the interim, in addition to bearing the cost of relocation.

3.3 Risk of climate change induced litigation

The traditional attitude of having unlimited resources and space has not yet been completely erased, despite the fact that there is growing awareness of environmental impacts and the need for sustainable development (Augenbroe and Pearce, 2000). Thus, if governments fail to take actions to protect the people against adverse impacts of climate change, legal actions demanding positive responses from the governments cannot be ruled out. For example, given the vulnerability of the people in ASEAN countries to adverse climate conditions, if the governments fail to take appropriate mitigation and adaptation actions, various individuals and social interest groups may pursue legal action.

In the circumstances, construction activities might be legally challenged in future on basis of failure to mitigate climate change or on the basis of failure to take necessary adaptive measures. Construction activities in areas under threat die to rising sea levels might be particularly vulnerable to such legal actions.

In addition to the traditional grounds for challenging the polluters under existing legal regimes, the right to file legal action against the governments and public bodies, requiring them to take necessary initiatives may be established on the basis that the importance of public participation to sustainable development has been recognized in international declarations as well as in the work of both international and local institutions. In fact, since the 1992 United Nations Conference on Environment and Development (UNCED) (also known as the Earth Summit) recognized the importance of participation for sustainable development (Principle 10 of the Rio Declaration) and the duty to use the environment in having regard to the needs of not only the present generation, but also the future generations (Principle 3 of the Rio Declaration), the right of public participation has become a common legal requirement in many countries. Further, many countries have adopted the Agenda 21 that was created as the accompanying plan to lay out the path for achieving sustainable development in line with the Rio Declaration. It holds public participation as a fundamental prerequisite for sustainable development (Meadowcroft 2004).

ASEAN as a group has taken initiatives to recognize the principles of the Earth Summit and Agenda 21, although the extent to which public participation may be recognized and facilitated in the decision making process for sustainable development may differ from country to country. The establishment in 2005 of the ASEAN Centre for Biodiversity during the 9th informal meeting of the ASEAN Ministers, with the aim of regional cooperation for sustainable use of bio diversity, serves as a good example of the regional initiatives.

The landmark case of *Oposa vs. Factoran*[2] in which the Supreme Court of Philippines recognized the right of 44 children to maintain a legal action to stop deforestation, through their parents, in which they claimed that they have instituted the action on behalf of "their generation as well as those generations yet unborn", serves as a good example of the judicial recognition of the rights of not only the present generation, but also future generations, to participate in sustainable development.

It should be noted that the trend for climate change related legal action against the governments and public authorities has been established in several recent decisions in legal actions instituted in Australia and the US, although these cases did not involve construction projects. For example, in the case of *Australian Conservation Foundation v Minister for Planning*[3] the Victorian Civil and Administrative Tribunal has held that GHG emissions from burning coal must be taken into account in a planning decision to approve a coal mine extension, i.e., the use to which the coal would be put must be taken into account in determining the environmental effects. More recently, in the case of *Gray v The Minister for Planning*[4], Justice Payne of the New South Wales Land and Environment Court reached a similar decision when he held that the GHG impacts of burning coal must be taken into account in the environmental impact assessment of new coal mines in New South Wales, under Part 3A of the Environmental Planning and Assessment Act 1979.[5]

In the US, in case of *Friends of the Earth et al., v. Mosbascher and Merrill*[6] the District Court for the Northern District of California has held that the US National Environmental Policy Act (NEPA) applies to major federal government projects that contribute to climate change. The case of *Native Village of Kivalina v. ExxonMobil*[7], et al. brought by some lawyers on behalf of a small community of Alaskan villagers who are being forced to relocate due to melting ice beneath their homes is another interesting development in the growing interest to litigate against climate change related harm. In this case, the cost of re-location (US$400 million) is part of a damage claim lodged against the defendants, five oil companies and 14 electric utilities, for creating a public nuisance due to their ongoing emissions.

As far as the ASEAN region is concerned, according to a recent statement from the Chief Justice Reynato S. Puno of the Philippines, the country will soon have its own contribution to international jurisprudence with the introduction of a new legal procedure called writ of kalikasan (nature), which aims to protect the right of Filipinos to a healthy environment (Manila Bulletin, January 31, 2010).

2 G.R. No. 101083. July 30, 1993

3 [2004] VCAT 2029, judgment of Justice Stuart Morris, available here:

http://www.austlii.edu.au/au/cases/vic/VCAT/2004/2029.html

4 [2006] NSWLEC 720

5 It is interesting to note that this case considers the principle of ecologically sustainable development ('ESD'), and on the causal link between individual greenhouse gas ('GHG') emitting developments and climate change. Further, the learned judge has applied two common environmental law concepts that are receiving increased judicial attention, namely, inter-generational equity and the precautionary principle. Id. paras 119, 122, and 127.

6 US District Court for the Northern District of California, 30th March 2007, judgment of Judge Jeffrey S. White, Case No. C 02-04106 JSW

7 This case is pending before the United States District Court for Northern District of California, Sa Francisco Division.

Availability of specific administrative law remedies of this kind will make it easier for the people to challenge government approvals for construction activities that will or is likely to endanger their living environment.

3.4 Risks to construction industry in ASEAN due to public protests

In addition to the risk of litigation based on environmental concerns, public protest against certain construction projects on the basis that they pollute the living environments of certain groups and or that they causes harm to natural resource, could also pose threats to the progress of the construction industry in the ASEAN region. For example, the residents of San Mateo, Rizal, Philippines have recently launched a protest action to stop the construction of a new garbage dump by the Rizal provincial government. It is alleged that the government is taking the initiative to construct the dump on a 19-hectare area spanning two San Mateo villages, Guinayang and Maly. The main grounds on which the project is being challenged are that it is to be located within the Marikina Watershed Reservation and it is expandable to 200 hectares, which would remove approximately half of the 473-hectare forest cover in the two villages, Guinayang and Maly (Philippine Daily Inquirer, January 17, 2009).

At times, public opposition to construction projects may result in projects being completely abandoned or cancelled due to court interventions. For example, in 2005, following a public protest against a landfill project, the Supreme Court of Philippines issued a ruling ordering the permanent closure of the landfill in Pintong Bukawe, San Mateo town, Rizal province. The basis of the decision was that Proclamation No. 635 signed by former President Fidel Ramos on Aug. 28, 1995 setting aside 71.6 hectares of the Marikina watershed reservation area for the sanitary landfill to address the garbage crisis in Metro Manila was unconstitutional as "first, the San Mateo site has adversely affected its environs and second, the sources of water should always be protected."[8]

4. Mitigation of environmental risks

4.1 Traditional risks

From the perspective of project developers, financiers, and other key project participants who have a commercial interest in a construction project, it is very important to assess environmental performance and management of the project as part of the normal credit evaluation process. The general aim should be to focus on the opportunities for environmentally acceptable or sustainable development and to minimize exposure to environmental risks.

8 Province of Rizal v. Executive Secretary, GR 129546, 13 December 2005.

Proper environmental impact assessments and careful evaluation of the existing legislation in host countries on environmental protection would help to mitigate the traditional environmental risks associated with construction projects. Further, although an extensive environmental audit can give parties to a construction project some comfort, the most effective mitigation measure for traditional environmental risks would be to obtain comprehensive insurance. This mitigation measure is attractive because of the following five attributes of insurance that make it an effective risk management tool: its ability to spread risk; its role in variance reduction; its ability to segregate risk; its encouragement of loss reduction measures; and its ability to monitor and control behaviour (Freeman and Kunreuther, 1997). That said, it should also be noted that insurance against environmental risks is not cheap. This is because environmental risk is difficult to measure due to uncertainties in its extent, timing and the definition of terms.

From the perspective of the public sector, the current practice in most regimes for dealing with traditional environmental risks is to apply the "polluter pays" principle on those responsible for causing environmental harm. This is done by way of environmental legislation which introduces penal provisions. Such processes are further complemented by legislations that employ environmental taxes that are designed to encourage businesses to use resources efficiently and discourage business practices that damage the environment. Further, there may be environmental education programmes that promote public knowledge on the need for environmental protection and efficiency.

4.2 Mitigation of risks related to climate change

Despite the current lack of effective multilateral consensus on how the responsibility of each state to deal with climate change should be dealt with, since the Earth Summit in 1992, several nations of the world have been working towards reducing the emission of GHGs at the national level. Some of these initiatives take the form of specific legislation aimed at imposing penalties and taxation to force those governed by such legislation to adapt climate friendly behavioural patterns and to promote sustainable development. Some others are mere policy initiatives without specific legislation to back them. There are also industrial standards that have been introduced, some being mandatory, and others merely voluntary.

The recent initiatives to deal with climate change have focused attention on the environmental performance of buildings and construction activity, particularly emissions from buildings, thus focussing more on mitigation. However, it is important to note that mitigating climate change alone will not be able to avoid all impacts of climate change. Given that there is no scientific evidence that climate change could be completely reversed, there is a need to anticipate and deal with the consequences of a changing climate while at the same time working to achieve long term reductions in GHG emissions. Thus, dealing with severe weather related events such as hurricanes, flooding, and coastal erosion would require, among other things, the use of new building techniques and materials to withstand adverse weather conditions. In addition, such events would also influence the choice of site for construction projects.

5. National and regional initiatives to deal with climate change related risks

5.1 National initiatives

The scientists agree that the adverse impacts of climate change that is felt by the current generation are the results of environmentally unfriendly activities of several decades ago. Likewise, there is also scientific consensus that effects of our current mitigation efforts would be enjoyed mostly by the future generations, and not us (IPCC, 2007). Thus, whilst promoting mitigation efforts to curb the GHG emissions, it is also important that we take action to adapt to the changing climatic conditions. In the circumstances, a three pronged system of initiatives could be suggested for the construction industry:

- Initiatives to mitigate climate change by reduction of GHG emissions;
- Initiatives to minimize the impact of climate change related disasters through better preparedness;
- Measures aimed at adaptation to climate change impacts.

The above initiatives could take various forms and include specific legislation aimed at reducing GHG emissions and various policy initiatives aimed at research and development of mitigation methods. They could also include various industry standards, some mandatory and some voluntary.

The initiatives that fall under the first category above are visible in most countries, irrespective of whether they fall into Annex 1 countries under the Kyoto Protocol or not. For example, the National Greenhouse Gas Inventory Data for the period 1990–2006 maintained by the UNFCC (2008) indicates that many of the Annex 1 countries have taken initiatives that have resulted in reduction of the GHGs emitted during the period 1990 to 2006. A good example of a non Annex 1 country that had taken the initiative to reduce GHG emissions is Singapore. Having ratified the Kyoto Protocol in April 2006, Singapore has made a voluntary commitment to reduce its carbon intensity by 25% from 1990 levels by the year 2012. According to the Singapore Ministry of Environment and Water Resources (MEWR), the country had achieved a 22% reduction in 2004 (MEWR, 2006).

The Bali Action Plan (Bali Road Map) which was adopted by after the 2007 United Nations Climate Change Conference held in Bali by the participating nations as a two-year process to finalizing a binding agreement to be effective after the Kyoto Protocol ends in 2012 recognizes that enhanced action on adaptation, including, consideration of international cooperation to support urgent implementation of adaptation actions is required (UNFCC, 2007).[9] However, as far as the second and the third proposed initiatives above are concerned, very little action has been taken in the ASEAN

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9 http://unfccc.int/files/meetings/cop_13/application/pdf/cp_bali_action.pdf

region. Lack of knowledge on the measures to be taken, lack of coordination and support among nations, as well as, lack of focus, may be the key reasons.

It is important for the ASEAN countries to understand that without their participation in the global efforts the objective of stabilizing atmospheric GHG concentrations at a safe level cannot be achieved. Further, it is important that these countries understand that climate change is not only an environmental problem, but also a development problem. This is because as mentioned earlier, the countries in the ASEAN region have some of the most vulnerable populations with the least adaptive capacity to climate change impacts.

5.2 Regional initiatives for ASEAN

Given that ASEAN members have a good track record of cooperation and are in the process of further strengthening the regional integration with the aim of transforming ASEAN into a single market and a production base, there is scope for taking regional initiatives to improve the region's capacity to adapt to changing climate conditions. Thus, learning from each other, transfer of knowledge and technology, standardization of procedures, designs and techniques and, where necessary harmonization of laws and regulations, are initiatives that can be facilitated at the regional level. For example, appropriate construction technologies and designs could be obtained from the more affluent members in the region instead of looking for them elsewhere. Standardization of techniques, designs and regulations would facilitate such process.

The member countries of the ASEAN region have not yet formally agreed on any specific regional approaches to deal with the environmental challenges the construction industry would face as a result of climate change. However, the foundation for the formation of such approaches has been laid in some of the recent regional understandings that have been reached. Some of the key understandings and agreements that have been reached are briefly explored below.

The ASEAN Economic Community Blueprint that has been signed on 20 November 2007 which all member countries have agreed to abide by and implement by 2015 with the aim of transforming ASEAN into a single market and production base, a stable, prosperous, and highly competitive region with equitable economic development, and reduced poverty and socio-economic disparities provides inter alia in its Article 55 that:

> *"While ASEAN strive towards accelerating the establishment of an ASEAN Community by 2015, it is important to ensure that such development is sustainable through, among others, mitigating greenhouse gas emission by means of effective policies and measures, thus contributing to global climate change abatement."*[10]

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10 http://www.aseansec.org/21083.pdf

The same Article provides further that:

> *"it is essential for ASEAN to emphasise the need to strengthen renewable energy development, such as bio-fuels, as well as to promote open trade, facilitation and cooperation in the renewable energy sector and related industries as well as investment in the requisite infrastructure for renewable energy development."*

This evidences the fact that there is regional recognition of the threats posed by climate change in general and the need for regional efforts in the form of policies and other measures to deal with them.

In Article 57 of the Blueprint, the importance of developing regional infrastructure is recognized. For example, one specific project that has been identified is the Trans-ASEAN Gas Pipeline project, in connection with; a time frame of 2010 to 2011 has been set for adopting common technical standards for construction, operation and maintenance. Adaptation of such common technical and design standards for the other construction projects in the region too should be considered. Such common standards would not only help the growth of the construction industry in the region, it would also help the region to collectively address some of the environmental concerns that have been identified in this paper.

The Singapore Declaration on Climate Change, Energy and the Environment that was signed by the members in November 2007 at the Third East Asian Summit expresses the regional concern about the adverse impact of climate change on socio-economic development, health and the environment, particularly in developing countries and the need to enhance their adaptive capacities, as well as the need to urgently act to address the growth of global greenhouse gas emissions.[11] It reaffirms the need inter alia to take an effective approach to the interrelated challenges of climate change, energy security and other environmental and health issues, in the context of sustainable development.

The Singapore Declaration on Climate Change stresses the need for all countries to address the common challenge of climate change, based on the principles of common but differentiated responsibilities and respective capabilities. Furthermore, it deals with the strengthening of cooperation on management capacity and measures for natural disaster risks raised by climate variability and change and other environmental challenges; the development of adaptation strategies to mitigate weather-related calamities caused by water; and the need to address the environmental challenges posed by rapidly growing urbanization in the region. Some of the measures that have been identified include the pooling of experience and resources in areas such urban planning including transportation, green building, water management, urban greenery and urban biodiversity conservation, sanitation and waste management, 3Rs (Reduce, Reuse and Recycle) and air, noise, water, and land pollution control. Further, the appreciation of initiatives such as "Low Carbon Society", "Compact Cities", and "Eco-Cities" have been declared.

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11 http://www.aseansec.org/21116.htm

6. Conclusions and recommendations

The construction industry is not only one of the major contributors to climate change, but also one of the industries that could be severely affected by them. Although climate change is affecting the ecological system of the whole world, some regions such as the South East Asian region are more vulnerable than the others due to their special geographic features. Thus, the efforts to mitigate environmental impacts and adapt to them would require pro active measures from the construction industry in ASEAN countries.

Of various risks that are associated with construction projects, environmental risks could spring up at any time during a project's life cycle. Mitigation of some environmental risks such as those related to existing legislation on environmental standards may not be too difficult. Such risks could be easily mitigated by the relevant project participants. However, taking action to deal with some environmental risks such as adverse impacts of climate change and the efforts to adapt to changing climate conditions would require action from the national governments as well as at the regional and global levels.

In the circumstances, ASEAN countries should take the initiative to introduce land-use planning and performance standards that would encourage both private and public investment in buildings to take account of climate change and the threat posed by it. Similar measures have been suggested for other countries, for example UK (Stern, 2007). This could be done by the introduction of voluntary mechanisms as well as building regulations that would introduce certain mandatory baselines as in the case of the Singapore Green Mark scheme. Such measures however, would have an impact on what is built, the locations of the buildings, as well as, building technologies and designs. As mentioned earlier, this could also affect the cost and time of construction.

There is evidence that ASEAN, as a region, is moving in the correct direction by understanding and identifying appropriate regional responses to common environmental risks. However, in order to facilitate the initiatives that need to be taken at the regional level, the ASEAN members should take the steps to implement the agreements that have been reached such as the Singapore Declaration and the ASEAN Economic Community Blueprint which have been discussed in this paper.

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Abstract

The current paradigm of continuous global economic growth is more and more questioned. The availability of existing resources, materials and energy, is becoming limited while facing a growing population at the same time. Consequently the usage of resources is rising enormously becoming a threatening factor for emerging industries. At the same time the environmental impact and pollution are increasing with global (climate) effects. The building industry has a huge impact on the use of resources. In Europe, at the beginning of the 21st century, more than two billion ton of building materials were used and world wide 40% of energy usage is building related. Therefore the building industry is one of the most relevant sectors which can contribute significantly to a more sustainable environment. The term sustainable built environment is related to the (Brundtland) idea that a built environment shall be created in order to meet the needs of the present population without compromising the ability of future generations to meet their own need. In this context material- and energy-aspects relevant for the built environment are highlighted. From a European perspective an inventory is made of proposed approaches from different companies, institutions, platforms and governments. The methodology used is a desk research of published visions, strategies and roadmaps. Based on the outcomes of this inventory an overview of the three main approaches will be made in relation to the directions in which solutions for materials and energy are sought for the Building Industry. Purpose of these approaches will be to formulate recommendations for managing minerals and energy in relation to the built environment.

Keywords: sustainability; resources; built environment; material efficiency; strategies

1. Introduction

Many people think that we have to change the world. Very few think that we have to change ourselves.
-Fiona Dittrich

It is beyond doubt planet earth will not be able to sustain the current way resources are being exploited (Wackernagel 1996). Changing is bound to be difficult since it affects our societies in every aspect. Since the 1970's, the use of natural resources as a pre-requirement for economic growth is a serious point of discussion. Although the predictions that we will face serious environmental and supply problems within 20 years, made by the 'club of Rome' (Meadows 1972), did not come true, the world is facing and will face serious environmental and economical challenges in the following decades. This fact and the Brundtland definition of sustainable development contributed to a more holistic view on sustainable development: the triple bottom line or people, planet, profit (Elkington 1994). The triple bottom line is a widely accepted definition of sustainable development since it integrates the economical aspects of the future challenges into technologically and socially orientated concepts. The purpose of this paper is to make an inventory of proposed solutions of different companies, institutions, platforms and governments in order to formulate recommendations for managing minerals and energy in relation to the built environment.

1.1 (Natural) resources in the built environment

The building industry is one of three mayor energy consummating sectors in our global economy. Buildings are consuming about 40% of the total amount of energy (WBCSD 2004, 2005b, 2007). It is also one of the four mayor CO2 emitting sectors, next to power generation, mobility and industry & manufacturing (WBCSD 2005b). Building industry is the most important consumer of the approximately 20 billion tonnes of minerals extracted worldwide per year (SERI 2009). For the 27 European member states the amount is 4 billion tonnes, which is 36% of the total of the extracted resources (Figure 1). In the United States 60% of the total materials flow (USGS 1998, BTRD 2008) and 40% of the primary energy consumption (BTRD 2008) is building related.

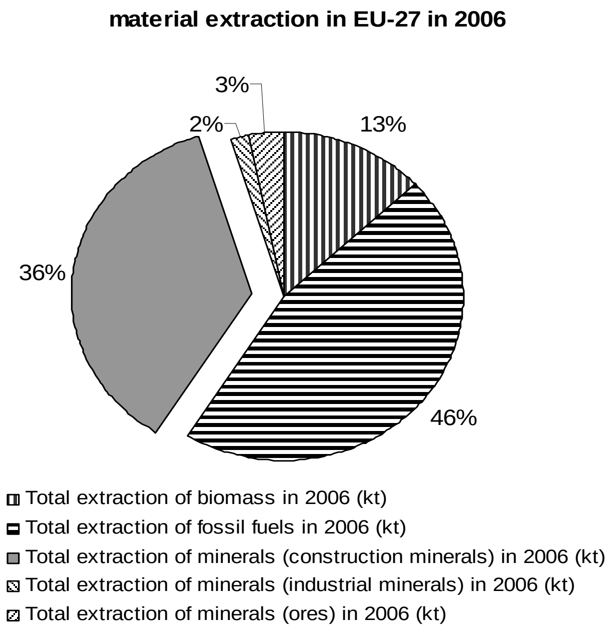

Figure 1: Extraction of materials in Europe (EU-27) in 2006 (SERI 2009).

The theorem that the use of materials is increasing with economic growth, is only partly true for highly industrialised countries. The consumption per capita remained e.g. for Europe on the same level at 16 tonnes per year while the economic growth was 50% (EC 2005) indicating an increasing material efficiency. But on a global scale the situation is different. If the world as a whole will follow traditional patterns of consumption, it is estimated that the global resource use would quadruple within 20 years. (EC 2005). According to Schmidt-Bleek (2009) a limitation of (non-renewable) resource use up to 6 tons per capita and year will be required in 2050, in order to achieve a sustainable development. According to the US geological survey the use of construction materials such as crushed stone, sand and gravel has increased from about 35 percent to 60 percent of total non-food, non-fuel raw materials consumption in the United States. Consumption of non-food and nonfuel agricultural and forestry products has dropped from about 60 percent to 5 percent of total raw materials consumption in the period 1900-1995 (USGS 1998). From this background the more sustainable use of resources (materials and energy) in the built environment is of enormous relevance in order to diminish the pressure on the environment and resources in future.

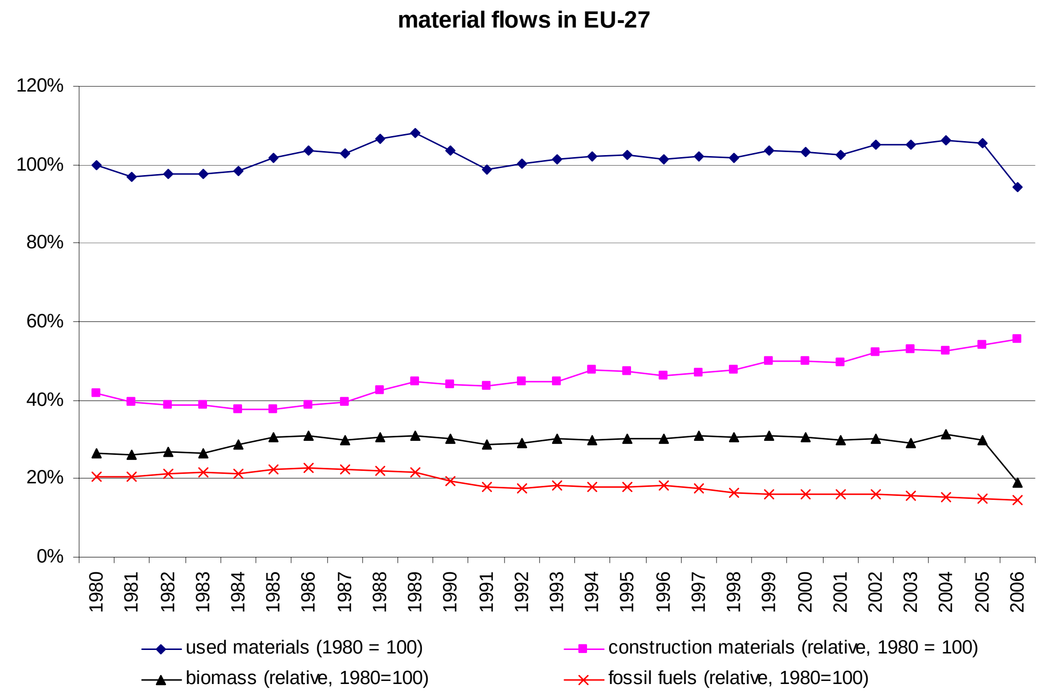

Figure 2: Used extracted materials in EU-27 1980-2006 Source: SERI (2009)

The use of extracted materials in the EU has been relatively constant since 1980. The use of fossil fuels is showing downward trend. An increasing use trend is noticed for construction materials, probably indicating a lower material efficiency in combination with slower technological progress. A decreasing trend in the extraction of construction materials would help reducing the environmental impact of the built environment.

1.2 The environmental impact of resources use

The environmental impact of (construction) materials is very complex as demonstrated in the LCA analysis of Huijbregts *et al.* (2003). They evaluated different types of impacts, like depletion of abiotic resources, land competition, global warming, stratospheric ozone depletion, acidification, eutrophication, photochemical ozone formation, or radiation and toxicity. Knowledge of several interactions is required in order to form a perspective for a more sustainable built environment which can form the basis for further steps.

As already mentioned, the resource use in the built environment is enormous in absolute numbers. The figures 3-5 demonstrate use of the most relevant materials in the built environment per capita and per year. Data based on life cycle assessments is used to indicate the relevance of materials on aspects like energy use, CO2 emission, water use etc. Figure 3 shows the relevance of cement, sand, gravel, steel and wood as the dominant bulk materials in the building sector. Figure 4 and figure 5 give indications of the water and energy use for the production of relevant materials. These figures are based on the data published in several references. It was noticed that there is a large variety in data and there are large data gaps. In order to get a better picture the figures presented were based on mean values. These data should not be used as exact numbers but rather as an indication, based on the report Sailer et al. (2009). Regarding the basic environmental indicators like CO2 emission, energy use, water use, it is obvious that a very limited group of materials contributes most to the unwanted environmental impact.

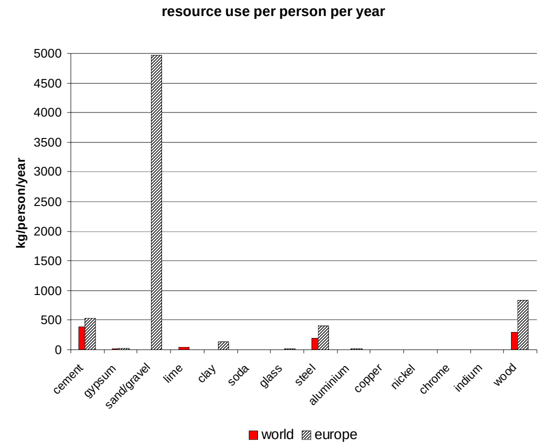

Figure 4: Use of base materials per person per year

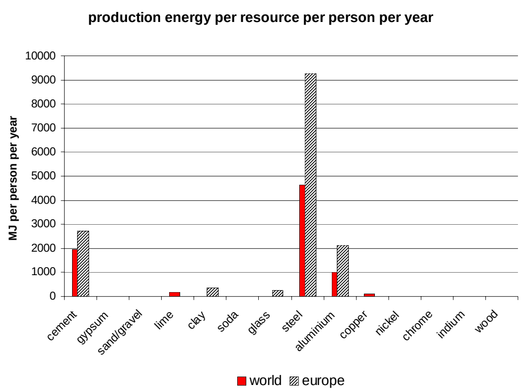

Figure 5: Energy use of building materials per person per year

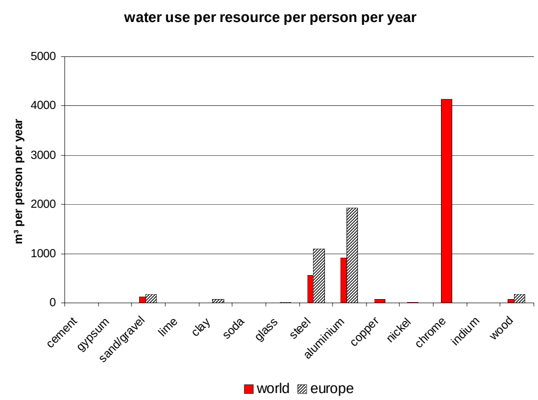

Figure 3: Water use of building materials per person per year

2. Suggestions for sustainable approaches

Different companies, institutions, platforms and governments have suggested a range of possibilities in order to reduce the current impact of resource use from the building industry. In order to formulate recommendations for managing minerals and energy in relation to the built environment first an inventory was made. In the appendix (table 1) an overview can be found of the different organizations, companies, branches and platforms that have been included in this inventory.

For materials the following themes were distracted from the strategies, vision documents and roadmaps (see table 2 in appendix for more information):

- Reduction of environmental effects
- Increase of productivity (materials & energy) in production processes
- Life cycle costs reduction for building materials
- LC and material management, socio-economic consequences
- From waste management to waste free: “the closed loop society”
- Sustainable use of natural resources and use of biological principles
- New multi-function materials
- Improvement of comfort (health, hygiene, safety and aesthetics)
- Diversification (different sources and different products), risk management
- Building methods and integration

For energy the following solutions can be derived in order to make the transition towards a more sustainable economy (see table 3 in appendix for more information):

- Diversification
- Research & development of new technologies
- Cost reduction of current technological options
- Reduction of fluctuations between supply and demand of energy
- Reduction of demand through the upscaling of technological solutions
- Reduction of demand through change of behaviour

For more details on these themes and solutions see Sailer *et al.* (2009) and Oostra *et al.* (2009).

3. Towards a framework of sustainable approaches

Since changes in the building material chain may have an enormous impact on the resource use and environmental impact, sustainability strategies are promoted at political level within the European

Union and other countries worldwide, e.g. EC (2005), ECTP (2005), NZCIC (2006), Cheng *et al.* (2008), EC (2008), BTRD (2008), Storey (2008), Faulstich *et. al.* (2009). Sustainability is also one of the main focus areas of enterprises active in the building industry e.g. CRH (2008), St Gobain (2008). They are giving input to the three main approaches which can be extracted from different political strategies related to resource use:

1) Reduction of resource use as the basis of sustainability.

2) Decoupling, the approach of dematerialization and transmateralisation

3) Use of resource potential along the value chain. Based on the value chains five fields of action are relevant: Resources, base materials, production of products, use of products, recycling.

In order to achieve substantial changes of the above mentioned approaches political supporting measures are required. Supporting measures are for example the development of an integrative resource policy which allows to combine all relevant fields in the value chain, controlling of resource use or the implementation of product responsibility which includes aspects like service life, recyclability or use concepts e.g. leasing or sharing (Faulstich *et al.* 2009).

3.1 Reduction of resource use as the basis of sustainability

An overtly clear first step in reaching a more environmentally friendly built environment is the reduction of resource use as such. An ultimate consequence of this approach could e.g. lead to smaller new buildings etc. Although not in line with the triple bottom line where people and profit are also taken into account, on a political level it is believed that an **absolute** reduction of resource use in the future might be unavoidable (BMU 2008). If we ‘simply’ start doing less there will be less productivity, less profit and less prosperity. Therefore there is also a necessity to combine a reduction of environmental impact (Saling *et al.* 2002), with social and economical factors as described by e.g. Millennium Ecosystem Assessment Board (MA 2005) or Krausmann *et al.* (2009).

3.2 Decoupling: the approach of dematerialization and transmaterialization

The term decoupling is an abstract description of a concept leading to a more sustainable economy. The idea is based on the aim of achieving both economic growth and reduction of unwanted environmental impacts at the same time (EC 2005, 2009). The concept based on economical and environmental indicators is widely used by governments and other policy makers, e.g. Makela (2009). The OECD proposes decoupling as one of its five objectives in environmental policies (OECD 2001).

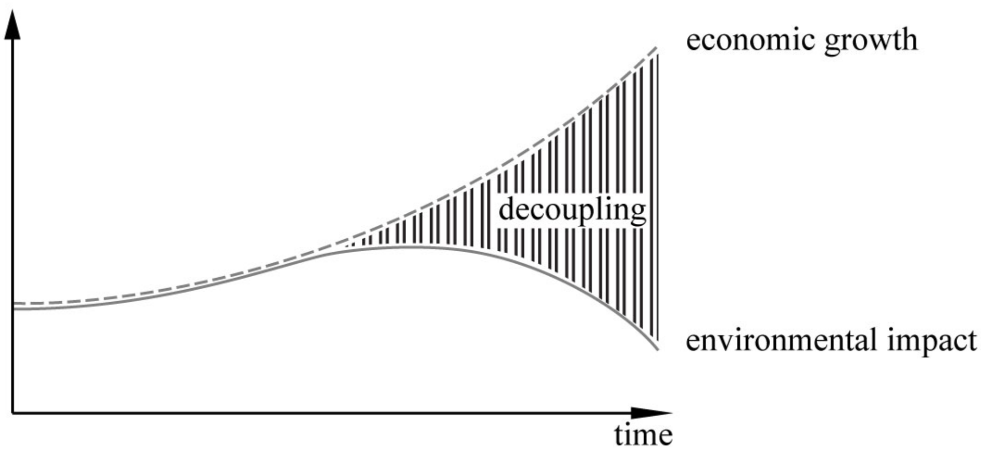

Figure 6: Decoupling the economic growth from environmental impact

In our society growth is generally seen as a prerequisite to sustain the existing levels of welfare. Essential in achieving a sustainable environment is the reduction of environmental impact. The challenge for policymakers is to facilitate and stimulate sustainable growth while at the same time ensuring the state of the environment is improving, or does not get worse. These are not necessarily competing goals. Economical growth, less unwanted environmental impact and improving material efficiency (dematerialization) at the same time are possible. The efficiency of the concept can be strengthened by combining dematerialization with transmateralization, substituting materials causing unwanted collateral damage for materials with a better eco-profile (EC 2005).

3.3 The material chain

In order to achieve significant impact, the whole chain from primary resource use to production, use and reuse has to be taken into account. This is necessary because the different fields within the chain interact. The efforts to improve sustainability in one step can be strengthened, reduced or prove counter effective through the effect it has on the next step in the chain (Faulstich 2009).

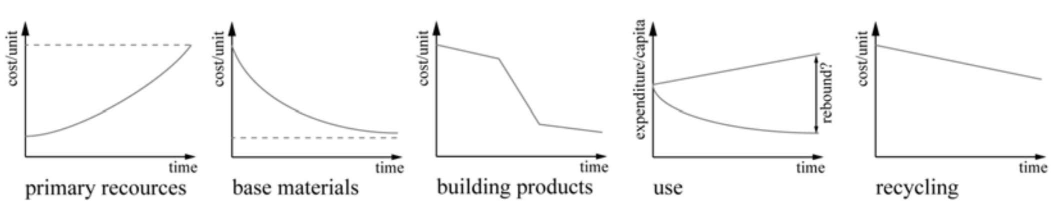

Figure 7 : Schematic presentation of the most important fields in the material chain. According to Faulstich et al. (2009)

3.3.1 Actions and approaches in the field of primary resources

The first step in the material chain is the mining of primary resources. Non renewable resources are mainly extracted from the earth (ground). The fact that the energy required for extraction grows exponentially with lower ore grades (Diederen 2009) is an example of the challenges ahead. This situation is especially true for several metal ores and fossil fuels. Technological improvements in mining technologies may help to extract materials in the future but the trend of increasing energy requirements in order to compensate lower mineral ore concentrations will continue.

In the raw material initiative (EC 2008) a more efficient raw material use in the EU is suggested, aiming to diminish the critical dependence of the EU on primary raw materials, to reduce import dependency, and to improve the environmental balance, while meeting the industrial needs for raw materials.

The “thematic strategy on the sustainable use of natural resources” (EC 2005) is also scrutinizing the primary resources used. One of the important issues is the creation of more knowledge and understanding of the production and environmental impact of natural resources on the following aspects:

- Improve our understanding and knowledge of European resource use, its negative environmental impact and significance within the EU and globally.
- Develop tools to monitor and report progress on material efficiency in the EU, Member States and economic sectors.
- Foster the application of strategic approaches and processes on resource management both in economic sectors and in the Member States and encourage them to develop related plans and programmes.
- Raise awareness among stakeholders and citizens of the significant negative environmental impact of resource use.

From an industry point of view the availability of resources is an important factor in the viability of an enterprise. This is visible in the statements of e.g. CRH (2008), St. Gobain (2008), Reitz (2009), Evonik (2008), Ollila, (2009) and emphasises the importance of strategically located long-term reserves in the major markets.

3.3.2 Base materials and approaches

Most of the primary resources have to be refined before useable material for (building) products is created. These processes are steadily being optimized, closing in on the theoretical values necessary for the physical/chemical feasibility. An example of such a limit is the CO_2 emission from the calcination of limestone to produce cement clinker, which is the main binding element of concrete. ($CaCO_3 \rightarrow CO_2 + CaO$). To produce this clinker from limestone a given amount of CO_2 is produced.

Based on this process there is no CO_2 free cement production possible. The same example also shows an optimization option: There is a certain (high) temperature needed to let this reaction take place. Generally this heat is nowadays produced by fossil fuels. Through increasing the environmental efficiency of the heat generation or using sustainable fuels the environmental impact can be reduced.

An important material topic of the European construction technology platform (ECTP 2005) is an increase of the resource efficiency of buildings and infrastructure during use through improved materials. More efficiency shall be achieved by expanding the limits of existing materials through understanding the underlying chemistry, biology and physics as well as through the development of smart, multifunctional active materials.

Examples of this approach are the actions undertaken by the industry to reduce the unwanted environmental impact of cement through optimization of operating cement plants, reducing clinker factor by producing blended cements ("low carbon" cement), using alternative fuels particularly biomass where available and permitted, reducing power consumption, investing in new state-of-the-art plant and replacement of inefficient process modules (CRH 2008). Another example in changes of base materials is the development of sulfur based cement (binders) which should reduce CO_2 emissions by 30%-50% (Ollila 2009).

3.3.3 Building product developments

A relatively large effect can be achieved through the redesign of building products, using different (more sustainable) base materials as well as improving the production processes. Through the huge amounts of materials used in the built environment, large improvements in the ecological impact can be achieved. Important issues are the use of alternative energy sources during the production and the use of renewable materials. Another topic is the improved predictability of, and efficiency of building material production processes. There is also a large potential in changing labor intensive processes into automated, intelligent feedback systems, thereby achieving high performance materials with reduced environmental impact. Another relevant topic is the development of new, multifunctional knowledge-based materials and construction systems adjusted to customer needs keeping in mind environmental and resource aspects.

An industry example of this topic is the development of energy-saving solutions, such as more energy efficient lighting systems, and fuel cells for generating electricity and heating water in the home (St Gobain 2008).

3.3.4 Use

During the long period a building is used, the environmental impact becomes visible. The effects were frequently created by former steps in planning and the production chain. The building's specifications for example, determine the environmental impact during the use phase. The amount of energy necessary to fulfil the building's user needs, the amount of maintenance necessary and the (technical and functional) lifetime of the building are greatly affected by the design and construction of the building. This is also reflected in the ECTP (2005) approach trying to reduce the *lifecycle* costs of building materials. Main criteria are maintenance cost reduction through more durable materials, less repair as well as aesthetical durability. There is a large potential for the earlier described ‘decoupling’ in the use phase of a building. The use of e.g. sustainable produced material with improved insulation properties or easy recyclable components can contribute to achieve a better eco-profile of the building during the use phase.

Although decoupling is most likely to contribute significantly to a more sustainable built environment, there is significant evidence that increasing material- or eco-efficiency of a product will lead to lower prices, causing an increase of consumption. The rising demand will cause increasing environmental pressure and a reduction of the positive environmental effect of the decoupling. This is phenomenon is called a ‘rebound’ effect (Alcott 2005, Berkhout 2000). If for example the efficiency of a boiler is increased and the energy use for heating is reduced, this efficiency gain will result in lower energy costs. This may stimulate the consumption of more energy (e.g. not turning down the heating at night) or spending the saved money on other products and services which lead to energy use e.g. an extra holiday flight. These examples show that in the end we have to consider the total balance and not only one aspect showing that rebound effects may decrease the effect of the environmental gain of an efficiency improvement. Berkhout et al (2000) concluded that the rebound effect is “*probably small: between 0% and 15 %”*, but this is not undisputed as is indicated by Sorell (2008).

3.3.5 Demolition and recycling

Recycling of construction and demolition waste is a relevant topic in many strategies (ECTP 2005, OECD 2001, CRH 2008, EC 2008, Faulstich 2009, EC 2005). Efforts to improve the recycling percentage of building materials are advocated in most visions. Hashimoto et al, (2007) expect that the amounts of waste construction minerals generated have been and will be at much lower levels than the domestic demand for construction minerals. These differences might indicate consistent growth of the stock of construction minerals. This growing stock will eventually become construction and demolition waste. The recycling of anthropogenic accumulated resources in cities is becoming more and more known as the concept of urban mining (e.g. Hüther (2006). The opportunities of urban resources are mentioned in the ECTP vision that is supporting the utilization of construction and demolition waste and other waste which offers a huge potential to minimize the environmental burden of the construction industry.

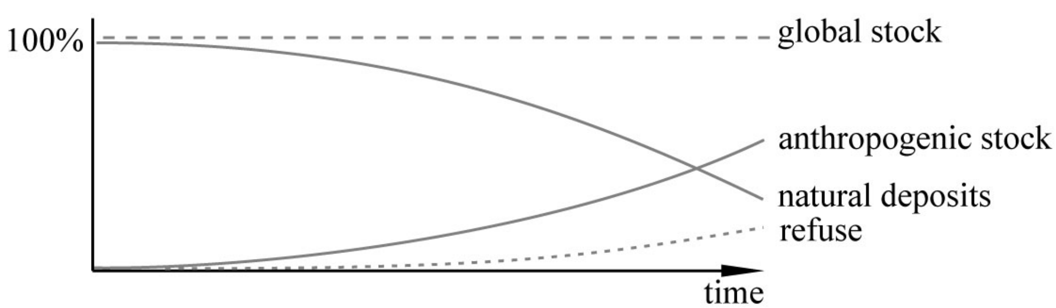

Figure 8: The growing anthropogenic material stock according to Rechberger (2004)

4. Conclusion

The enormous resource consumption, for both materials and energy, within the built environment is bringing the building industry more and more into the focus of efforts to optimise resource usage, to reduce material efficiency and to improve its environmental profile. The fact that buildings are consuming about 40% of the total amount of energy world wide (WBCSD 2004, 2005b, 2007) and e.g. in the United States 60% of the total materials flow (USGS 1998, BTRD 2008) is building related, shows the resource optimisation potential in these fields, but also the threats if we continue to increase the amounts currently used. A positive aspect is the limited number of building relevant materials with a high environmental impact. If the production processes and use of these materials can be improved a relatively large impact is generated.

Three main directions were derived from this inventory towards possibilities to reduce the current impact of resource use form the building industry from the strategies and visions of different organisations, companies, platforms and governments. First, a sustainable development requires a clear limitation of the current resource use in the future (Schmidt-Bleek 2009). It is discussed if and how that aim can be achieved considering the resource aspect as well as related economic and social questions (BMU 2008). Current technological developments like CO_2 reduced cement or asphalt can contribute to reduce CO_2 emissions considerably and technological concepts like “Net-Zero Energy, High Performance Green Buildings” (BTRD 2008) are steps into a more sustainable future. Second, to improve the environmental effect of the building industry a greater diversity of building materials could be beneficial, in which specifically optimal materials for specific situations are developed. This niche approach improves (environmental) efficiency and creates less dependence on a relatively small group of materials. Finally it is expected (Faulstich 2009) that a more clear reduction of resource use could be achieved if the activities in the different fields of the value chain can be embedded into a political strategy, which will ameliorate possibilities for co-ordination. This will also require a clear definition of resource based aims and targets of the building industry in order to be able to control the resource streams in the future.

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World energy council (2007): 2007 survey of energy resources, world energy council, 2007

WSA (2009): World steel in figures 2009, world steel association

Appendix

Table 1 Governements, organisations, companies and platforms

	The Netherlands	**European**	**Other counties**	**World**
1. Governement	SenterNovem Central governement Local governements	EACI/IEE CEN EC EP		UN(FCCC) IEF
2. Knowledge institutes	TU/e UR AER EIB ECN TNO M2I Deltares	Graduate school Euroconstruct Foresight programme (UK)		IPCC IEA ECBCS
3. Companies		CRH St Gobain Pilkington Evonik		
4. Platforms	PeGO DeltaNeth Regieraad PSIBouw	ENBRI ERAbuild Euracobuild	WTCB NSTC	CIB WBCSD INIVE
5. Business organisations	Holland Solar Uneto VNI Bouwend Ned Aedes Neprom	EREC ECTP FIECESTTP PV Platform EURIMA		CABA AIVC

Table 2 Themes for materials (Sailer 2009)

Relevant themes building materials	**Sources**
1) Reduction of environmental effects	– ECTP vision 2030, (2005) – ESTEP sustainable use of resources (2009) – CIB, working commission 115, 2008 – EC, towards a Thematic Strategy on the Sustainable Use of Natural Resources (2003)
2) Increase of productivity (materials & energy) in production processes	– ECTP vision 2030 (2005) – Evonik 2008 – ESTEP sustainable use of resources (2009) – EC, towards a Thematic Strategy on the Sustainable Use of Natural Resources (2003)
3) Life cycle costs reduction for building materials	– ECTP vision 2030 (2005) – CIB WG 115 publication 322: lifecycle design of buildings, systems and materials
4) LC and material management, socio-economic consequences	– ESTEP sustainable use of resources (2009) – EC, towards a Thematic Strategy on the Sustainable Use of Natural Resources (2003) – CIB WG 115 publication 322: lifecycle design of buildings, systems and materials
5) From waste management to waste free: "the closed loop society"	– ECTP vision 2030, (2005), – Wal mart Sustainability vision statement 2007, – ESTEP sustainable use of resources (2009) – CIB WG 115 publication 322: lifecycle design of buildings, systems and materials
6) Sustainable use of natural resources and use of biological principles	– CIB WG 115 publication 322: lifecycle design of buildings, systems and materials; – Büro für Technologiefolgenabschätzung im deutschen Bundestag, 2006, – Innovations- und Marktpotenzial neuer Werkstoffe, Monitoringbericht 2007
7) New multi-function materials	– ECTP vision 2030, (2005), – Innovations- und Marktpotenzial neuer Werkstoffe Monitoringbericht 2007
8) Improvement of comfort (health, hygiene, safety and esthetics)	– ECTP Vision 2030 (2005) – ESTEP sustainable use of resources (2009)
9) Diversification (different sources and different products), risk management	– ESTEP sustainable use of resources (2009)
10) Building methods and integration	– CIB WG 116 publication 300: deconstruction and material reuse – An international overview

Table 3 Directions for solutions mentioned for energy transition (Oostra 2009)

Diversification	Deltares, 2009; EC, 2008; ECN, 2007; EREC, 2008; Foresight, 2008
Research & development of new technologies	AER, 2007; Deltares, 2009; E2B, 2009; EC, 2008; ECN, 2007; Ecofys, 2007; EIA, 2008; PEGO, 2007; EP, 2009; EREC, 2008; Foresight, 2008; SET; IEA, 2008, OCW&EZ, 2008; TU/e; UNFCCC, 2009; S&Z, 2007; WBSCD, 2004-2007
Cost reduction of current technogical options	AER, 2007; E2B, 2009; EC, 2008; ECBCS, 2008; Ecofys, 2007; EIA, 2008; PEGO, 2007; EREC, 2008; Foresight, 2008; HollandSolar, 2005; IEA, 2008; S&Z, 2007; WBSCD, 2004-2007
Reduction of fluctuations between supply and demand of energy	Deltares, 2009; EC, 2008; ECBCS, 2008; ENBRI, 2005; EP, 2009; Foresight, 2008; SET; HollandSolar, 2005; IPCC, 2007; UNETOVNI, 2007
Reduction of demand through change of behavior	AIVC, 2008; EC, 2008; ECBCS, 2008; ECN, 2007; BF, 2007; Ecofys, 2007; EIA, 2008; ENBRI, 2005; PEGO, 2007; EP, 2009; Foresight, 2008; IEA, 2008; IPCC, 2007; OCW&EZ, 2008; S&Z, 2007
Reduction of demand through change of behavior -obligation (e.g. switching off appliances during peaks) -creating awareness & acceptance	 Foresight, 2008 Foresight, 2008; IEA, 2008; OCW&EZ, 2008; UNETO-VNI, 2007; WBSCD, 2004-2007

References used in table 2 and 3 are not necessarly included in the references of this paper. Only the references used in the main text of this documents are included. The remaining references used in the table can be found in the subsequent reports (Sailer 2009, Oostra 2009).

Water Conservation in Brazilian Buildings: State-of-the Art and Main Challenges Ahead

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Abstract

Water conservation contemplates rational use of water and use of alternative sources, like rainwater and gray water. Rational use of water can be obtained basically by leakage repair, users' awareness for rational use and installation of water saving components. Brazil had developed an extensive program to establish the adequate volume for water closets, and since 2002 only low flow toilets are available in the market. There are additional programs that contemplate other water saving fixtures, aiming at assuring products' quality to the final user. However, leakages are still frequent in many building typologies and it is necessary that users become sufficiently informed to change their behaviour regarding water use to avoid wastage. Water metering is also important to improve water consumption management. In Brazil multi-residential buildings usually have just one meter and total consumption is simply divided into all users, disregarding their consumption profiles. Consequently, there is no stimulation for water saving measures and attitudes. This reality is changing as some Brazilian cities have just implemented laws for implementing sub-metering systems. On the other hand, alternative water sources have being used for non-potable applications, although no standard is in place yet to relate minimum water quality requirements and contact level with the final user. This paper presents how water conservation actions have been developed in Brazil and the main challenges ahead. Some case studies are also presented to demonstrate success of implemented actions, as well as a proposal of topics related to water conservation to be considered in an assessment system for residential buildings in Brazil to stimulate designers, constructors and other stakeholders to incorporate sustainable building concepts in their practices.

Keywords: water conservation, sustainable, building

1. Introduction

The need to preserve energy is one of the first factors that have motivated the surge of the so-called green buildings since the 70s. Through the years, this concept has developed to sustainable buildings, a more comprehensive concept, also contemplating social and economic dimensions, according to which buildings are supposed to go beyond energy efficiency to meet a series of requirements concerning occupants' health and comfort, impacts on the urban infrastructure and on local contexts, added to those generated by the materials used, the construction activities, as well as use, operation and demolition of built structures. The general principle of sustainability consists of putting into practice some actions that neutralize three effects: running out of resources; polluting of the ecosystem; and disrupting the natural systems by the destruction of land and the biodiversity. The use of water by the society is not sustainable, in the sense that more clear water is extracted from the ecosystem than it is able to replenish naturally, and too much polluted water is discharged.

The difficulty in obtaining financial resources, the increase of investments needed to accomplish sanitation projects to meet the needs of accelerated urban growth, added to the geometric growth of irrigated areas and other usage conflicts that might occur, have caused the adoption of measures aiming to control water use in urban environments. Water conservation has become a major subject in several programs in different countries. Water consumption distribution varies according to the building type and also between similar buildings. However, there is a portion actually used and another that is wasted. The wasted water is the amount that is lost because of excessive or improper use and leakage. For that reason, water conservation in buildings involves action in two different areas: the technical and the human. The technical area activities include leakage detection and correction, installation of water-saving equipment and systems and an effective management system, possible trough sub-metering. The human area involves change of habits and the adoption of rational water use procedures. Both areas need to be considered for the success of a water conservation program. (New Mexico Office of State Engineer 1999).

Actions to be developed in a water conservation program are closely related to the buildings life period. For new buildings, building systems design must consider the optimization of the consumption of potable water, with the application of alternative water sources for simple use and the management of such resource consumption, with the adoption of improved design strategies including minimization of the number of joints and ensured accessibility for maintenance, coupled with implementation of consumption management systems according to the needs in each building. In existing buildings, the principles are essentially the same, but some technological solutions may not be practicable. Actions for demand management are therefore usually prioritized over the ones related to supply management, such as alternative water sources, like rainwater and gray water.

Brazil has around 12% of the world water and 53% of the water in the American continent. However, 80% of the national water resources lie in regions with lower population density. The great urban centres, on their turn, present scarcity scenarios due to a combination of natural (un)availability conditions and river pollution. Furthermore, water and sewage urban infrastructures are available only for a small part of the population. Although 98% of the Brazilian municipalities have some type of water supply service, only 64% of households are connected to potable water networks. For the sewage system, the situation is worse: 52% of the municipalities have sewage networks, collecting sewage from mere 35% of homes. From those, about 10% of the municipalities treat only part of the sewage generated, while some municipalities dump 100% of the produced sewage *in natura* into rivers and seas (ANA 2009).

Consumption sub-metering is fundamental for water demand management. Brazilian multi-residential buildings usually have just one meter and the total consumption is equally divided across all users. Consequently, there is no encouragement for water saving. Since about two years ago, laws concerning water sub-metering implementation in residential buildings have being created in several cities. SABESP, the biggest state Water Utility Company in Brazil, is currently developing a program in conjunction with the academy for professional training for the design, construction and operation of sub-metered water supply systems (ProAcqua 2009).

Summing efforts to those actions, it is paramount to stimulate designers, constructors and other stakeholders to incorporate sustainable building concepts in their practices. Standardization could do this, but it usually establishes only the minimum performance requirements and it is not enough to differentiate different levels of sustainable performance (Silva 2003). In this context, researchers of five Brazilian universities worked on the development of a sustainability assessment system for social housing in Brazil, having water conservation as one of the categories considered (John et al 2007). This paper presents how water conservation actions have been developed in Brazil and the main challenges ahead. Two case studies are presented to illustrate the savings from water conservation programs implemented in existing buildings at the University of Campinas (UNICAMP) campus and at municipal schools in the city of Campinas, Sao Paulo.

2. Water conservation - a decade of actions

The need for conservation policies has become evident in Brazil since the mid 80´s, particularly after the International Symposium on Water Economy of Public Supply, held in 1986. Since then, some initiatives had certain continuity; but only after the 1990s, conservation concerns attracted enough attention to offspring more focused actions, such as the Rational Use of Water Program in Sao Paulo (PURA), launched in 1995. PURA was developed based on an agreement among the University of Sao Paulo (USP), the Sao Paulo State Water Utility Company (SABESP) and the Institute for Technological Research (IPT). This program included development of technology database, institutional laboratories, technology evaluation programs, analyses of water conservation programs in residential buildings, quality programs and specific water conservation programs in different building typologies. In 1997 four case studies were developed in Sao Paulo. The first study was developed in two elementary schools, the second in a police station, the third in a hospital and the last one at USP campus. From this point on, several water conservation programs started to be developed, more intensively at first in the state of Sao Paulo, and then in other regions of the country (Silva et al 2002).

The National Program of Water Conservation (PNCDA) was launched two years later. PNCDA developed technical support documents comprising planning of the conservation actions, technology for public water supply systems and for water supply and drainage systems in buildings, as well as educational campaigns.

In 1998 the Federal Government launched the National Program of Quality and Productivity in Housing (PBQP-H), with the major purpose of combating non-conformity of building materials and systems components. Among PBQP-H Sectorial Programs, the one dedicated to vitreous china plumbing fixtures had specific goals concerning toilets and discharge appliances, which resulted in limitation of toilets discharge volume to under approximately 6 litres by 2002. This program is unique and represents a very successful partnership between the industry and the academy to improve performance of water consuming components.

The National Water Agency (ANA) was created in 2000, aiming to implement the national policy of water resources established by the federal act 9433/1997. This agency has the mission of regulating water use in the country and promoting its sustainable use, avoiding water pollution and wastage and ensuring water quality and quantity to current and future generations (ANA 2009).

Other initiatives concerning water conservation have been carried out, also out of the federal field of action. Since municipal laws have been implemented, water sub-metering is becoming more frequent in multi-residential buildings. In the second half of 2007, SABESP signed an agreement with the Center of Development and Documentation of the Building and Urban Infrastructure (CEDIPLAC) to guarantee the performance of these systems. Three parts compose this program: professional training, technological innovations and environmental education (ProAcqua 2009).

3. Water conservation program for existing buildings

Within PURA's scope, a methodology was proposed in 1999 for the development of water conservation programs in buildings (Oliveira 1999). The methodology is structured in three steps: consumption analysis (consumption history investigation, investigation of cold and hot water supply system and the users' activities, preliminary analysis of the consumption), consumption diagnosis and definition of the intervention plan.

From the consumption analysis, the water consumption indicator (IC) can be determined. The IC is the relation between the volume of water used during a certain period of time and the number of consumers agents in that same period. The consumer agent is the most representative variable of the use of water in a given building type (for example, inhabitants, for apartment buildings, and students, for school premises). Investigation of the cold and hot water supply systems and of the users' activities aims to understand the water consumption pattern of the building. It involves the registration of water points of use, leak detection, investigation of special water supply systems (for water towers in the central air conditioning system, for example), non potable uses and water quality required and, most important: the users' behaviour when using water.

After these activities are concluded, the water consumption diagnosis can be carried out and expressed through several indexes, such as: the leakage index (relation between the number of leaking points and the total number of points of use of water), the water loss index (relation between the lost volume in leaking during a certain period of time and the total volume of water used in the building in the same period), and others. It is also necessary to identify the activities responsible for the largest amount of consumption in the building and the main actions to reduce the identified wastes (Oliveira 1999).

The intervention plan must be prepared from results of the consumption diagnosis and involves a preliminary techno-economic analysis for the definition of actions to be implemented. In buildings in operation, the main activities to be proposed are users' awareness, leakage correction and installation of water saving components. For maximized effectiveness, such activities must be followed by the implementation of a consumption management system that allows regular consumption checking. In this sense, sub-metering has a fundamental role. However, installation of water meters does not represent savings per se, it is necessary to manage the collected data in order to decrease and control water consumption. Regular maintenance is not a reality in some cases in Brazil and it is common to find - discrete and significant - leakages, particularly in public buildings. It is also frequent to find people doing their activities with a great quantity of water (dishwashing, tooth brushing and landscape irrigating with a continuous flow, taking a long shower, among others). Consequently, actions that address these topics have a great impact in the water consumption.

3.1 Case studies

Both case studies discussed here were developed in Campinas, Sao Paulo, Brazil. Campinas is a city located about 100 km away from Sao Paulo city, with an area of 795,697 km² and population of 1.059.420 inhabitants in 2006. The first case study was developed at the campus of the University of Campinas (UNICAMP), which was officially inaugurated in 1966. The campus encompasses approximately 250 buildings spread over a large extent of land, about 518,675 m². In 2006, there were 17,275 undergraduate students and 22,044 graduate students, summing up a daily population of more than 40,000 people. In 1999, when PRO-ÁGUA, the campus water conservation program, began, the monthly water consumption was around 98.000 m³. The second case study was carried out in a group of nursery and elementary public schools. The Brazilian school system consists of private and public schools, and is composed by nursery school, elementary school, high school, undergraduate and graduate school.

3.1.1 Campus of the University of Campinas

The first activity within PRO-ÁGUA was the investigation of the cold water supply system and the users' behaviour while executing water-consuming activities. Faucets are the most frequent fixture (approximately 30%), washbasins ranked second. There were 1269 close-coupled water closets and 1003 valve operated water closets, representing 10.4% and 8.2% of the total number of sanitary fixtures, respectively. Sink faucets represent about 15.6% of the total number of fixtures and the majority of these fixtures are located in the laboratories. The incidence of failures is similar for all types of sanitary fixtures. About 231 sanitary appliances presented some kind of failure, being the most frequent ones found in the faucets, which presented leakage indexes between 1% and 38%, with an average of 15.3%.

Figure 1 illustrates the leakage indexes for two buildings in the university campus. The correspondent water consumption diagnosis demonstrated that the following actions should be prioritized: leak repairing; installation of water saving components and installation of sectored water meters in the campus. Lavatory and urinal faucets were chosen for the installation of water saving components, because these devices are present in all buildings and do not require major adaptations in the building system. Metering faucets were installed in 2118 lavatories and in 531 urinals.

After leakage repair, water consumption decreased between 4 and 25%, in average. The range of reduction in consumption by installing water-saving components was between 2 and 46%, in average. Figure 2 shows the water consumption reduction after these actions for four buildings of the UNICAMP campus.

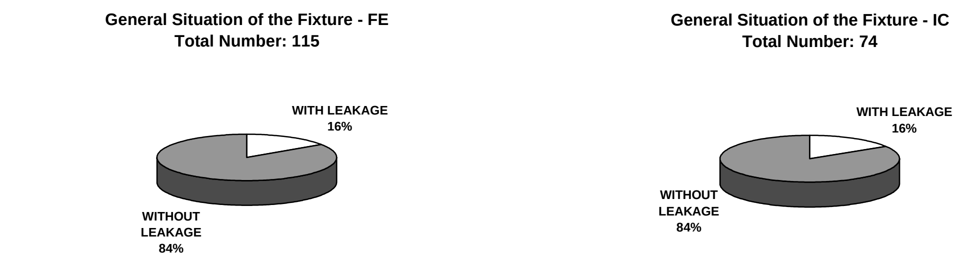


Figure 1: Leakage index of two buildings of the UNICAMP campus

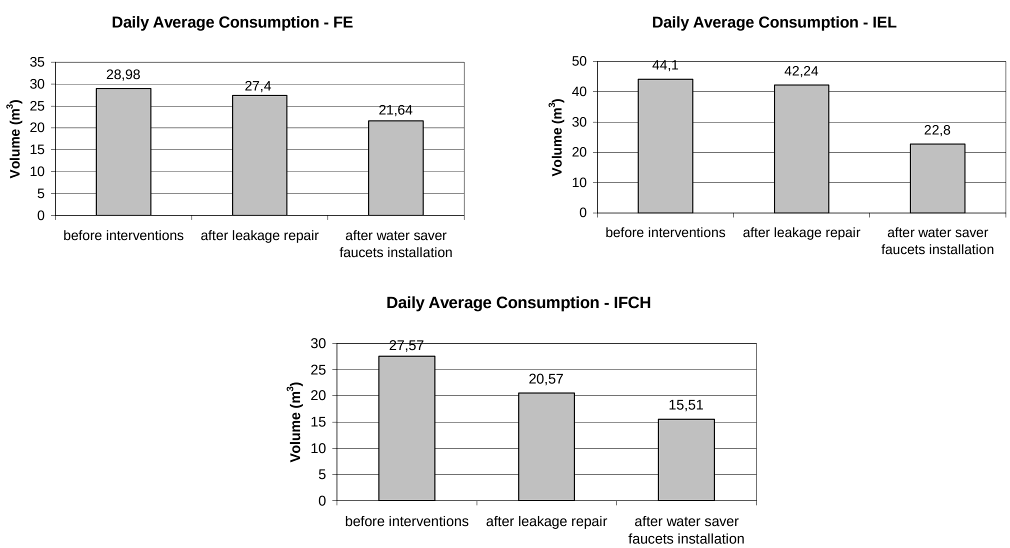


Figure 2: Daily average consumption after leak repair and water saving equipment installation for a sample of buildings

Questionnaires were applied to evaluate the users' satisfaction with the water saving components. Approximately 89% of 1201 users considered the new lavatory faucets as better or equal to the older ones, and 84% of the male population said new urinal valves are better or equal. Figure 3 shows that the water consumption of the campus has decreased in 24% from 1999 to 2001. It represented about an economy of R$240,000 (approximately USD 130,000) per month on that date.

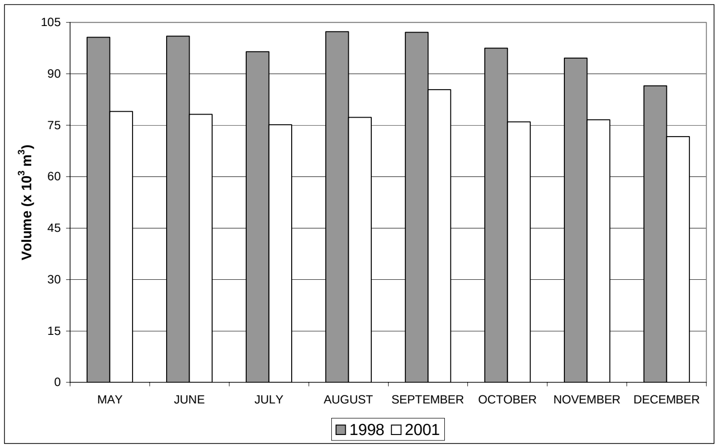


Figure 3: Reduction of the total water consumption at the UNICAMP campus due to PRO-ÁGUA

3.1.2 Nursery and Elementary Public Schools Campus of the University of Campinas

Although this research project contemplated four types of public schools, only 122 units of nursery and elementary schools were included in this paper's scope. Based on the water consumption indicator, geographic location and type of school, 73 units of nursery and elementary schools were investigated (46% of the public municipal nursery units on that date). As in the study carried out at the UNICAMP campus, the first activity was the investigation of the cold water system. Obtained results indicated that 60.3% of the valve operated WCs and 57% of the lavatory faucets had leakage indexes up to 50%. The highest leakage indexes were found in the appliances to which students have direct contact. In addition to specification of durable components and implementation of preventive maintenance routine, it is necessary to develop a general program for water conservation awareness among users in order to reduce the leakage rate.

A questionnaire was applied to survey the water usage. Interviews were carried out and complemented by a field observation in three schools to determine a typical water consumption day and to estimate the consumption distribution. Obtained results showed that (a) for the nurseries, 45% of the consumption is in the bathrooms, 43% in the kitchen and cafeteria, 8% in the laundry and 4% in external spaces; (b) for the kindergarten units, 71% of the consumption is in the bathrooms, 25% in the kitchen and cafeteria, and 4% in external spaces; and (c) in the pre-school units, 86% of the consumption is in the bathrooms, 10% in the kitchen and cafeteria, and 4% in external spaces. Intervention plans were elaborated based on these results and the resultant impacts estimated and reported to the Municipal Department of Education, which started implementation of the recommended actions according to the resources available. Afterwards, a pilot study was developed in a sample set of fundamental schools (seven to fourteen year-old students). A technical analysis assessed the installation of water saving components in a typical fundamental school. Table 1 shows actions planned for that school.

From observations of users' behaviour, it was verified that the students' toilets accounted for the greatest consumption levels, followed by the kitchen, and therefore should be prioritized in the installation of water saving devices.

Table 1: Intervention plan for a fundamental school.

Sanitary appliance	*Intervention: installation of*
Valve operated toilet	*low flush toilets (6.8 litres/flush)*
	low flush toilet with anti-vandal finish
Lavatory faucet	*metering faucet*
	metering faucet with anti-vandal finish
Channel-like urinal	*individual urinal with metering valve*
	individual urinal with anti-vandal metering valve
Sink	*faucet with aerator*
Tank	*faucet with aerator*
General use faucet (external)	*restricted-access faucet with a screw*

In practice, such actions are usually implemented gradually, prioritizing the points with the greatest impact on consumption, so as to gather resources, from the savings, to finance implementation of further actions. The case study status allowed however for evaluation of other combinations and situations, so water saving components were installed in all consumption points. Table 2 shows the estimated consumption reduction. The average historic consumption indicator was 23.7 litres/student*day, which multiplied by a total of 585 students and 22 workdays in a month, would result in a consumption of 305,019 liters (305 m^3) of water per month. Applying the estimated reduction, the monthly consumption would decrease to 139m^3.

Table 2: Consumption reduction estimation.

Settings	*Appliances*	*Current consumption (litres)*	*Estimated consumption after installation of water saving components (litres)*
WCs *KITCHEN* *OUTDOOR Areas*	*Lavatory, valve operated toilet, urinal, sink, tank (laundry), faucet*	*13,238*	*6,036*
Estimated consumption reduction			*54,5%*

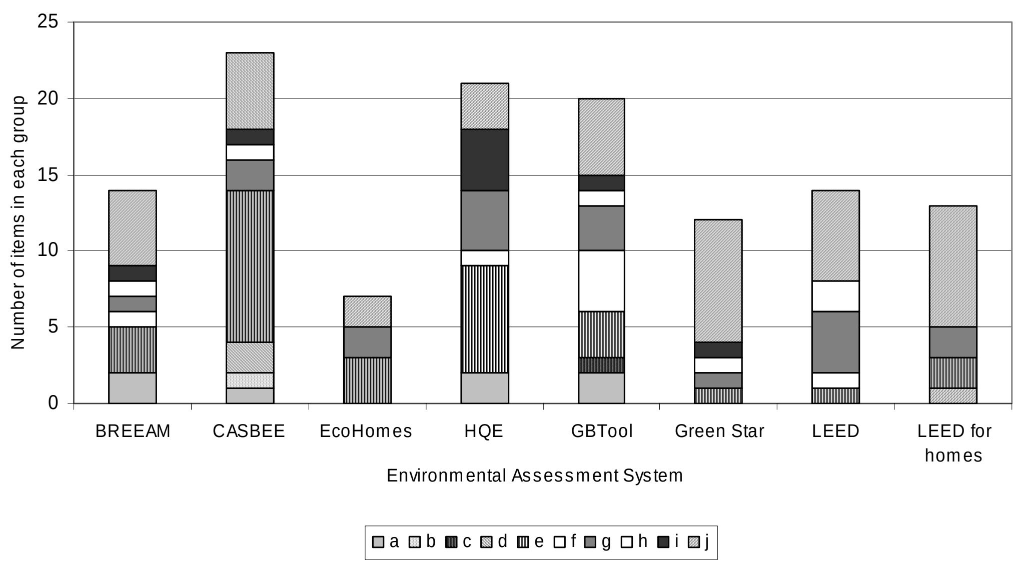
Much has been done in Brazil toward water conservation implementation in buildings in operation. On the other hand, for new buildings, water conservation action is not as advanced. It is necessary to develop mechanisms that would engage agents in the construction industry supply chain to demand and provide higher sustainability performance at all levels and allow users to identify buildings with distinguished environmental performance levels. In both fronts, building assessment and rating systems can play a fundamental role.

4. Environmental assessment systems in use in Brazil

2. From analysis of some of the most relevant environmental assessment methods around the world, topics related to water supply and drainage systems in buildings and water usage may be grouped in the following categories, (

Figure **4**): adaptability, functionality and maintainability, reliability, costs, energy, selection of products, materials and construction processes, site selection and interference of the building with its surroundings, load on the local infrastructure (rainwater), load on the local infrastructure (sewage), health, air and water quality and water conservation.

A poll conducted in 2002 among different stakeholders in the construction industry (Silva, 2003) unveiled that the most challenging environmental issue perceived for the City of São Paulo was water scarcity, ranked higher than aspects like materials impact on human health (65%), noise pollution (63%), CDW management (63%), overall implementation costs for environmental measures (56%) and maintenance easiness (56%), as shown in Figure 5.



a - adaptability, functionality and maintainability **b** – reliability **c** – costs **d** – energy
e- selection of products, material and processes **f** – site selection **g** – local load (rainwater)
h – local load (sewage) **i** – health and air and water quality **j** – water conservation

Figure 4: Topics related to building systems (water supply and drainage) in selected environmental building assessment systems

A similar survey in Germany (Blum et al. 1999 cited OECD 2003) indicated that perceived relevancies for both demand (i.e. water saving fixtures) and supply management (i.e. alternative water source) were very closely ranked, and surpassed only by issues related to energy use in a temperate climate, environmental quality of materials and governmental action to increase renewable sources in the country's energy matrix. Conversely, in the São Paulo context, while water saving fixtures and devices were considered as extremely relevant (71%), alternative rain water use was considered essential by only 12% of voters, and would therefore receive a very low relative relevance had an assessment method been developed at that time.

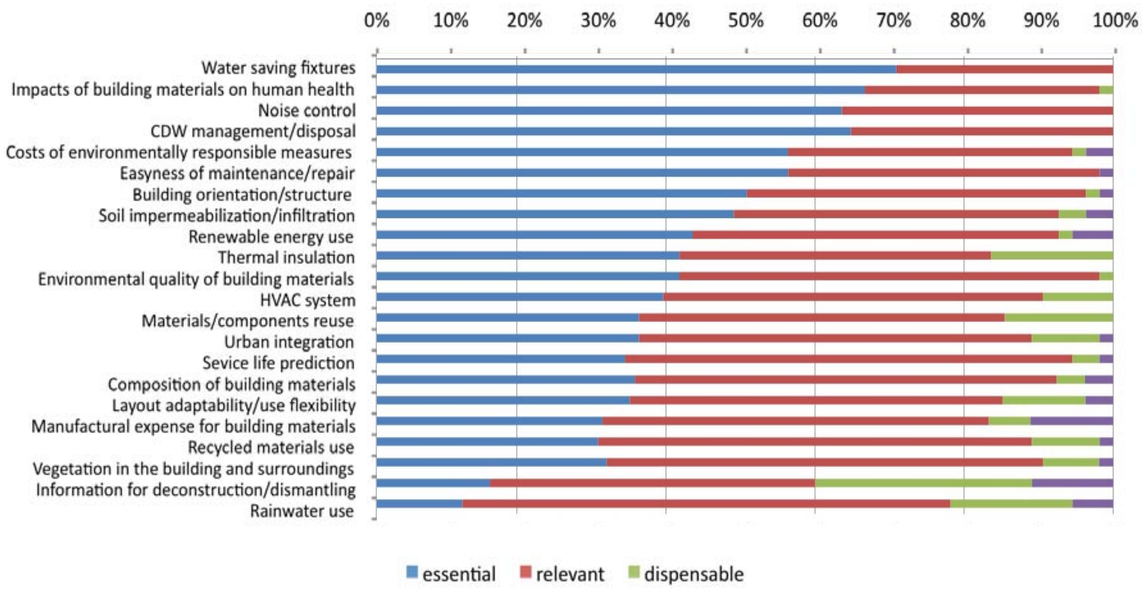


Figure 5: Perceived relevance from items to compose the environmental assessment module of buildings in Brazil (Silva, 2003). Voters could choose from four relevance levels: "essential", "relevant", "dispensable" and "no opinion" (in purple)

Since then, three building environmental assessment methods have entered the Brazilian market: LEED, the AQUA Process (High Environmental Quality), and IPT (Institute for Technological Research) Environmental Reference. The latter two methods were specifically developed based on local demands. The AQUA Process is based on the French method HQE (Haute Qualité Environnementale) and has 14 items grouped in 4 categories: sustainable construction, resources management, comfort and health. Water demand management represents 10.5% of the total score (Fundação Vanzolini 2009). On its turn, the IPT Environmental Reference considers 6 categories: urban environment, water conservation, energy and atmosphere, materials and wastes, indoor air quality and building performance. In this method, 20% of the total score is dedicated to water demand management (Techne 2009). All these methods attribute credits to supply management, considering not only rainwater harvesting systems but also grey- or even black water reuse. Nevertheless, standardization related to alternative water use in Brazil is still a very incipient approach.

A research project for the development of technologies for more sustainable housing construction has been carried out since 2004 by a multidisciplinary team of researchers from five Brazilian Universities. This project is sponsored by FINEP (Research and Projects Financing) and CNPq

(National Council for Scientific and Technological Development) aiming, among other goals, to develop a methodology for assessing the sustainability of residential typologies in the design phase (John et al. 2007). The proposed assessment methodology comprises nine categories: water, energy, materials selection, components and systems, outdoor areas and infrastructure, indoor air quality and health, construction site, operation and maintenance, social management and construction management. The category dedicated to water contemplates three issues: (1) reduction in the consumption of potable water, by limiting the flow rate at the points of use, reducing the use of potable water for irrigating the landscape or using alternative water sources, (2) water consumption monitoring, trough sub-metering, and (3) management of rainwater, by controlling the volume of rain water directed to the public drainage system (Ilha et al. 2009).

These methodologies can help Brazilian professionals to select the best alternatives for the design; however it may be not enough for guaranteeing the rational use of water in the use phase. Equipments play their role up to a certain extent, but *people* will be ultimately responsible for the water consumption when the building comes into operation. It is therefore critical to reinforce the importance of commissioning, a step often neglected for water systems but fundamental to check design and installation conformity, teach people how to use water rationally and also ensure operational training by building handover (Silva 2009).

5. Final remarks: the challenges ahead

The results obtained in both case studies presented in this article indicate great impact of water conservation action and should be implemented in different kinds of buildings around the country. However, despite efforts for developing strategies for water conservation, there is still much to be done for the effective its effective incorporation into the design and construction reality in Brazil. Firstly, main established national standards for design of - cold and hot - water supply and drainage building systems, which were published more than ten years ago, do not contemplate water conservation consistently. For example: water sub-metering and the optimization of the consumption by using pressure and flow regulators or other types of water saving technologies, which are important issues for water conservation, are not considered in the standard. Systems for non-potable water use, which are encouraged by all environmental assessment methods, are only treated in a simplified standard for rainwater harvesting, implemented in 2007, and punctual water reuse topics in local standards for sewage treatment systems. There is no standard in place for gray water reuse, regardless of the several risks posed by the use of non-potable systems, such as unpredicted cross-connection and water misuse for activities other than planned.

Designers and builders should be able to design these new systems and it is therefore fundamental to promote the necessary training of all professionals involved in the process. Universities must urgently incorporate the concept of sustainability in their curricula. It is also important that engineers and architects work together since the design outcome, in order to define the best strategies to be adopted. Linear, sequential project development needs a paradigm shift towards integrated design process (7GROUP et al. 2009). Still, all the actions described above do not guarantee that actual future consumption of water in buildings will be as planned. People - and not just equipments - will be responsible for the water consumption when the building comes into operation. Hence, commissioning of the water systems is of paramount importance to ensure building systems perform as designed, instruct users on rational water and ensure operational training by building handover.

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Education Challenges for Sustainable Design and Construction

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Abstract

Delivering buildings with higher environmental and social performance objectives, at a feasible cost, requires re-invention of the design and construction processes, but so far it usually proceeds in fairly traditional phases, while the sustainability focus makes the content of each phase substantially more complex. A building delivery process that facilitates continuity of thought coupled with understanding of sustainable design concepts is crucial. Integration is fundamental not only within the design teams, but also across the design and construction workflow, in order to facilitate this continuity and understanding. Based on a generic green building delivery process model, this paper highlights the activities required at each stage to integrate green innovation. Authors then briefly review the current teaching status of the desirable professional capabilities identified in Brazilian undergraduate building programs, and share their reflections on possible approaches and methods to further induce knowledge-building for future professionals.

Keywords: sustainability, building design, architectural design process, engineering education, environmental literacy

1. Introduction and background

Achieving a clear pathway towards a sustainable future requires innovation and organizational change, so that building professionals have the core understanding or vision for sustainability - not just the integration of sustainability concepts within the curriculum. Universities worldwide have reacted through adoption of different policies, like encouragement of development of “capabilities” curriculum (Graham et al. 2003) and other innovative approaches and methodologies to explore sustainability across the disciplines in higher education and explore ways of changing curriculum and graduate skills towards sustainability (Tilbury et al. 2004).

Sustainability goals boost the demand for design integration in pre-design and design phases, which on their turn requires:

- New team compositions;
- Identification of interconnected decision areas;
- Establishment of goals and tangible metrics of design sustainability;
- Use of adequate tools for design integration support;
- Active building process management (on strategic, tactical and operational levels).

A building delivery process that facilitates continuity of thought coupled with understanding of sustainable design concepts is crucial to the successful delivery of buildings with higher environmental performance objectives (IEA 2001; Mendler 2001; Isaacs 2002; Kibert 2005). Integration is fundamental not only within the design teams, but also across the design and construction workflow, to facilitate this continuity and understanding (Lewis 2002).

Even though delivering more sustainable building requires this re-invention of the design and construction processes, so far it usually proceeds in fairly traditional phases, while the sustainability focus makes the content of each phase substantially more complex. Whatever the case is, environmental literacy of involved professionals becomes crucial (Graham et al. 2003). Environmental literacy is a function of understanding of required environmental knowledge, coupled with technical ability and willingness to use that accumulated knowledge (Orr 1992). An environmentally literate building professional not only knows how to design, construct or manage buildings that contribute to ecologically sustainable development, he or she is also confident enough to *act* on the basis of the acquired knowledge (Graham et al. 2003).

2. Approach

A generic green building delivery process model was developed. Agents, activities and knowledge/capabilities required at each stage to integrate green innovation are pointed out. Brazilian undergraduate building programs are briefly reviewed regarding current teaching statuses of the identified desirable professional capabilities. Possible approaches and methods to further induce knowledge-building for future professionals are discussed.

Error! Reference source not found. highlights some major process and decision-making activities, and professional essential capabilities to typical delivery process for buildings with sustainability performance objectives. If the goal is also to tackle social aspects and configure the so-called strong sustainability, other objectives and capabilities are added.

Table 1 – Delivery and use process for buildings with environmental performance objectives.

CONCEPTUALIZATION

• ***Develop a sustainability brief (water, energy, waste, materials, IEQ, social, economic)***
• ***Assemble a sustainable design and construction (SDC) team***
    • *Require that design services address certification processes and documentation*
    • *Include SDC expertise requirements in RFP/RFP*
    • *Employ SDC consultant(s)*
    • *Develop consultants briefs*
• ***Conduct pre-design meeting***
    • *Develop a SDC vision*
    • *Establish Sustainable Design Criteria, targets and benchmarks. Set priorities*
    • *Establish certification targets, if applicable*
• *Investigate subsidies and finance opportunities to facilitate integration of elements for higher performance levels/certification*
• ***Develop performance-based building program***
• ***Establish energy and lighting budget***
• *Develop partnering strategies*
• *Develop project schedule*
• *Review laws and standards*
• *Conduct research*

DESIGN
Schematic Design • *Assess site biodiversity/potentials (e.g. for building reuse, local partnering/logistics)* • *Confirm sustainable design criteria* • *Refine targets with project team for inclusion in contracts* • *Set* ***sustainability budgets (water, energy, waste, materials, IEQ, social)***

- *Develop reporting and verification documents/tools for all SDC areas*
- ***Develop sustainable solutions, compliant with briefs defined***
- ***Start building modelling (energy and thermal, BIM, 4D, 5D)***
- ***Evaluate sustainable solutions** for compliance with budget and targets**.** Conduct **value** engineering/**continuous cost optimization** (30%)*
- *Report on progress*

Design development

- ***Integrate systems***
- ***Develop monitoring techniques, including equipment needed and protocol documents**. **Develop a commissioning plan***
- ***Refine** sustainable solutions. **Evaluate sustainable solutions against set targets.** Conduct **value** engineering/**continuous cost optimization** (60%) Construction Docs*
- *Commission design docs*
- *Develop a vendor list, according to materials brief/targets*
- *Verify material **test** data. Check compliance with brief*
- ***Document** sustainable materials and systems. Report on progress*
- *Accommodate documentation for certification (include in specifications and organize necessary templates and protocols/plans).*
- *Conduct **Quality** Assurance and **Review***
- *Conduct **value** engineering/**continuous cost optimization**, Check cost (90%)*
- *Report on progress*

Documentation

- *Update specifications to ensure intent of brief supported*
- *Check specifications comply with sustainability brief*
- *Check contract docs against set budgets*
- *Report on progress*

CONSTRUCTION

Bidding

- *Develop pre-tender induction for each trade*
- *Include SDC areas in tender assessment docs*
- *Include SDC areas in tender contracts*
- *Hold pre-bid walk-through:*
    - *Discuss green goals and solutions developed*
    - *Discuss certifications specific requirements (such as plans, special submittals and procurement process for construction*
- *Report on progress*

Construction • *Hold pre-construction meeting* • *Develop **sustainability briefs (water, energy, waste, materials, IEQ, social, economic)** reporting checklists* • *Develop environmental management plan for site/neighbourhood relationship channels* • *Develop induction for trades with construction team* • *Check design for compliance with budget and targets* • *Set prescriptive requirements* • *Detail SBC accounting procedure agreed and applied* • *Monitor and review submittals of all documentation for green products & systems, by contractor* • *Evaluate substitution requests and materials submittals, based on environmental goals established* • ***Commission** the systems. Test and fine-tune (water, energy) building systems, special systems/components, check materials, test IEQ* • *Report on initial compliance* • *Ensure development of detailed operation and maintenance materials/training required* • *Report on SDC additional costs/efforts/problems/lessons learned* • *Develop materials schedule compliant with IEQ plans* • *Demonstrate program of building tuning and adjustments to suit occupancy and actual operation* • *Final demonstration of compliance with budgets, targets and prescriptive requirements set* • *Develop simple building user "how to", with phone numbers of all maintenance staff members* • *Set up maintenance schedule and reporting mechanism* • *Put **"black box"** in building with as-built plans and SBD area schedules (e.g. materials list, vendor list, design for disassembly plans)* • *Monthly report on progress*
POST OCCUPANCY
Facility Operation & Maintenance • *Hold **pre-occupancy education & training** meeting to educate building users and O&M team about sustainable attributes of the project and how to operate and maintain the building* • *Perform planned **maintenance.*** • *Conduct **post-occupancy** (performance-in-use) evaluation* • ***Regularly measure and confirm** (building/systems) performance* • *Document performance-in-use.* • *Report on maintenance schedule* *Refurbishment* • *Carry out a LCC-benefit analysis on technology improvement. Refer to materials schedule* • *Ensure refurbishment represents a net sustainability benefit* *Demolition* • *Use "black box" to plan recycling and reuse schedule*
***Source:** Modified from Public Technology Inc. (1996), Graham et al. (2003), Silva et al. (2009)*

In addition to learning what these activities and interventions contribute to the project, students must also develop the professional capabilities that will allow them to effectively implement sustainability strategies (Graham et al. 2003).

During conceptualization, organizational and management capabilities are strongest players. With the exception of the multidisciplinary "green" team, most of them are already well known and integrated to a typical project delivery process. Major distinctions are related to (1) establishment of green design goals and criteria, which demands previous knowledge not only about what it means, but also about how to measure and to verify if and when they are reached; (2) development of performance-based building programs, which demands migration from the comfortable tradition of using prescriptive parameters to performance-based ones, not completely manageable at design stage; and (3) establish energy and lighting budget, which demands integration of building simulation and a solid previous knowledge on building energy performance indicators. Building professionals are usually very little familiar with these three elements.

In design phase, it is expected that professionals be able to (1) not only develop green solutions, but – again - also to (2) evaluate their performance/success, and (3) integrate systems for optimal performance. Systems integration depends largely on the integration of the team and design process as a whole. Cost checks are usually the most familiar part, very present in traditional process. The key change here is the change in focus from seeking the lowest possible cost or opportunities to cut costs, to interactively estimating costs of the best added value solution.

In the construction phase, tasks are mostly related to (1) ensuring that what was designed is actually built, which demands an overall knowledge of best environmental alternatives and keeping an attentive eye on commissioning; and (2) if the project seeks some kind of certification, providing proper documentation. In Brazil, commissioning is a term familiar only for professionals in the HVAC, special systems or risk-involving fields, being practically unknown in the building sector. In the past two years or so, this has changed a little, mostly due to introduction of foreign building environmental certifications in the Brazilian market. Commissioning is still seen as a bureaucratic step more than an opportunity to ensure the designed performance across the building service life. Communication with and across construction teams is fundamental, as many good solutions may grow from bottom-up. Effort to provide suppliers, purchasing, materials and components physical and performance testing, commissioning procedures documentation is also exaggeratedly magnified, as it is the strongest driver pushing outward contractors' comfort zones.

Finally, the occupancy phase is virtually never taken into account (Silva et al. 2009). Except for the residential sector, owner-occupied building models represent a tiny parcel of the Brazilian market, which is clearly characterized by a vast dominance of speculative construction. The resultant premature shortening of the delivery process perspective reinforces negligence of performance in-use assessment. Continuous performance monitoring during use and POEs are rare and usually restricted to academic circles, despite their potential to detect opportunities for significant improvements in performance upon often rather simple adjustments. Students must be trained to conduct them and to see them as an integral part of their daily practice and, most of all, to create the culture of documenting their work and use it to improve their own skills in future projects.

3. Analysis of the current teaching status of the desirable professional capabilities identified in Brazilian undergraduate design and building programs

In Brazil, structure development for SB education and training has not followed the recent, rapid growth of interest within the construction community on the theme (Gomes et al. 2008). Setting aside environmental management topics in specific careers, sustainability issues are seldom inserted in pedagogic structures. SB-related courses are predominantly elective courses, suggesting this might have been the path found to insert new content without requiring dramatic curriculum reformulations. Undergraduate courses are most frequently related to indoor comfort, building physics and generic courses on building and the environment; while courses on building simulation, waste recycling as building materials, sustainability of the built environment, water management in buildings, and facilities management appear at graduate level. Due to the little awareness among construction stakeholders and virtually inexistent qualification for designers, planners and workers, conclusions from several design and construction meetings and round tables on the subject have consistently pointed out capacity building for knowledge multipliers as the most challenging barrier to be overcome for consolidation of sustainability as strategy for the Brazilian construction sector (Gomes et al. 2008).

No common set of guidelines for planning, design, construction and operation of a more sustainable built environment are available for local conditions. Committed professionals must overcome the language and technological barriers while analysing foreign recommendations and standards under the light of local climate and peculiarities. Knowledge transfer and education on the client side can break a vicious circle and creates a virtuous one instead as future users/occupants are slowly becoming aware of building impacts and the meaning of sustainable building. Sustainable practices that are already part of the building culture and traditions are still not perceived as such and the idea of a sustainable building is currently linked to and limited by the presence of a certain technology and a combination of odourless paints, green roof, water sub-metering and solar panels for water heating (Gomes et al 2008).

Education and training (E&T) at all levels and for all stakeholders are important drivers for change and strategic initiatives to foster SBC implementation include (Gomes et al 2008):

- Introducing concepts in programmes at all complexity and formality levels, awareness raising of market actors, civil society and government spheres, amplify formation of specialists;

- Introducing sustainability assessment of the built environment into regular design practice;

- Formatting and implementing training through close synergy between local and international specialists.

- Reinforcing regional research network, by establishing centres of excellence and increasing international collaboration;

- Creating Demonstration Projects;

- Creating and enhancing knowledge transfer opportunities, by training architects and planners on one side, and adjusting developers and decision makers towards SBC on the other.

Sustainable design ultimately means to work out of professionals' comfort zone, as traditional practice is evidently not working anymore. As a "green" building is ultimately the outcome of "green" decisions, professionals and students therefore need to develop an understanding of how to make such decisions, and manage the green building with the appropriate procedures which ensure that the "green" innovations are integrated. An important goal for education in building professions is obviously helping students to develop their environmental literacy (Graham et al 2003).

Several of the abilities/activities that compose integrated delivery processes are currently treated by undergraduate architecture and engineering courses as skills attributable to the so-called *specialists* that can be hired in case of *special* needs, so that the architect or engineer does not really need to have them. Particularly in the case of energy performance, heavily weighted in the broader sustainability concept, it is impossible to advance in design if designers do not have a solid foundation on building physics, low-energy and bioclimatic concepts (Kowaltowski et al 2005). Simulation must also be introduced as early as possible to future designers, who should be able to understand and - even more important –question results (Delbin et al 2006). As pointed out by Reed (cited Yudelson 2008), it is critical to break up the narrow boundaries of specialists to return to a more holistic way of viewing design. The author continues: *"…shifting the nature and practice of design from a linear, simplistic cause-and-effect process to one that considers issues from multiple and interrelated systems perspectives is resisted more than any other aspect of green design"*. Market professionals still lack tools to completely instrument and support such process reinvention though, as it will be further discussed in the next section.

4. Possible approaches and methods to further induce knowledge-building for future professionals.

Continuous learning and update programs for faculty members' must be structured as they were probably trained to cope with an obsolete and slower-changing context. Knowledge about the environmental effects of building (as a process) and of buildings (as outcomes) should be taught (Graham et al. 2003). Environmental knowledge must be gained as the students learn about the building development life cycle and the roles that different project stakeholders play in adhering to environmental performance requirements at different project phases. Such knowledge should always be put in a decision-making context, as teaching environmental knowledge in stand-alone subjects, disconnected from problem situations which this knowledge must influence, undermines the development of students' ability to learn how or when to enact their environmental knowledge.

From the architectural education perspective, authors argue for an approach that structures and models design thinking to make explicit for students the knowledge to be learnt and the strategies they might use to integrate and construct this knowledge in a project. Because of design studio experiential tradition, however, project-based learning is considered a particularly effective way to engage students in design learning (Quinlan s.d.). Moreover, this approach uses design projects to create a real-world context, which favours environmental literacy development.

Evidence-based design appears as a more recent approach, particularly relevant when it comes to sustainable design, requiring command of multidisciplinary knowledge and computer analysis tools. Similarly, for civil engineering education, the critical point seems to be the integration between a strong knowledge of mathematics and physical concepts taught and their engineering applications in properly designing, analysing, cost estimating, constructing and operating the built environment.

The 2005 update in Brazilian engineering curricula enforced, among others, mandatory graduation final assignments. The most promising possibility to emulate real world experience appears through special whole-building design ateliers, which integrate advanced architectural studios and final assignments across different engineering courses and even with other backgrounds. Though apparently simple, this is also the most challenging effort, since in most cases it would require profound adjustment of curricula structures across distinct teaching units.

Hedges et al. (2009) stress the role of collaborative models for design curricula connection to foster socially responsible, green building design and experimented distance collaborations involving students of architectural and engineering programs in three universities to understand the nature of student collaborations connected with other disciplines. Similar experience is described by Beckman et al. (2006) for green product development.

Either in professional practice or in education environments it demands a great deal of effort to adapt and shift away from a compartmented teaching with stand-alone subjects to an integrated and multidisciplinary way to build the student's knowledge on the design and construction process. Similarly, conventional studio's atmosphere does not use the necessary tools or offer an environment integrated and multidisciplinary enough to solve real world problems. Architectural design is taught in isolation. So are all other design disciplines. Final architectural studios claim for integrated solutions, but seldom reach this goal in full extent. If integration is not experienced at formal learning environments, the learning curve while in practice will be enormously elongated, at high rejection rates.

5. Conclusions

Integrated practice introduces the design consultants (other disciplines) earlier during the conceptualization phase, in a connection that occurs prior to the commencement of criteria design. The result is a condition where other disciplines are acting as equal project stakeholders at an earlier juncture contributing to potential architectural design outcomes. Development of Building Information Modeling (BIM) platform not only facilitates this new stakeholder partnership but also supports the second emergent theme of sustainability: the ability to manage information about building materials and building processes and carry out performance simulations (Hedges et al. 2009). Performing whole building energy, water, and carbon emission analyses early in the design process is essential for sustainable building design and a fairly difficult undertaking in a traditional CAD workflow, due to models interoperability and training limitations. As part of the BIM workflow, on the other hand, analysis process is greatly simplified, allowing architects to get immediate feedback on their design alternatives, as well as to early collaborate with their MEP and other design partners. For the high-quality, computable design information it provides, even on early stage building designs, BIM is seen as the process cornerstone to support design integration and analysis accuracy.

Also, BIM can be considered as a technology with which lean construction is likely to progress, once they are complementary in several important ways. When applied to building design, lean thinking implies: reduced waste through the elimination of unnecessary process stages that provide no direct value to the client, such as with producing drawings; concurrent design to eliminate errors and rework, as far as possible; and shortened cycle durations (Koskela 1992; LCI 2004 cited Eastman et al. 2008). BIM enables all these goals which are also required for sustainable design and construction. Nevertheless, interoperability remains one of the major concerns to applying this methodology. Its usefulness will naturally be proportional to familiarity to the used modelling tool features but, more relevant: to previous availability and degree of integration to model databases.

Because BIM is a revolutionary shift away from drawing production, the set of skills needed is quite different. Whereas drafting is the laborious act of expressing ideas on two-dimensional media, whether paper or screen and demands familiarity with the language and symbols of architectural and construction drawings, modelling is akin to actually erecting a building and demands a very good understanding of the way buildings come together. It therefore makes very good sense for skilled architects and engineers to model directly, rather than instruct others to do it for them solely for recording sake.

However, most architecture and engineering courses still restrict teaching of applied computing to CAD software use, losing sight of the benefits of building simulation and BIM, perhaps the most promising integrative synthesis to design process. Great expectations fall over BIM as a methodology to leverage the construction industry integrated project process which involves improved information quality, building products, visualization tools, cost estimates, and analyses leading to better decision-making during design. It is an optimized way of thinking the building project from the beginning, providing an adequate environment for a collaborative integration of the design team, owners, contractors, subcontractors and all stakeholders, as well as for an education context. It means a new approach to building construction, enabling considering sustainable measures and evaluating them along all project phases.

Leading schools of architecture and civil engineering in Brazil have started to shift the focus from teaching geometric and volumetric space representations to modelling a parametric representation (BIM), in which linked information about physical and mechanical properties of materials and components provides the necessary knowledge to simulate construction planning (CAD 4D) and costs estimating (CAD 5D) allowing a more comprehensive and realistic design. By doing so, it is expected to pave the road for the curricula changes necessary to make it available from their first year. The complexity of the construction information model the student develops will grow as knowledge is acquired within the course so that, by the final graduation project, the student would be able to deal with full, real-case sustainable design and construction project applications. Adoption of BIM by design professionals is likely to develop in parallel.

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The Brazilian Agenda for Sustainable Dwellings: Criteria for Water Conservation

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Abstract

The water management in buildings is one of the most important tools to be considered in a regional sustainability agenda. Considering the Brazilian continental dimensions, it is necessary to take into account regional characteristics of water resources and water demand in order to obtain effective results by means of the actions which optimize the water use in dwellings. The evaluation of regional water resources takes into account two basic parameters: superficial waters and underground waters. The demand varies not only according to climatic conditions, but also to different activities, such as cultural, economic and social aspects of users. The degree of regional water scarcity can be evaluated by means of the water balance which is the ratio between the volumes of water resources and its demands. This result makes it possible to plan the most adequate water conservation procedures to be implemented in dwellings. Thus, the main purpose of this work is to present guidelines for the proposition of a water regional agenda for dwellings. The methodology used was the proposition of a water agenda which takes into account all the information and data related to the water resources and water demand in Brazil, published by the National Agency of the Water – ANA. The strategic action proposed by the Brazilian National Program against the Wastage of Water – PNCDA was also considered in this methodology. The results show that a water agenda must consider the following steps: strategic objectives, pointer, goals and actions. The role of this work is to implement actions adjusted to different regions in Brazil with a better cost-benefit ratio which will contribute for the increase of the sustainability in dwellings.

Keywords: sustainability, water conservation, water supply system, water agenda, dwellings

1. Introduction

Brazil, despite featuring one of the largest masses of water per capita, approximately 33000 m^3/inhab.year, suffers from lack of water, mainly in the great metropolises. This is due to poor distribution of water between different Brazilian regions. In parallel with this poor distribution of water, there is a lack of treatment of sanitarian sewage.

Thus, planning and management of water in dwellings are fundamental for a more sustainable use of this natural resource. Taking the continental dimensions of Brazil into consideration, the elaboration of a local agenda becomes necessary, which contemplates characteristics of availability and of demand of water in order to obtain effective results of implemented actions. The availability of water in a region is evaluated in function of surface and subterranean waters. The demand varies in function of climatic conditions, activities, social aspects, culture and economic factors of the users.

The most attractive actions for water conservation in buildings can be defined by the evaluation of the degree of the scarcity, calculated considering the relationship between demand and availability of water resources having as a target an indicator of consumption as reference. Therefore, this work has as the objective to present an action plan to the formulation of a regional agenda for the water resource in Brazil, showing aspects that must be considered in each case, having in mind the environmental sustainability of buildings.

1.1 Water conservation programs in Brazil

The scarcity of water and energy in some Brazilian regions, apart from the lack of treatment of sewage, has stimulated the development of public policies through water conservations programs. The most important Brazilian water conservation programs were initiated in the 1990s providing significantly positive results as described below.

1.1.1 National program of water conservation - PNCDA

In function of the increasing demand of water in major urban centers along with resulting social and economic problems of the greater cost of water treatment, coupled with the enormous lack of sewage treatment, the Brazilian government, in 1998, introduced the Brazilian National Program of Reduction of Water – PNCDA.

The general objective of PNCDA was to promote rational use of potable water in Brazilian cities, for the benefit of public health, environmental sanitation and the efficiency of services, providing an ever higher productivity of existing assets and postponement of part of the investments for the amplification of systems (Silva et al., 1999).

The PNCDA developed some Technical Support Documents comprising planning of the conservation actions, technology of public water supply systems, technology of water and supply and drainage systems in buildings, and educational campaigns, such as (Gonçalves et al., 1999), (Cardia et al., 1998) and others.

One of the results of the PNCDA, in conjunction with the National Program of Quality and Productivity in Dwellings and Habitat – PBQP-H, contributes to the reduction of the consumption of the volume of flushes in water closets from 12 liters to 6 liters (Gonçalves et al., 2000). It is important to emphasize that Brazilian WC cisterns of 6L flushing volume are exported to various countries in the world including Canada and the United States among others.

1.1.2 Rational water use program - PURA

The PURA – Rational Water Use Program was established in 1996 by means of an agreement among Escola Politécnica of University of São Paulo, the São Paulo State Water Utility Company - SABESP and the IPT - Instituto de Pesquisas Tecnológicas. This water conservation program was structured in six macro-programs, which were developed simultaneously. These programs include: Technology database, Institutional laboratories, Technology evaluation programs, Analyses of water conservation programs in residential buildings and dwellings units, Quality programs and Specific water conservation programs in different types of buildings (Gonçalves and Oliveira, 1997).

This sixth macro-program structured the accomplishment of case studies in office buildings, schools, hospitals, among others, that aim for the development of methodologies and intervention procedures to be applied to other sites. Some case studies were implemented in São Paulo in 1997 and respectively named, PURA-EE (elementary school) PURA-HC (USP University hospital) and in that year, studies for the Program application at the *campus* of University of São Paulo began. This meant the beginning of the PURA-USP as a case.

The results of these case studies were very good and have stimulated the implementation of PURAs in other types of buildings in all of Brazil (Oliveira et al., 1999), (Silva et al., 2002).

1.1.3 Quality and productivity program of water submetering systems - ProAcqua

Currently the ProAcqua Program, which has resulted in a partnership between the São Paulo State Water Utility Company – SABESP and the CEDIPLAC – Center of Development and Documentation of Urban Infrastructure and Habitation in 2007, is being implemented in the city of São Paulo and has as an objective to improve the quality of the water submetering systems in buildings. These objectives have been reached through qualification of professionals and the control of the quality of the water measurement systems. These steps have contributed to a reduction of the consumption as a result of improvement in management of water use in residential dwellings.

1.1.4 New challenge: the Brazilian water agenda

As presented, the Brazilian water management programs have continuously evolved and present satisfactory results. At present, in function of the necessity of the development of a sustainability evaluation system, the Brazilian government has a challenge of proposing an agenda, which contemplates different environmental, social, economic and cultural characteristics for various regions, in function of the continental dimensions of Brazil. According to Ilha et al. (2009), the development of an environmental assessment system requires the identification of the most important topics to be considered in each theme for each region, due to the local environmental agenda.

The application of this agenda will result in a higher environmental, social and economic efficiency as the proposed actions for implementation will be compatible with the characteristics in the supply and demand of water in each region, oftentimes vastly different one region to another. Thus, the main purpose of this work is to present guidelines for the proposition of a regional water agenda for dwellings.

2. Methodology

The methodology used was the proposition of a water agenda, which takes into account all the information and data related to the water resources and water demand in Brazil, published by the National Agency of the Water – ANA (2007). The strategic action proposed by the Brazilian National Program of Reduction of Water – PNCDA (1997) was also considered in this methodology, as followed:

- tariff policies;
- regulations and technical standards;
- reduction and control of water loss;
- incentives for the acquisition and installation of efficient equipment;
- utilization of alternative sources of water for less qualitatively demanding uses;
- information campaigns and education campaigns;
- research and development.

The activities made for the development of the water agenda were: estimate of the degree of scarcity of local water, identification of the water consumption indicators reference (IC), definition of actions and respective impacts of the reduction of the consumption of water.

The estimate of the degree of scarcity was elaborated considering the data made available from ANA (2007) to the 12 Brazilian hydrographical regions defined by resolution 32 from the National Council of Hydro Resource – CNRH (2003). It should be noted that this data reflects an initial water availability of above the actual available level, due to restrictions imposed on the water resources by its different uses, such as: commitment to the quality of water, flow rates to dilution of effluents, operation of reservoirs and maintenance of minimum flow rates that was not taken into account in the water availability. The aforementioned document also presents data relative to the precipitation in the country, which annual average is 1797 mm, varying from less than 800 mm in semi-arid regions in the Northeast, to more than 2500 mm in the Amazon.

The impacts of the expected reduction were estimated based on the experience of the authors of this article in water conservation programs, and also the available bibliography. The definition of the action plans, in turn, was made taking the average distribution of consumption in dwellings into consideration.

3. The Brazilian agenda for sustainable dwellings: criteria for water conservation

The United Nations has utilized as an indicator for water availability per inhabitant, in major regions, the ratio between the average annual flow rate and the population in a region. On the basis of this indicator, Brazil is considered rich in water resources, with an availability of 33000 m^3/inhab.year. It must be observed, however, that a significant variety in this indicator can be found in the 12 Brazilian hydrographical regions, with instances of low availability associated with elevated population concentration, as is the case in the city of São Paulo, which has less than 500 m^3/inhab/year - representing a scenario of water scarcity.

The ratio of demand to supply of water resources can be classified in: Excellent (less than 5%); comfortable (5 to 10%); worrying (10 to 20%); critical (20 to 40%) and very critical (above 40%) ANA (2007). This value displays a comfortable situation in only some regions of the country. However, some regions present a very critical ratio of demand to supply. Hence, the proposed water agenda in a specific region or community should be elaborated as a function of the ratio of demand to supply of water as the classification presented in ANA (2007). Its structure should incorporate the following aspects:

- **Water consumption indicator (IC) –** reference value used to establish target and actions to be implemented in the building, (L/person.day).

- **Reference value for IC**: 100 L/person.day is the minimum value for this indicator, so that it does not damage hygiene conditions and the health of users. Other IC values were also considered such as 180, 160, 140 e 120 L/person.day;

- **Target –** defined in function of the ratio between the demand and the supply of water;

- **Actions** – established in function of the desired target in order to reach the IC reference value. Three subcategories are proposed for the actions to be implemented: reduction of potable water consumption either due to local scarcity of water or with the purpose of reducing the volume of sewage**;** management of potable water and rainwater.

According to Marcka (2004), the environmental education does not provide direct and quantifiable results in terms of reducing water consumption, but constitutes a fundamental strategy for the success of all other strategies and action plans on the local agenda. Moreover, the education of younger generations contributes to the promotion of a more conservationist culture and can in fact be considered a way of implementing “preventive conservation”.

Another action, which must be permanently implemented, is the detection and elimination of leakages in pipes and hydraulic components, as they in certain cases have a significant impact, especially in parts of systems suffering the effects of excessive hydraulic pressure – or rather, higher than 300 kPa.

The implementation of retention systems or infiltration of rainwater does not generate reduction in water consumption, but it contributes to reduction peak flow rates of rainfall in urban drainage systems and, consequently, flooding and diffused pollution. Then, it is recommended a survey of average precipitation in the weather bureau closer to the building due to spatial variation and seasonal behaviour of the rainfall.

For the selection of actions to be implemented, an evaluation of hydraulic pressure is recommended as available flow rate depends on the size of the same, or rather, in systems where the hydraulic pressure is low (30 to 100 kPa), the installation of a flow rate regulator in a wash basin, for example, will compromise the activities in this point of utilization, apart from not reducing the consumption of water.

4. Results

The Brazilian agenda for water resources is structured according to Table 1, which presents consumption reference indicators, reduction targets and recommended reduction actions as a function of the ratio between the demand and the supply of regional availability of water. It should be noted that the impacts of reduction, in case of pressure reducer valves and other water saver components, refer only to the utilization point and not the total water consumption of the building.

Table 1: Guidelines for a regional agenda for water sustainability of dwellings

Ratio of demand to availability of water resources	*Less than 5% (Excellent)*	*5 to 10% (Comfortable)*	*10 to 20% (Worrying)*	*20 to 40% (Critical)*	*Bigger than 40% (Very critical)*
Reference water Indicator (L/ person.day)	*180*	*160*	*140*	*120*	*100*
Reduction target (%)	*10 - 30*	*10 - 30*	*20 - 40*	*20 - 45*	*20 - 50*
Action and impact of reduction (%)	*Environmental education, detection and correction of leakages (not measurable)*				
	Water submetering system				
	(10 - 30)[1]				
	Pressure reducing valves		*Pressure reducing valves*		
	(5 – 20)[1]				
	Water saver components		*Water saver components*		
	(5 – 30)[1]				
			Efficient irrigation		
			(10 – 30)[1]		
			Plants which consume little water		
			(1– 5)[1]		
			Alternative source at least in irrigation		
			(10 – 40)[1]		
			Retention system or infiltration		
			(not measurable)[2]		

Actions to reduce the volume of sanitation sewage

[1] impact of reduction in relation to consumption of the component or conventional system

[2] does not reduce the consumption of water although contributes to the reduction of flow rate peaks in urban drainage systems

To exemplify the application of the guidelines presented in Table 1, a building to be built, which is in operation in a region in which the ratio of demand to availability of water is worrying (10 to 20%). In Table 1, the target for reduction is from 20 to 40%. For this, the target can be reached, only with environmental education, detection and correction of leakages and a water submetering system of water consumption. With the installation of pressure reducers, a reduction of 10 to 30% can be reached in the points of consumption, in which this component can be installed and not in the system. In this case, in order to determine the impact of reduction in the total consumption of water, it is necessary to estimate a utilization standard in the referred points of consumption.

5. Final considerations

The local agenda must incorporate environmental education as a permanent action, as it will enable users to make qualified and sensible choices in questions related to the consumption of water in dwellings. The use of water agenda leads to the optimization of the actions to be implemented include:

- the knowledge of local and regional conditions;
- choice of actions with better cost/benefit ratio;
- use of appropriate technologies to the reality found at the local, which conform to technical and national standards;
- qualification of professionals in best practices in the project and the implementation of plumbing systems;
- maintenance of quality standards of water related to end-uses.

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Sustainable Design and Feng Shui: A Case Study of an Office Building in Sydney

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Abstract

Interactions between humans and environments are a part of an everyday process. In the western contemporary architecture, these interactions with the natural and man-made environment called Sustainable or Green Design. In the East, the ancient Chinese knowledge of Feng Shui aims at creating a harmony between environment, buildings and people. It has influenced most traditional building design in China for thousands of years. With a desire to improve the relationship between human and the environment, there is an increasing interest for architects and other building professionals to apply the concepts of Feng Shui into building design and the built environment. It is suggested that interpreting Feng Shui knowledge would embrace the western concept of sustainable design. This paper analyzes and compares the concepts of sustainable design with Feng Shui. A case study of a well recognized sustainable designed office building, Workplace6 in Sydney is used to illustrate the similarities and differences between concepts of sustainable design and Feng Shui in terms of environmental design. The findings indicated that both sustainable design and Feng Shui concepts are aimed at the creation of the enjoyable space and balance between natural and the built environment. However, sustainable design focused on the measurement and performance of physical attributes, whereas Feng Shui concepts emphasized on the balance and harmony of physical forms and spatial arrangement which are difficult to be measured and quantified.

Keywords: sustainable design, Feng Shui, green star, Workplace6

1. Introduction

Sustainable design is the philosophy of design the built environment to comply with the principles of economic, social and ecological sustainability (McLennan, 2004). Sustainable design emphasizes on a holistic approach to eliminate negative environmental impact through skillful and sensitive design. The goal of sustainable design is to look at all the systems together and to make sure they work in harmony. This integrative design process is similar to the Chinese holistic view and the Feng Shui approach to the built environment (Humphreys, 1976).

Feng Shui is a body of ancient Chinese wisdom in knowledge and experience related to the built environment that has been accumulated for more than three thousand years. The principles and practices of Feng Shui aimed at creating a harmonised built environment for people to live in, and it represents a traditional Chinese architectural theory for selecting favourable sites as well as a theory for designing cities and buildings (Lee, 1986). There are two main schools of thought and practice in Feng Shui: the Compass School and the Form School. The Form School approach has been well recognized and widely accepted by Feng Shui researchers as comprising the scientific bases in the analysis of built environment (He, 1990; Cheng and Kong, 1993). The Form school established a holistic approach that allows integrated components and elements to be considered for the built environment (Mak and Ng, 2008).

Since the late 1960's the impact of western civilisation and technology has grown to global proportions, more western scholars became aware of the limitations of the modern scientific paradigms that failed to explain the whole realm of natural phenomena and began to recognize that there are similarities between modern science and eastern philosophy (Capra, 1975). Joseph Needham (1959), in his book series "Science and Civilisation in China" began to appreciate the value of Feng Shui in ecology and landscape aesthetics. According to Needham (1959, p.361) Feng Shui "embodied ... a marked aesthetic component, which accounts for the great beauty of the siting of so many farms, houses and villages throughout China".

Kevin Lynch, a pioneer of environmental behaviour research, in his book, "The Image of the City", concluded that Feng Shui is an open-ended analysis of the environment where new meanings, new poetry, and further developments are always possible (Lynch, 1960). Anderson and Anderson (1973) recognized that Feng Shui is an aspect of Chinese cultural ecology, and called Feng Shui "the traditional Chinese science of site planning", containing "an organized body of knowledge, intensely practiced in application, and of specific intent" (Anderson, 1973, pp.127-128).

Furthermore, Freedman (1979) accepted that Feng Shui is based on self-evident propositions and the expertise of scientific men and called it "mystical ecology". Nemeth (1993) recognized that "cosmographic interpretations of geomancy maps can both teach Western peoples and remind East Asians that in the organization of human activities in physical space, principles that engender productive economic, ecological, and ethical relationships may be governed by a natural law" (Nemeth, 1993, p.94). Bruun (1995) suggested that Feng Shui is a system of statements on the man-nature relationship in an environment of holistic thought, and man and landscape are linked together in a system of “immanent order”.

Nowadays, as many researchers seek to establish a deeper understanding of these relationships between the human and natural environments, architects and building professionals begin to recognize Feng Shui as a broad ecologically and architecturally connected paradigm. Hwangbo (1999) believed that the practice of Feng Shui is an intuitive matter involving site selection and spatial organization, and it has strong parallels with the western concept of geometry in architectural design.

This paper explores the relationships between the concepts of sustainable design and Feng Shui in environmental design using a case study of an office building in Sydney. Firstly, a set of five concepts of sustainable design and five Feng Shui concepts in terms of environmental design are identified and compared. Hence, a well recognized sustainable designed office building, Workplace6 in Sydney is used as a case study to illustrate the similarities and differences between the concepts of sustainable design and Feng Shui environmental design.

2. Comparison of sustainable design and Feng Shui

The sustainable design includes many areas such as waste and recycling, energy, water, building design, emission, indoor environmental quality (IEQ), alternative transport, landscaping, and about everything that do affects everything around human, aims to eliminate negative environmental impact and maintain ecologically sustainable completely through skillful and sensitive design (McLennan, 2004). Many of these ecological sustainable design concepts are quite similar to the traditional views that were derived from the eastern philosophy and Feng Shui principles and practice. Dong and Zuehl (2009) recognized that there is a set of five fundamental concepts for sustainable development. They are constructivism, circular design, energy efficiency, balance between natural and the built environment, and thinking global and buying local. These five fundamental concepts are then compared with the five Feng Shui concepts in terms of environmental design.

2.1 Sustainable design concepts

(1) Constructivism: Sustainable design is based on studies from constructivism (an approach to cognitive psychology and social psychology) to create spaces that built knowledge and skills for the end user. This concept is based on human interactions with their environment to enhance the environment to make the space more enjoyable for the people using it (Dong and Zuehl, 2009).

(2) Circular design: This circular design concept is based upon the idea of “cradle to cradle” (McDonough and Braungart, 2002). It is a new design paradigm of “reduce, reuse, recycle” through the intelligence of natural systems (i.e. the effectiveness of nutrient cycling, the abundance of the sun’s energy, etc.). McDonough and Braungart explained how to put eco-effectiveness into practice to create products, systems, and buildings that allow nature and commerce to fruitfully co-exist.

(3) Energy efficiency: Energy efficiency can be achieved by site planning and building design in accordance to sunlight and the use of various building materials and technology. Buildings and environments that are adapting energy efficient ideas are increasing environmental satisfaction from its end users as well as decreasing the consumption of natural resources.

(4) Balance between natural and the built environment: Studies done by U.S. Green Building Council and other green design advocates have shown that by bringing natural elements (such as sunlight, plants, water features, etc.) into a person's environment will change the behavior of the user in the environment to a more harmonious and enjoyable space (Widener, 2009).

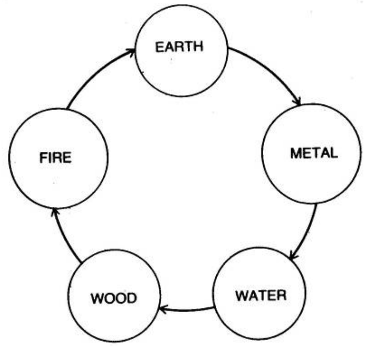
(5) Thinking Global and Buying Local: Dong and Zuehl (2009) recognized that all the concepts of green design can be bottled up into this concept. It comes from the ideas of thinking about the global economy, environment and well being which in result should allow the design world to buy from local markets to reduce energy costs, wasted materials and increase the environments overall well being.

2.2 Feng Shui concepts

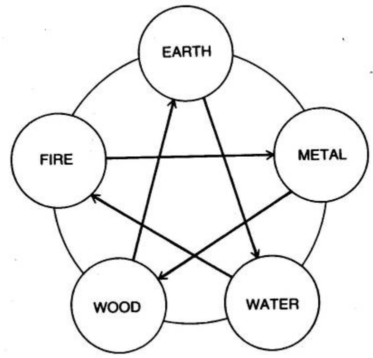
The concept of sustainable design in the western world only dates back three decades ago to deals with the harmonious relationship between human and nature. However, Feng Shui, the ancient Chinese knowledge that aims at creating a harmony between heaven, earth and human has influenced most traditional built environmental design in China for thousands of years. Five fundamental Feng Shui concepts in terms of environmental design are summarized below.

(1) Unity between Heaven and Human: This is the fundamental principle of Feng Shui, means the harmony between the universe, earth and human energy. Energy is valued in both the physical and the invisible forms known as "*Qi*" (natural energy or breath of life) in the traditional Chinese Feng Shui culture. Feng Shui designs are aimed at a balance and harmonious environments that can produce an ample amount of good *Qi* and filter out the bad *Qi* (Skinner, 1982).

(2) The Five Elements Cycles: Ancient Chinese believed that in the universe, including heaven, earth and human beings, every thing has an attribute according the five elemental groups of substances. These five elements are fire, water, metal, wood and earth. The characteristics of each of these five elements and their mutual relationships are based on observed natural phenomena, and their relationships are identified as productive and destructive cycles as shown in Figure 1.



Productive cycle



Destructive cycle

Figure 1: Productive and Destructive Cycles of the Five Elements (Walters, 1989)

(3) Yin and Yang Harmony: Ancient Chinese believed that in everything there are two opposing parts: Yin and Yang. Yin represents the passive principles in nature exhibited as darkness, cold and wetness. On a human level, Yin symbolizes femininity and passive, and also represents the realm of the dead. Yang represents the active principles in nature exhibited by light, heat and dryness. On the human level, Yang symbolizes masculinity and active, and also represents the realm of the living. Yin and Yang are about balance and harmony within a space, designed to create balance in the users' life when engaging in the space (Feuchtwang, 1974).

(4) Form School Model: The Form School is primarily based on the verification of the physical configuration of mountains and watercourses surrounding sites and buildings. These elements comprised the basics of the Form School approach and were known as the "Five Geographical Secrets", namely, dragon, sand, water, cave and direction (Lip, 1979). Contemporarily, Form school approach has been recognized as comprising scientific basis in the analysis of the built environment (He, 1990; Wang, 1992; Cheng and Kong, 1993; Mak and Ng, 2005; Mak and Ng, 2008). The combination of these five Feng Shui geographical elements and the four emblems (green dragon, white tiger, black tortoise and red bird as the four cardinal directions) produced the classic Feng Shui model. This model has been interpreted in diagrams of spatial organization of auspicious mountains and watercourses in most of the ancient Feng Shui literature (Shang, 1992; Cheng and Kong, 1993; Han, 1995; Yi et al., 1996; He, 1998). A simplified model was established by Mak (2009) to illustrate the relationships between the key elements of the five Feng Shui geographical secrets being considered and how dragon vein, four emblems in sand, water feature, cave and bright court, and their directions were integrated (Figure 2).

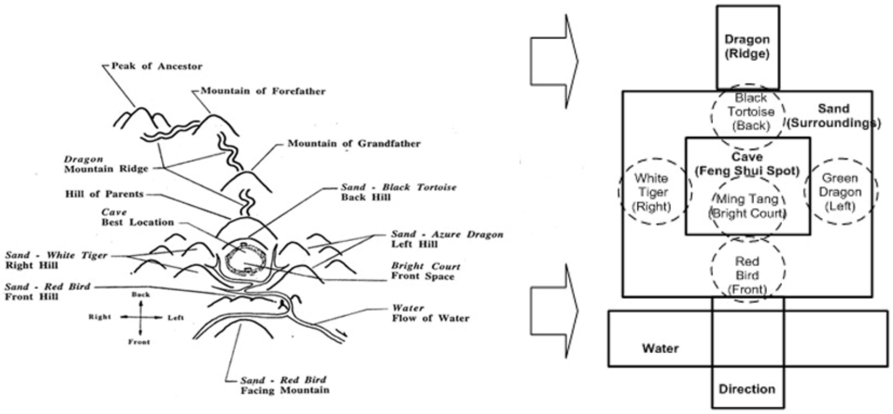


Figure 2: Simplified Feng Shui Model (Yi et al., 1996 and Mak, 2009)

(5) Balance between Interior and Exterior Spaces: When describing the site conditions and the design of buildings, most of the Feng Shui texts, such as *Yang Zhai Shi Shu* (Ten Books on Dwellings of Living) categorized space into "Outer Form" (exterior) and "Inner Form" (interior). According to Lee (1986), the Outer Form can be identified as the location of the site, conditions that surround the site, topographical conditions of the site and the shape of the site. The Inner Form can be identified as the layout of the building, elevations of the building, and elements of building. The concept of a Feng Shui model not only applied to landscape and site selection, but it can also be applied to the internal layout of buildings. Therefore, whether it is dealing with physical or topographical elements, or housing structure, or the proportional relationships of the interior of a building, the same principles and relationships of the Feng Shui model are still applied. Feng Shui scholars, Cheng and Kong (1993) provided a further classification of space into four design modules: surrounding environment, external layout, internal layout and interior arrangement (Figure 3).

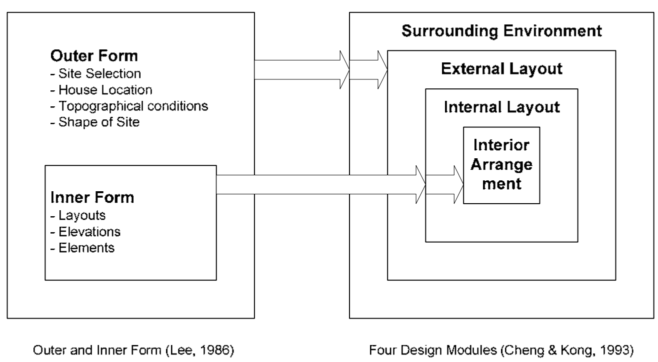


Figure 3: Four Design Modules (Mak, 2009)

2.3 Comparison of sustainable design and Feng Shui concepts

When comparing the concepts of sustainable design and Feng Shui, there are similarities and differences. Firstly, the concept of constructivism translates well into the principles of harmony between universe, earth and human in Feng Shui. The ideal environment for Feng Shui is these three aspects as they intersect and overlap. These three circles can be found in sustainable design as social contexts, environment and human as shown in Figure 4.

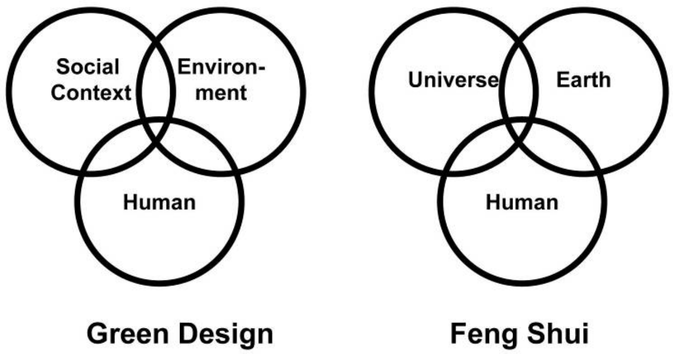


Figure 4: Comparison of Principles of Green Design and Feng Shui (Dong and Zuehl, 2009)

The second principle of Feng Shui is the productive and destructive cycles of five elements, which is similar to the circular design or McDonough's "Cradle to Cradle" concept. The third Feng Shui concept is the balance and harmony between Yin and Yang, which also matches with the concept of sustainable design of balancing between natural environment and the built environment. For the fourth and fifth concepts in sustainable design, the energy efficiency and buying local concepts are focused explicitly on the sources and consumptions of natural resources. However, the Feng Shui concepts of Form school model and balance between interior & exterior spaces are focused on the physical form and spatial arrangement of the built environment.

3. Case study

3.1 An office building in Sydney

A recently completed office building, Workplace6 in Sydney has set the highest standard in sustainable design in NSW. The site, as shown in Figure 5, opposite Star City Casino on the waterfront at Darling Island, is managed by the Sydney Harbour Foreshore Authority (SHFA). SHFA initiated the contract for a benchmark building in environmental design with owner the GPT Group, developer Citta Property Group, in conjunction with design and build contractor Buildcorp Australia.

The location of Workplace6, in the Sydney CBD fringe market of Pyrmont, is seen as an increasingly sought after destination for tenants seeking cost effective office space with close proximity to the CBD. With high profile frontage to Pirrama Road, Workplace6 is positioned on the highly visible South East corner of the Darling Island peninsula as shown in Figure 6. Accenture and Google have leased 96 per cent of the office space for 12 and 10 year terms respectively, while Doltone House has signed a 15 year lease for the 1,800 sqm retail space on level 1 (Sustainable Property News and Forum, 2009).

Figure 5: Location of Workplace6
(Spears, 2009)

Figure 6: Front Elevation of Workplace6

Construction of Workplace6 commenced in April 2007 and completed in November 2008, it provides approximately 18,200 sq m of space over six storeys and offers some of the largest commercial floor plates in Sydney, of over 3600 sqm as shown in Figure 7. Main building features include:

- 16,200 sqm of office space over five levels, and 1,800 sqm of ground floor retail space
- large floor plates, with a typical floor area of 3,620 sqm
- open central atrium zone providing a sense of space in the lift lobby
- core zone, allowing light to reach the centre zone of each floor
- no point on the large floor plate is more than 12 metres from an external window or the atrium
- parking for 135 cars and provided 120 bike racks

Workplace6 is a prime grade office building achieving world leading standards in environmental design and resource efficiency. According to the nine categories of the Green Star rating scheme (Australian Green Building Council, 2009), the building has awarded a total score of 83 points (Spear, 2009). It is the first commercial development to achieve a 6 star Green Star rating for design in NSW and is targeted a 5 star NABERS energy and water rating, the highest rankings available in all ratings and classed as "world leading". It is designed to reduce greenhouse emissions by 70% and cut drinking water consumption by almost 90% compared to an average existing office building (GPT, 2009). Key environmental initiatives include:

- a gas-fired generator to generate power for the building onsite, reducing the peak load by 25 per cent; the waste heat from the generator is then used to run an absorption chiller that will cool the building
- use 25 per cent Green Power drawn from wind and solar sources

- a black water recycling system that will treat sewage on-site. Potable water yielded from black water recycling will be used for toilet flushing, with excess water offered to the local community for irrigation of the adjacent parks and gardens (Figure 8)

- rejection of waste heat from the building to the adjacent harbour, in lieu of the use of cooling towers; this will have the effect of significantly reducing the water consumption of the building, as well as eliminating the risk of legionnaires disease

- roof mounted solar panels to heat the building's hot water supply

- the use of recycled materials, sustainable timber and minimal use of PVC and VOCs

Figure 7: Typical Floor Plan
(Spears, 2009)

Figure: 8: Grey water distribution
(Spears, 2009)

- maximisation of natural light with central atrium and optimize indoor environment quality through the use of chilled beam technology (Figure 9)

- operable facades which allow tenants to install open and fresh air wintergardens in various locations,

- maximisation of window openings overlooking Sydney city and harbour

- high technology facade and sun shading devices to reduce heat load on the building.

Figure 9: View of Central Atrium (Spears, 2009)

3.2 Analysis and discussion

With all the sustainable design features, Workplace6 has achieved massive saving in energy and water consumption. As a result, the greenhouse gas emission of Workplace6 is 39 KgCO2 per sqm, compared with an average standard building is 87 KgCO2 per sqm. In addition, the water consumption is 2.1 million litres per annum compared with an average standard building is 31.1 million litres per annum (Spears, 2009). The analyses for the features of the case study according to the five sustainable design concepts are outlined in Table 1.

Table 1: Analysis of the Features in Case Study according to Sustainable Design Concepts

Sustainable design concepts	***Features in Case Study***
(1) Constructivism	• *Achieved a 6 star Green Star rating for design* • *Targeting a 5 star NABERS energy rating* • *Central atrium and staircase provided a sense of space and communication*
(2) Circular design	• *Use of recycle materials, sustainable timber and minimal use of PVC and VOCs*
(3) Energy efficiency	• *Use of gas tri-generation to reduce peak load* • *Use of solar power hot water system* • *Use of chilled beams*
(4) Balance between natural and the built environment	• *Use of open central atrium to provide natural light* • *Operable facades which allow tenants to install open and fresh air wintergardens in various locations*
(5) Thinking global and buying local	• *Use harbour water for heat rejection in lieu of the use of cooling tower*

In accordance with the Feng Shui concepts, the provision of an open central atrium is a prime feature of Workplace6. This design is similar to the traditional courtyard houses in Beijing that, under the Feng Shui principles, provided the balance between natural and built environment, Yin and Yang harmony and the sense of unity between heaven and human (Xu, 1998). The analyses of the features of the case study according to the five Feng Shui concepts are tabulated in Table 2.

Table 2: Analysis of the Features in Case Study according to Feng Shui Concepts

Feng Shui concepts	***Features in Case Study***
(1) Unity between heaven and human	• *Use of open central atrium to bring the natural environment inside the building, however, natural features, such as plant or water features are not provided in the building*
(2) The five elements cycles	• *Use of open central atrium and staircase to provide communication and circulation pattern, however, the five elements and their features are not provided*
(3) Yin and Yang harmony	• *Use of open central atrium to provide a balance between natural and built environment, and sense of space, however, the size of the atrium is in relatively small proportion of the large floor plate area*
(4) Form School model	• *The building is located between the community park on the North and Pyrmont Bay Park on the South-East, and backed by the StarCity Casino complex on the South and South-West* • *Use of curtain wall system to provide maximized Sydney harbour view to the North and East* • *Open space provided in front of the entrance to the building*
(5) Balance between Interior and exterior spaces	• *The entrance door to office at each floor opens to a corridor that connecting to the open central atrium provided a balance between interior and exterior spaces* • *Operable facades which allow tenants to install open and fresh air wintergardens in various locations* • *Connecting interior spaces to exterior through natural light from windows and central atrium, maximized external view to Sydney harbour, and greater fresh air supply*

There are similarities and differences between sustainable design and Feng Shui concepts. From the analysis of the case study, the sustainable design concepts aimed at the creation of the enjoyable space for human interactions and balance between natural and the built environment, which can be translated to, under the Feng Shui concepts, the unity of heaven and human and the Ying and Yang harmony. In this case study, the provision of the open central atrium is a prime feature to satisfy these concepts from both sustainable design and Feng Shui considerations.

According to sustainable design, the circular design concepts of “reduce, reuse and recycle” are key sustainable features of the case study that lead to the achievement of 6 star Green Star rating. However, following the Feng Shui concepts, the productive and destructive cycles of the five elements according to the nature of the elements, such as, material used, shapes, colour, orientation, are abstract and difficult to be identifiable.

For the sustainable design considerations, the energy efficiency and buying local concepts that focus on the sources and consumptions of natural resources are translated into measurement of physical attributes, such as, light, thermal, water, air quality, etc. These concepts focused on how the man-made environment affects people and their performances. In contrast, the Feng Shui concepts of Form School model and balance between interior and exterior spaces are emphasized on the balance of physical forms and spatial arrangement. It is focused on the balance, harmony and experience of the environments but these aspects are difficult to be measured and quantified.

4. Conclusion

This paper has compared and contrasted the concepts and practices between western sustainable design and Chinese Feng Shui using an office building - Workplace6 in Sydney as a case study. The findings have suggested that both concepts are the same in term of focusing sustainable development that is to minimize impacts on natural environment. The distinct feature of western sustainable design has more emphasis on measurement of physical attributes such as efficiency of water and energy consumptions; whereas Feng Shui is unique and the emphases are on balance of Ying Yang, exterior and interior, the relationship between human and surrounding environment. However, the western sustainable design cannot avoid using of new technology and reinvestment, in which the effect of sustainability has been impaired. The interpreting Feng Shui knowledge has embraced the western concept of sustainable design. But Feng Shui concepts such as productive and destructive cycle are intangible and difficult to be measured. Ideally, if Feng Shui concepts can be considered and applied into the western sustainable design that will enhance the effect of sustainable development. Improving scientific research on Feng Shui and how Feng Shui concepts are measured and work together with western sustainable design are areas for further study.

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Economics of Green Design and Environmental Sustainability

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Abstract

In spite of the huge environmental and energy problem in Nigeria, designers have not seen the need for a shift from their traditional method of designing buildings. The purpose of this report is to highlight the need for green and sustainable design in Nigeria using Lagos as a case study with focus on the effect of green design on environmental sustainability including economic implication, occupiers preferences with respect to building components and services to ascertain the level of their appreciation of green elements and the energy situation in Nigeria as an incentive for green design and energy efficiency considerations in design and construction. Questionnaires were distributed to various groups which include; residents (households) at Dolphin and Abraham Adesanya estates Lagos and also 1040 households in 8 local government areas of Lagos to determine the extent of power (electricity) problem in the city. The paper concludes that there is need for a holistic adoption of green design as lack of it has been observed to be adverse to efficiency in buildings and environmental sustainability in the state.

Key words: ecological design, environmental sustainability, green building, sustainability.

1. Introduction

The term "green" and "sustainable" design is often used interchangeably though there are shads of meaning implied by each. Sustainability is a goal that allows for the continuing improvement of standard of living without reversible damage to resources we need to survive as species (Lehrer 2001). Green design is intended to develop more environmentally benign products and processes. The application of green design involves a particular framework for considering environmental issues, the application of relevant analysis and synthesis, methods and a challenge to traditional procedures for design and manufacturing (hendrichson, Conway – Schempt, Lave and McMicheal, Undated). The green approach to architecture is not something new as it has existed for years. What is new is the realization that green approach to the built environment involves a holistic approach to the design of buildings; that all the resources that go into a building, be they materials, fuels or the contribution of the users need to be considered if sustainable architecture is to be produced (Brende and Vale 2007).

In Nigeria some buildings embody one of the various verifiable characteristics of green design. Buildings with holistic approach are yet to be seen.

Sustainable development is the challenge of meeting growing human needs for natural resources, industrial products, energy, food, transportation and effective waste management while conserving and protecting environmental quality and the natural resource base essential for future life and development. This concept recognizes that meeting long term human needs will be impossible unless we also conserve the earth's natural, physical and chemical system (Gottfried, 1996). This is also in tandem with environmental sustainability. There is no doubt that sustainable development concepts, applied to the design, construction and operation of buildings can enhance both the economic welfare and environmental health of communities in Nigeria and other third world countries. This is more apt in this era of climate change.

Embracing green or sustainable concept in design is aimed at reducing energy, operation and maintenance cost, reduced building related illness, increase the productivity and comfort of building occupants; reduce waste and pollution and increase building and component durability and flexibility. It is important that the focus of green concept be embraced from the early stages of building design, planning and construction according to Gottfried (1996) the decision made at the first phase of building design and construction can significantly affect the costs and efficiencies of other phases as recent studies have shown that green building measures taken during construction or renovation can result in significant building operational savings, as well as increases in employee productivity. In essence, building related costs are best revealed and understood when they are analyzed over the life span of the building.

In Nigeria, Green concept, sustainability and environmental issues are hardly put into consideration when designing a new building or renovating an old one. This results in a short fall in user satisfaction, functional space planning, service type and sustainable building components are often neglected during design and construction.

In Nigeria, the first bank head office located in Marina Lagos, would have been more appropriate for temperate countries like the United Kingdom or France as provision was not made for natural ventilation and lighting. Whenever power from the main grid (public electricity) fails and by any act of the devil electricity generators have operational challenges, everywhere will be in darkness and the entire workplace will be suffocating.

In some estates like dolphin, the level of natural lighting and ventilation leaves much to be desired. It is equally very surprising that some buildings in Environmental science faculties of some universities are not given the touch of green or ecological sustainability in their design and construction.

This paper aims at highlighting the need for green and sustainable design in Nigeria using Lagos as a case study. This will be achieved through the following objectives:

- To determine the effect of green design on environmental sustainability including its economic implication

- To find out if occupiers through their preferences of design components and service appreciate green design elements in buildings.

- To determine if the energy situation in Lagos – Nigeria provides incentives for green design to achieve energy savings.

2. Literature

According to Lehrer (2001), to work towards creation of sustainable development, one must understand the environmental impacts of buildings and their relative importance. The most and best understood impact is caused by energy use from building operations.

The primary energy loads in buildings are created by lighting, space heating and cooling equipment and domestic hot water. The production and consumption of this energy contribute to air pollution, acid rain and global climate change.

Udechukwu and Johnson (2008) describes green buildings as a generic term that generally refers to the practice of increasing the efficiency and performance of building through better sitings, designs, construction, operation and maintenance. They (Udechukwu and Johnson) further submitted that conventional construction methods have been linked to environmental damage including depletion of natural resources, air and water pollution, toxic waste and global warming. Conventional buildings have a significant impact on the environment including wetland depletion and deforestation (Otegbulu 2007)

2.1 Dimensions of Green design and Environmental Sustainability

Dimensions of green design include; energy efficiency, water efficiency, waste reduction, building operation, construction, maintenance, occupant health and productivity, climate and environmental integration (Sustainable neighborhood). The study of green design goes beyond the physical building itself but extend to environmental interactions. The green buildings characteristics overlap with many other neighborhood elements installation of water conserving features, recovery of non – sewage waste water and use of pervious pavings around buildings have obvious implication for the design of water, wastewater and storm water infrastructure respectively. The use of vegetation in neighborhood design also overlaps; trees shade buildings and shield them from wind while green roof buildings may both reduce storm water runoff and provide evaporative cooling. Furthermore, the potential for energy efficient buildings may both reduce storm water runoff and provide evaporative cooling (Engel – Yan, Kennedy, Saiz and Pressnand 2005).

In most Nigerian cities, environmental considerations are not considered in community design. For instance, Dolphin Estate Lagos is built on reclaimed wetland and the unbuilt area fully covered with interlocking concrete and asphalt in some areas without adequate drainage. This result in extensive flooding that takes between 8 – 48 hours to drain. Developed estates are devoid of shades resulting in hostile climatic conditions. Trees and vegetation have been used in cities for hundreds of years to positively influence the urban micro – climate. Some of the dimension of Green design in relation to environmental sustainability will be discussed below.

2.1.1 Energy efficiency

Gottfried (1996) submits that 50% of the energy used in building is devoted to producing an artificial indoor climate through heating, cooling, ventilation and lighting. According to the author, a typical building energy’s bill constitutes approximately 25 percent of building’s total operating costs in the United States. However, estimates indicate that climate – sensitive design with the use of appropriate and available technologies could cut heating and cooling energy consumption by 60 percent. Heating is however not important in tropical climate regions like Nigeria where cooling is mostly required. The design of the building must reflect consideration directed towards reduction in energy cost

Federerer in (Engel – Yan et al 2005) describes the effect of trees in modifying the urban microclimate, which affects both comfort and building space conditioning energy use. Microclimatic temperature is affected by radiation, convection and evaporative cooling. Trees affect microclimate through their effect on these processes. Federer considers shading to be the most important method by which trees affect the microclimate. Simpson and McPherson (2001) gave several recommendations for locating urban trees to maximize energy saving in several regions of the United States. They are of the view that east and west orientation provides shades when sun angles are lower and conclude that larger trees should be used to maximize benefits. They did find that except for southerly orientated trees, energy savings are generally inversely proportional to tree – building distances. They concluded that factors such as climate conditions, electricity emissions factors, building construction and tree growth rates, must be considered in energy savings and carbon dioxide emission reduction calculation. Trees abound in Nigeria but most often building sites are cleared of all vegetation (trees) and covered with asphalt or concrete which often have adverse environmental consequences. Energy could also be saved through provision for natural ventilation and lighting in building design. This can be achieved through proper positioning of windows and perforated walls in appropriate parts of the building. In some types of buildings this can be achieved through roof ventilation using cold multi – functional ventilators. Energy saving through natural ventilation and lighting could further be enhanced through wide windows and external doors and good material choice in window design like glazed windows of different brands (Fulleton 1978, Hachler, Holderen 2008; and lippiatt and Norris 1996).

Electrical appliances and fittings incorporate into building design and should be energy efficient. There is therefore the need to get the most useful output from energy sources. At this point, it is necessary to explain that energy efficiency of a device is a comparison, or ratio, of the useful energy output. This ratio is always related to the particular circumstance (the season, timing, desired end result e.t.c.). For example, a typical incandescent bulb converts only 10% of input electrical energy into light energy, the rest goes into heat. The efficiency in this case is 10%. If many light bulbs are turned on at the same time, there will be need to turn on the air conditioners to provide a cooling effect in the room, which implies more inefficiency. Under very cold or winter conditions, it will be efficient to use incandescent bulb as the heat provided will likely reduce the use for heaters in temperate areas (DeGunther, 2008).

According to Shomolu (2006) many homes in Nigeria are built without due regard for energy conservation. Things will have to change when power reform fully takes root and people are made to pay full value for the electricity they consume.

If we use Lekki Phase 1 in Lagos as an example, with at least 2000 homes presently occupied, and with an average of 75 lamps per household (internal and external, servant's quarters, e.t.c.). There will be at least 150000 lamps in the estate. Most likely they will be the old fashioned energy wasteful incandescent bulb types with ratings of 60watts and 100watts.

Household lighting alone will thus be accounting for between 9,000,000 watts and 15,000,000 watts, I.e 9MW or 15MW. By replacing all the lamps with the more modern and more efficient, “energy Saver” lamps now easily available in the market, the lightning load in the estate can be reduced to between 750,000 watts and 3,000,000 watts, i.e between 0.75MW - 3MW. This probably would eliminate load – shedding within the estate. On a national scale, more MW capacity would be released to supply more continuous power to more customers. This will reduce the number of power stations required in the country.

2.1.2 Water efficiency

According to Gottfried (1996), water conservation and efficiency program have begun to lead to substantial decreases in the use of water within buildings. As demand on water increases with urban growth, the economic impact of water conservation and efficiency will increase.

Water efficiency not only can lead to substantial water savings, it also can reduce the requirement for expansion of water treatment facilities. Water efficiency can be enhanced by installing water conserving features, and the collection of rain water, and recovery of non-sewage waste water for other purposes (Engel-yan et al 2005). In some parts of Nigeria like Anambra state, lots of households store water in underground concrete tanks which they use during the dry season as pipe borne water is not reliable.

2.1.3 Construction

Materials flow and cycle is a technique for tracing material use and location over time. For example, steel is routinely recovered from demolished buildings and other products such as automobiles, melted and re-used in close recycle loop. Some materials are disposed into landfills. These materials can equally be recovered and reused (Hedrickson et-al undated).

Application of green buildings and concepts can yield savings during the construction process. Measures that are readily easy to implement can result in savings to the contractor or developer. Some of these include; lower energy by monitoring usage, and installing energy efficient lamps, lower water costs by monitoring consumption and using storm water, lower material costs with more careful purchase and re-use of resources and materials among others.(Gottfried,1996).

Designing and manufacturing green products require appropriate knowledge, tools, production methods and incentives. These design tools will help identify design changes that have lower costs while improving material use and recyclability (Hendrickson 2008 and Roberts 2007).

2.1.4 Building operations and maintenance

Direct design should focus towards lowering of operating and maintenance costs in buildings through reduced utility and waste disposal costs and salaries (Gottfried 1996). According to Gottfried, recycling chutes, a viable green alternative, allow direct discarding of material from any floor in the building to the basement. This can sort materials automatically from any floor to the basement saving labour costs. Unfortunately this is not a common feature in Nigeria buildings. Once a building is operational, training of management and maintenance staff, including education and effective green building measures such as new cleaning products and new building codes and standards can help them maintain the building in resource efficient and economically favorable manner.(Gottfried 1996 , Lappiat and Norusis 1996, Lehrer 2001, Soderbaum 2008).

3. Study area

The study Area is metropolitan Lagos - Nigeria. Lagos was the former capital of Nigeria until 1991 and still remains the commercial capital of the country.

According to 2006 National census, its total population stands at 9,014,534 people. This data is however being disputed by the Lagos State government who put the population at 17,552,942.

The land area of metropolitan Lagos is approximately 999.6m^2. It has twenty (20) local government councils out of which seventeen (17) falls within metropolitan Lagos. The metropolitan area has a population of 7,937,932 and 15,532 households.

The particular areas studied in the area include Dolphin Estate (low – medium density) sharing boundary with Ikoyi Lagos, and Abraham Adesanya Estate (medium density) along Lekki – Epe axis Lagos.

Dolphin estate comprised of duplexes and flats. The flats are in the lower part of the estate. Abraham Adesanya estate is mainly comprised of duplexes.

Dolphin estate has an almost impervious covering around the buildings which does not allow fast drainage of storm water. Questionnaires were also administered to eight other local government areas including; Alimosho, Apapa, Eti – osa, Ikeja, Kosofe, Mushin, Mainland and Surulere to generate data on the use of generators in the study area.

4. Research method

In adopting a survey for this study two structure questionnaires were prepared for Dolphin and Abraham Adesanya estates and another for the eight local government areas. In Dolphin estate, there are 882 duplex houses (441 blocks) and 621 flats. Questionnaires were distributed to 65 households in the duplexes and 55 households in the flats making a total of 120 and 48 responded in each case, with a total of 96 responses. In Abraham Adesanya estate, questionnaires were distributed to 150 households of which 91 responded. In both estates questionnaires were addressed to head of households.

The questionnaire on Dolphin estate is designed to find the effect of lack of Green design in the covering around the buildings where everywhere is covered with interlocking concrete without regard that it is a reclaimed wetland. The questionnaire assessed the duration of flooding after rain and cost of damage to their assets as a result of the prolonged flooding.

With regard to Abraham Adesanya estate the questionnaire is designed to investigate household preferences with respect to ventilation and natural lighting. The study also extends to the use of generators as an alternative source of energy through questionnaires administered to 1040 households in the eight local governments in the study area with 774 respondents.

Table1: Flood Duration

	Duration	*frequency*	*percentage*		*Duration*	*Frequency*	*Percentage*
DUPLEX	*Less than a day*	*22*	*45.83*	*FLATS*	*Less than a day*	*5*	*10.87*
	Between 1-2 days	*8*	*16.67*		*Between 1-2 days*	*5*	*10.87*
	Between 2 -4 days	*4*	*8.33*		*Between 2 -4 days*	*10*	*21.74*
	Between 4-7 days	*12*	*25*		*Between 4-7 days*	*26*	*56.52*
	Total	*46*	*100*		*Total*	*46*	*100*

Source: Field survey 2007

From table 1 above the average duration for storm water to drain after heavy rainfall is 2.56 days per household for those living in the Duplex houses and 4days per household for those living in flats. The Gap in duration is due to the fact that the estate is sloppy. The flats are located at the lower part of the slope. The situation is so bad that in critical situations residents have to use canoes to cross to the road.

This problem affects the productivity of residents of the estate. In effect, residents of duplex houses and flats loose 2,205 and 2,402 man hours respectively each time there is heavy rainfall.

Table 2: Economic impact of flood on households

	₦	*frequency*	*percentage*		*₦*	*Frequency*	*Percentage*
FLATS	*10,000 – 100,000*	*19*	*59.38*	*DUPLE X*	*10,000 – 100,000*	*1*	*5.26*
	100,000 – 200,000	*4*	*12.5*		*100,000 – 200,000*	*6*	*31.58*
	200,000 – 300,000	*1*	*3.13*		*200,000 – 300,000*	*2*	*10.53*
	300,000 – 400,000	*1*	*3.13*		*300,000 – 400,000*	*3*	*15.79*
	Above 400,000	*7*	*21.88*		*Above 400,000*	*6*	*31.58*
	Total	*32*	*100*		*Total*	*18*	*100*

Mean damage= N1557,656 Mean damage=272,500

Source: Field survey 2007

The average loss or damage on property caused by the flooding in flats is N157,655.25 while that of the duplex is N272,500.00. This could be explained by the fact that people staying in the duplex area are richer and have more valuable assets. The figures above indicate the economic impact of the flooding in the study area due to lack of green design. This is also adverse to environmental sustainability. The total cost of flood related damage on their asset is N338,248,755 (N240,345,000 for duplex houses and N97,903,755 for flats).

Table 3: Preference Hierarchy for Building Services/Component (Residential Development)

Variables	*Relative Index*	*Ranks*
Constant Electricity	*0.912*	*1*
Reliable Water	*0.900*	*2*
Amount of space	*0.899*	*3*
External/internal design	*0.849*	*4*
Window type/ventilation	*0.771*	*5*
Floor finishing	*0.752*	*6*
Natural lighting	*0.744*	*7*
Wall finishing	*0.723*	*8*
Security	*0.721*	*9*
Mobile phone reception	*0.716*	*10*
Parking space	*0.708*	*11*
Toilet quality	*0.708*	*12*

Archiving/Storage facilities	*0.699*	*13*
Elevator/lift	*0.654*	*14*

Source: field survey 2009

From table 3 above there is evidence that due to the poor power situation in the country, residents of the estate have relatively high preference for natural lighting and ventilation as both ranked 4 and 6 respectively. This implies that households will be willing to pay for Green design buildings. The positions of the preferences however indicate that some of the respondents may not understand the link between natural ventilation, lighting and energy savings. If they do, their position may alter.

Table 4: Number of Hours of Electricity Supply per day

	On the average, how many hours do you enjoy electricity supply a day?						
	1-5 hours	*6-10 hours*	*11-15 hours*	*16-20 hours*	*24 hours*	*None for some days*	*Total*
ALIMOSHO	*38* *40.0*	*41* *43.2*	*4* *4.2*	*5* *5.3*	*0* *0.0*	*7* *7.4*	*95* *100%*
APAPA	*30* *50.0*	*20* *33.3*	*10* *16.7*	*0* *0.0*	*0* *0.0*	*0* *0.0*	*60* *100%*
ETI-OSA	*27* *27.0*	*0* *0.0*	*17* *17.0*	*6* *6.0*	*2* *2.0*	*19* *19.0*	*100* *100.0*
IKEJA	*24* *28.9*	*21* *25.3*	*13* *15.7*	*13* *15.7*	*3* *3.6*	*9* *10.8*	*83* *100%*
KOSOFE	*54* *62.8*	*19* *22.1*	*3* *3.5*	*2* *2.3*	*0* *0.0*	*8* *9.3*	*86* *100%*
MAINLAND	*60* *60.0*	*30* *30.0*	*0* *0.0*	*0* *0.0*	*0* *0.0*	*10* *10.0*	*100* *100%*
MUSHIN	*33* *34.0*	*38* *39.2*	*8* *8.2*	*1* *1.0*	*0* *0.0*	*17* *17.5*	*97* *100%*
SURULERE	*31* *32.3*	*32* *33.3*	*14* *14.6*	*0* *0.0*	*0* *0.0*	*19* *19.8*	*96* *100%*

Source: Field survey 2008.

Data from table 5.4.2 shows that majority of households in the study area have electricity power supply between 1-5 hours a day more particularly Kosofe (62.8%), Mainland (60%), Apapa (50%), Alimosho (40%), Mushin (34%) and Surulere (32.3%). Some do not even have power supply for some days. This is a serious problem considering the socio-economic of electricity to urban households.

Table 5: Ownership of Private Electricity generator *Table 6: Frequency of use of electricity generator*

	Do you have a standby generator		
	YES	*NO*	*Total*
ALIMOSHO	*78* *80.4*	*19* *19.6*	*97* *100%*
APAPA	*60* *85.7*	*10* *14.3*	*70* *100%*
ETI-OSA	*91* *91.9*	*8* *8.1*	*99* *100*
IKEJA	*72* *81.8*	*16* *18.2*	*89* *100%*
KOSOFE	*68* *80.0*	*17* *20.0*	*85* *100%*
MAINLAND	*50* *62.5*	*30* *37.5*	*80* *100%*
MUSHIN	*51* *54.3*	*43* *45.7*	*94* *100%*
SURULERE	*58* *61.7*	*36* *38.3*	*94* *100%*

Source: Field survey 2008.

	If your answer to 28 above is yes, how often do you use it?					
	Daily	*1-3 times a week*	*4-7 times a week*	*Once in a long while*	*Others*	*Total*
ALIMOSHO	*57* *73.1%*	*11* *14.1%*	*6* *7.7%*	*3* *3.8%*	*1* *1.3*	*78* *100%*
APAPA	*50* *83.3*	*10* *16.7*	*0* *0.0*	*0* *0.0*	*0* *0.0*	*100%*
ETI-OSA	*75* *82.4*	*8* *8.8*	*7* *7.7*	*1* *1.1*	*0* *0.0*	*91* *100*
IKEJA	*28* *40.0*	*24* *34.3*	*14* *20.0*	*4* *5.7*	*0* *0.0*	*70* *100*
KOSOFE	*454* *67.2*	*9* *13.4*	*12* *17.9*	*1* *1.5*	*0* *0.0*	*67* *100%*
MAINLAND	*30* *60.0*	*10* *20.0*	*10* *20.0*	*0* *0.0*	*0* *0.0*	*50* *100%*
MUSHIN	*33* *67.3*	*3* *6.1*	*11* *22.4*	*2* *4.1*	*0* *0.0*	*49* *100%*
SURULERE	*39* *66.1*	*4* *6.8*	*10* *16.9*	*5* *8.5*	*1* *1.7*	*59* *100%*

From table 5, it could be seen that between 60% and 92% of households in the study area use private electricity generators as alternative power supply. Some of these generators are substandard and cause air pollution. Data from table 6 indicates the frequency of usage. The highest frequency of usage is in Eti – osa local government area (91.9%) followed by Alimoso local government (80.4%). Households should therefore be encouraged to use inverters in their homes which can partly be financed with money used in buying and fueling generators.

5. Discussion and conclusion

Like the design process, the design of green buildings and sustainable environment involves creative arrangement of components and details to meet a set of specifications/guidelines subject to other constraints. Results from the table indicate that Nigerians are not green conscious in building design and environmental management. The rampant use of generators most of which are substandard instead of adoption of natural ventilation and lighting in their design is a practical indication of a nation which is not conscious of the link between environment, good health and economic development. The amount of man hours lost due to flooding and damage to households' property constitute a serious problem to both government and households. In order to avert a gloomy future for our environment, there is need to reduce to bare minimum the use of non – renewable resources, manage renewable resources to achieve sustainability and reduce with the ultimate goal of eliminating toxic and otherwise harmful emissions to the environment including emissions contributing to global warming.

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Managing Quality and Environmental Costs in Construction Industry

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Abstract

Construction companies that pay attention to quality and environment stay ahead the competition and survive in the modern competitive market place. A variety of tools are available to companies to help them achieve this goal. Certification to ISO's management standards, ISO 9001 and ISO 14001, has become increasingly necessary in today's global trade. ISO 10014 provides top management with information to facilitate the effective application of management principles and the selection of methods and tools that will lead the sustainable financial success of an organization. This paper focuses on managing quality and environmental costs and reaping the benefits of the ISO 9001 and ISO 14001 certifications. It discusses and presents the findings of a action research case study. It presents a computer-based quality and environment cost management system. The development of a quality and environmental cost management system requires more action research-driven approaches to cover all the relevant angles of the investigated research objectives and to generate added value by capturing construction companies' real-world problems. Thus, action research (AR) method was followed for designing and developing the computer-based system presented in this paper.

Keywords: construction, environment, projects, quality, system

1. Introduction

In the current construction markets, the concern to meet customers' requirements is added to the concern to improve economic and financial performance for the company itself. Costs, quality and environment are important aspects of construction projects for performance analysis and its linkages (Rouse and Chiu, 2009).

Efficient project execution is a key business objective in many domains and particularly so for capital projects in the construction industry. The main purpose of quality and environmental management systems should always be to improve a business's economic and financial performance (Boerner and Jeczen, 2004). Companies that pay attention to quality and environment stay ahead of the competition and survive in the modern competitive market place. A variety of tools are available to companies in order to help them achieve this goal (Ramanthan and Yunfeng, 2009). Certification to ISO's management standards, ISO 9001 and ISO 14001, has become increasingly necessary in today's global trade. These standards are built on the eight quality management principles: (1) customer-focused organizations; (2) leadership; (3) involvement of people; (4) process approach; (5) system approach to management; (6) continual improvement; (7) factual approach to decision-making; (8) mutually beneficial supplier relationships (Hele, 2003; Zeng et al., 2005). The quality and environmental management systems are the bridges that leads the customer to the product she/he wants (Nicoloso, 2007).

Today, no construction company can afford to ignore the quality and environmental costs of its projects. There are many factors in the construction industry that can influence the quality and the environmental performance of construction projects, both positively and negatively, and so it is increasingly important to manage their quality and environmental costs. Only a few studies have so far been carried out on the integration of quality and environmental cost management systems, and this the paper presents a novel integrated model to solve this problem. This paper focuses on managing quality and environmental costs and reaping the benefits of the ISO 9001 and ISO 14001 certifications. Three case studies are discussed and a computer-based system for quality and environmental cost management is described.

2. Methodology

The development of a quality and environmental cost management system requires more action research-driven approaches to cover all the relevant angles of the investigated research objectives and to generate added value by capturing construction companies' real-world problems (Alvesson, 1996). Action research (AR) takes many forms, and indicates diversity in theory and practice among action researchers, so providing a wide choice for potential appropriate actions for their research question. AR allows researchers to spend time in organizations and to research the research hypothesis on an operational basis. Thus, action research is an approach that aims both at taking action and creating knowledge or theory about that action (Coughlan and Coghlan, 2002). The researchers are professionally involved with the organizations in question (Hameria and Paatela, 2005). The strength of action research is its ability to support the creation of a new model or system, as with the development of a computer-based system for quality and environmental cost management. This made it appropriate to approach our work with action research. In addition, this approach is flexible in how it collects relevant data and aims to provide validation during the course of the system's development. Action research is collaborative and cyclical, and is described in the current literature as a recurring cycle of planning, acting, observing and reflecting (Kyrö, 2004). Building on Kaplan and Norton (1993) show a feasible way to develop a quality and environmental cost management system, which is characterized by expert interviews and workshops.

Three construction projects of potential ones were selected for participation in this research project. In accordance with Smith and Smith (2007), these construction projects were regarded as "action research case studies". They also worked as real-life case-study material in the firm. This provided first-hand experience of the problems at both firm-level and project-level, and, by interacting with the people directly involved identified potential ways of resolving them (Yee et al., 2006). In this study the approach was implemented by having two members of the research team gather data and accompany a large construction firm throughout the system's design process over a period of 11 months. The action research process was implemented in several phases. During these phases the data were gathered through workshops, from company documents, interviews conducted with various groups (including managers and employees), within the project organization and from field notes made during the assignment. The interviews collect field data for empirical modeling (Humphreys et al., 1996) in order to select relevant data and information artifacts from the list of potential items. The semi-structured interview is a useful mechanism for assessing the research situation (Goldman et al. 1995; Robson, 2002). This provided first-hand experience of the challenges at project-level, and, by interacting with those directly involved, identified potential ways of resolving them. Twenty semi-structured interviews were conducted, aimed at collecting information about the entire operating process of the quality and environmental management system (QEMS) in a construction project. To guide the interviews, a paper based questionnaire with open and closed questions was developed on the basis of literature research (Goldman et al. 1995) and presented at all interviews. The interviews were preceded by visits to the selected projects which included informal conversations with potential informants. The existing practices under the QEMS in the construction site were analyzed, including the overall characterization of quality and environmental management processes with respect to the plans, procedures, records and control as well as the management of costs supported by this system. The semi-structured interviews are split between into several sections with distinct goals. There is a section on the characterization of the subject, another one focused on measuring and recording the costs in the system and a third one that approaches nonconformance and complaints. There is a section responsible for analyzing the benefits of the QEMS, a section which studies the status quo of information and communication, another one that introduces the topic of performance and improvement indicators. Finally, the subjects are presented with additional suggestions.

3. Theoretical background

The implementation and certification of quality (ISO 9001) and environmental (ISO 14001) systems has become an important activity (Zeng et al., 2007). Some research studies have focused on the benefits and effectiveness of quality and environmental management systems (Briscoe et al., 2005; Johansson and Palmes, 2005; Poksinska et al., 2006; Khan, 2008; Tsai and Chou, 2009). For example, Poksinska et al., (2006) shows that an external benefit of implementing ISO 9001:2000 is improved customer relations; the internal benefits most often mentioned relate to the standardization of organizational processes. Petroni (2001) states that implementation of ISO 14001 and subsequent registration can facilitate progress towards increased market share, improved working climate and customer satisfaction, improved efficiency of operations and processes, and cost reduction. Johansson and Palmes (2005) note that quality programs, viewed as an investment, can be assessed in financial terms at each phase of their cycle. Khan (2008) points out that, ISO 14001 or ISO 9001 certified companies around the world insist that certification is a prerequisite for business relationships. Tsai and Chou (2009) note that ISO 9001 standard has contributed to better quality, greater customer satisfaction, and higher profits and ISO 14001 standard has contributed to better environmental performance, greener products, and more transparency for and acceptance by external environmentally concerned stakeholders. Other studies, meanwhile, have focused on integrating two or three management systems from various viewpoints (Karapetrovic and Jonker, 2003; Dubinski et al., 2003; Low and Pong, 2003; Labodova, 2004; Zeng et al., 2005; Jørgensen et al. 2006). The integration of the quality and environment systems creates better chances of saving costs, improving effectiveness and achieving economic and financial benefits by allowing the synergy of tasks within the two systems - unique and integrated strategies, compatible goals and a single standard regarding for product and service consistency (Salomone, 2008). From many different angles and in any construction company, the achievement of financial and economic benefits from organizational assets and resources is a key factor for staying competitive in the current markets. In 1974, this concept was approached by the American Society for Quality Control and in 1979 by Crosby (Wang and Guo, 2007). The NP 4239:1994 standard establishes an important foundation and guidelines for the quantification of quality costs, and it even provides measures for improving productivity. The appearance of failure mode and effects analysis (FMEA) has been welcomed and applied in a wide range of industries such as aerospace, nuclear, chemical and manufacturing (Chin, et al. 2009). The FMEA technique aimed at to define, identify and eliminate known and/or potential failures, problems, errors from the system, design, process and/or service before they reach the customer (Linton, 2003; Stamatis, 1995). A number of ways for classifying the quality and environmental costs were developed. Generally, quality and environmental costs can be classified into conformance/quality costs and non-quality/failure costs (Ireland, 1991; Holland, 2000; Love & Irani, 2003). The quality and environmental costs derive from the effort invested in achieving quality and clean production in the given products/services. These costs can be divided into prevention costs and assessment costs. The ISO 10014:2006 standard by provides guidelines for achieving financial and economic benefits through the application of eight quality management principles (ISO, 2006). In relation to economics it is relevant to highlight the ISO 10014 standard which provides guidelines for assessing the viability and profitability of the QMS (Ribeiro, 2006). Studies show that senior management's attention and focus is more easily captured when facts and figures resulting from quality improvement are presented as return on investment figures (Brad et al., 2006). However as pointed out by Choi et al. (2009) the appropriation of quality management costs and independence of the quality management organization is still unsatisfactory in the construction industry. The above discussion reveals a gap in the literature as to how construction companies manage the quality and environmental costs to become more profitable and to reap the benefits of quality and environmental management systems. It is important to bridge this gap because construction companies are concerned with this issue.

4. The action research case study

A computer application based on the balanced score card method is available to all managers through the firm's intranet. This application displays monthly indicators of the overall compliance status of the QEMS processes. This program aids decision-making and monitoring the QEMS performance. In addition, it helps the firm to keep an eye its quality and environmental goals, alerting too any deviations from pre-determined performance targets. The three selected projects were all under construction and all of them have implemented a documented CCMP. There were twenty semi-structured interviews with project managers, environment and quality technicians, quality and environment directors. The most immediate finding from interviewees is that OPWAY assigns much importance to the financial value quality and environmental non-conformances. The costs handled by the QEMS and which are accounted for by OPWAY are the costs of failures, which includes the non-conformities and complaints. The majority of non-conformities are detected during the execution and accounted in monthly periods. Non- conformities have a considerable impact on project cost and time. The interviewees were of opinion that management effort should mostly be directed towards the prevention of failure to reduce costs in future works. They also agree with the need to change the way complaints are handled, to take a more proactive approach along with the creation of a user's manual. Most of the interviewees stressed the importance of the performance indicators which allow them to assess the QEMS effectiveness each month. But the interviewees agreed that there is no way to track and assess the quality and environmental cost of their projects. Most of non-conformities are associated with subcontracted works.

5. The quality and environmental management system

The quality costs models found in the bibliography proved to be too broad in terms of their practical application and, therefore they had to be adjusted. The case study action research helped the authors to develop a quality and environmental cost structure adjusted to the nature of construction projects. The cost structure used in the research work, like those found in the reference bibliography, was split into two groups: 1) costs of conformity; and 2) costs of non-conformity (Table 1). The costs of achieving conformity are subdivided into prevention costs and the cost of assessment at firm and project levels. The costs of non-conformity are subdivided into the cost of internal failures and cost of external failures. A distinction was made between costs that only relate to the firm's operations (F) and costs directly linked to the construction projects (P). External training involves all employees not deployed to any construction projects. Internal training and audits involve people from certain departments within the firm and people pertaining the projects' organizations. In the latter case, the corresponding costs pertain to the construction project in question, despite being accounted simultaneously as company costs. The same applies to human resources' costs for employees operating from headquarters and dealing with some or all ongoing construction projects.

The UML language (Unified Modeling Language) was used in the specification and design of the proposed model. This modeling language can be used build a representation and specification of the components of a computer based system (Korth et al., 2002). The UML Class Diagram was chosen for development of the conceptual model. This conceptual model describes the static structure of the system with objects (entities) characterized by attributes and operations. Figure 1 presents a view of such specification. The business partner consists on an abstract entity – generalization – which can be specialized as “Client” and “SC_S” (Subcontractor or Suppliers). The Client represents an entity which can file “Complaints”, can award “Construction Project” and can be the auditor in relation to an “Audit Cost”. A “Construction Project” represents ongoing construction works and those works already delivered but still within the warranty period. The “Construction Project” is an entity to which human resources (“HR”) are assigned (quality and environment employees).

Table 1: Cost structure

Quality and Environmental Cost Structure at Firm level (F) and at Project Level			
Costs of Conformity		*Costs of Non-conformity*	
Prevention	*Assessment*	*Internal Failures*	*External Failures*
QEMS Planning, implementation, operation and maintenance (F/P)	*Trials and Inspections (P)*	*Waste (CP)*	*Complaint Handling (CP)*
Internal (F/CP) and External (F) Training	*Trials’ contracts with third parties (P)*	*Non conformities handling, reworking (CP)*	*Compensation (CP)*
Equipment for Inspections and Trials (P)	*External and internal Audits (F/P)*	*Interruptions (CP)*	*Fines (CP)*
Infrastructure and Equipment (environment) (P)	*Compliance with legal requirements* *Deposition rate (P)*	*Fines (CP)*	

Construction Projects may be the target of “Complaints” and be associated with Non-conformant Product (“NCP”) or Non-conformity (“NC”). It also has a “Client” and one or more Sub-contractors and Suppliers (“SC&S”) (two independent relations in the diagram). The project includes Training Costs for its employees as well as Audit Costs (two independent relations). Lastly, all specializations of Mandatory Costs are associated with one Construction Work and may or may not be associated with the specializations of Eventual Costs. An “NCP_NC” may have the responsibility of an SC_S or of an HR. Each NCP_NC occurs in a Construction Project. This entity may result from a work-control cost or from an audit (two independent relations) and is linked to a cost of handling an NCP. The occurrence of such costs may or may not cause interruption costs or fines. Based on the specification, a computer based system was developed. Figure 1 describes its high-level architecture. The developed system’s aim is to support quality and environment cost management in the construction industry. It should support consultation, insertion, updating and deletion of stored information as basic support operations available to any quality and environment technician and project manager (construction site), or director of quality and environment (company headquarters).

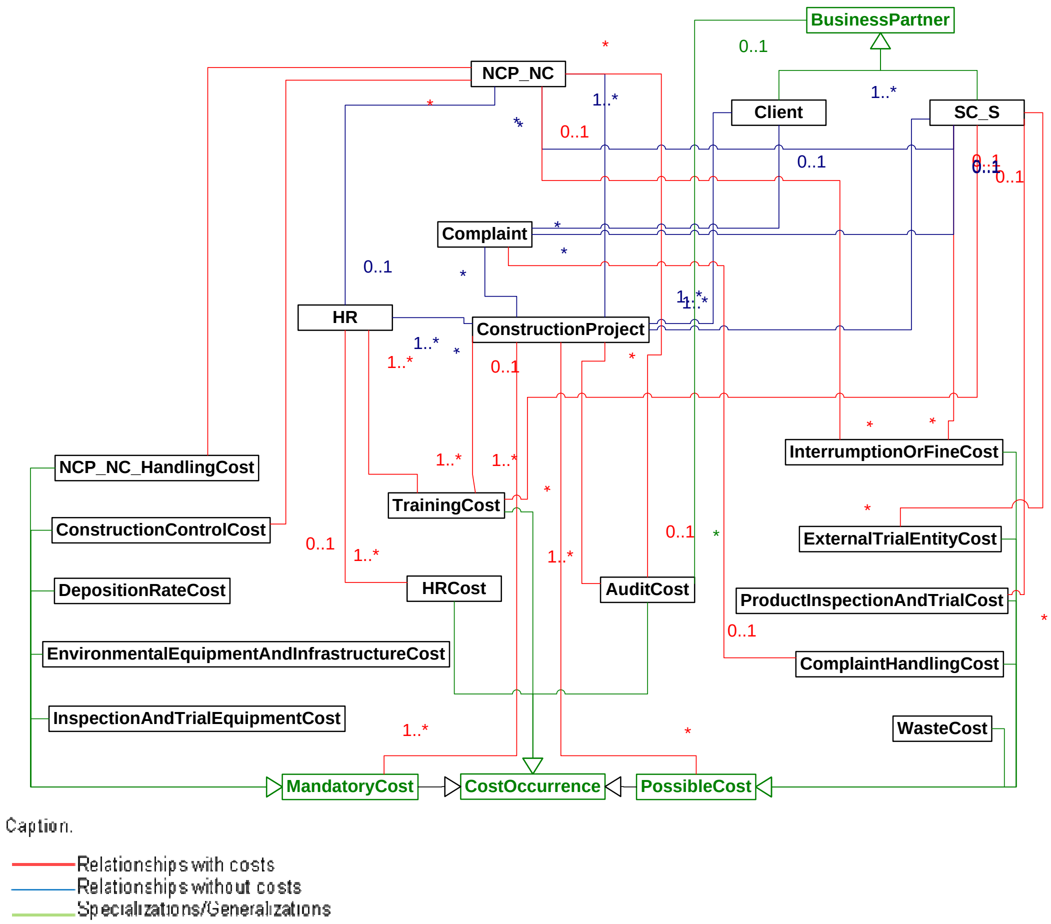

Figure 1: Conceptual model

To implement this system, a Microsoft SQL database application was developed for storing both the conformity quality and environmental costs and non-conformity quality and environmental cost. These costs can be registered in such a way that they could be associated with the corresponding process or activity in a given construction project. The system is functionally divided into two sets of components: the quality and environmental cost database (QECDB) and the quality and environmental cost management system (QECMS). The latter component includes a user interface. The user interface navigation between pages and forms was made possible with the creation of a switchboard (control panel). The system can provide cost reports that include a set of performance indicators to aid decision-making and the discovery of sources of waste or causes of non-conformance. For a given construction project, the following indicators are calculated:

- Prevention Indicator (total prevention costs / construction project budget);
- Failure Indicator (total failure costs / construction project budget);
- QEMS Indicator (total costs / construction project budget).

In the global reports, the following indicators are calculated and shown:

- Prevention indicator (total prevention costs / total QEMS costs);
- Failure Indicator (total failure costs / total QEMS costs).

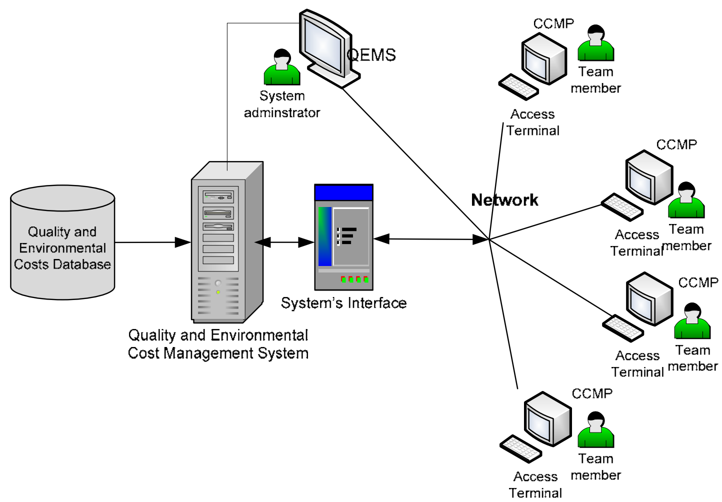

Figure 2: System's architecture

Figure 3 shows one of the forms for editing and viewing the costs of a client's complaint during the warranty period. The proposed system was tested by applying it to several applications real cases to evaluate the functionality of the program in the form of representative examples. Manual tests were carried out on the interface, functions and data flow, simulating daily usage in a real context with the participation of several professionals. This was supplemented with the creation of summarized cost reports for the QEMS. The testing and validating of the software application was conducted simultaneously with a constant search for flaws or improvement opportunities. Testing the many components of a software program is essential in these stages, and it can be assumed that the verification and the testing of software applications is included within the concept of software validation. This application's verification and validation not only considered each of its components individually but it also analyzed the application as a whole, considering the models from the designer and user perspectives (Jagdev et al., 1995). The QECMS was tested repeatedly through several stages until the system reached a state that assures the validity of the proposed model. The tests comprised manual inspections and validation, focusing on the programs' expected functionality according to the requirements, the programming techniques used to achieve expected performance and reliability and ergonomics according to future usage situations (Greif, 2006).

6. Conclusions

This paper describes a computer-based system for managing quality and environmental costs in the construction industry. The system tasks are derived from the provisions in the ISO 9001 and ISO 14001 standards and designed to be integrated with other computer-aided project management functions through the firms network. A conceptual model was defined to represent the information used in the system tasks based on three action research cases within the real environment of a large construction firm. The developed system will render the assisted quality and environmental management tasks more effective. Its use was tested on data from different construction domains. It is an essential performance assessment tool for the QEMS. The authors followed up usage and usefulness during the system's implementation. It enables action based on concrete results and data and thus supports the continuous improvement of the management system – a point highlighted as essential in all normative documents in this field of work and which completes the plan-do-check-act (PDCA) cycle. For the quality and environment research area, our study will hopefully encourages more research on real cost management applications in the construction industry. Finally, we must acknowledge the limitations of our work since there is a need to take the development of the proposed model further.

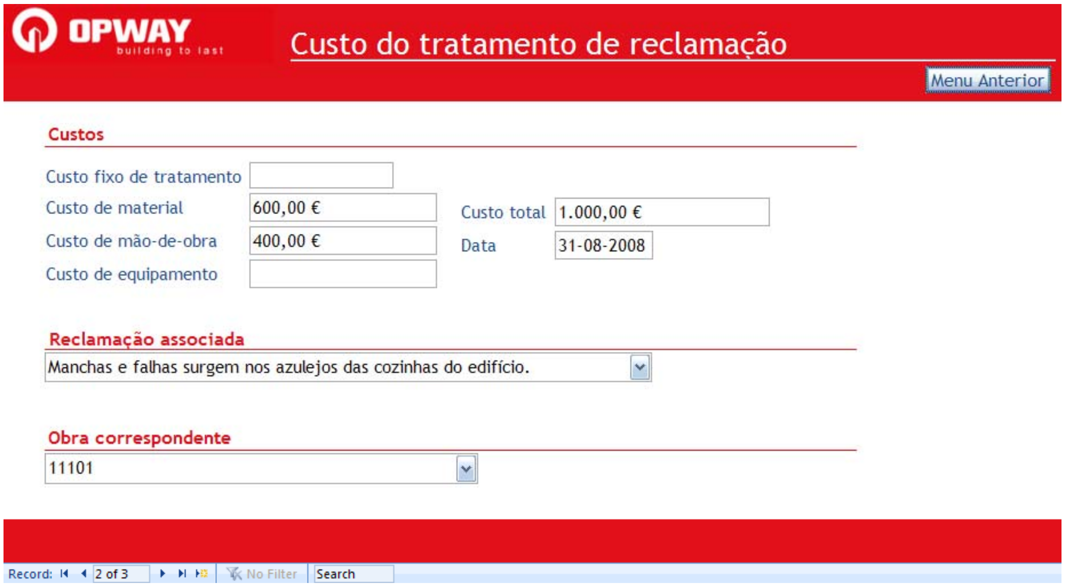

Figure 4: A complaint form

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A tool of CO2 for Sustainable Planning and Design

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Abstract

A tool of CO2 for sustainable planning and design. Based on the Green House Gas Protocol (GHG Protocol) whereby a methodology for CO2 accounting relating to emissions of all kind of emitting enterprises (from stationary combustion, from purchased electricity, Heat or Steam, from transport or mobile sources). However as can be seen by the accounting methodology and the equations presented in this research, the literal application of this methodology to the emissions of greenhouse gases in cities or urban areas is not easily feasible. Because it is a methodology that requires measurements accuracy, in order to ensure fairness in buying and selling shares of carbon, it is difficult to apply in environments of great complexity. We developed an accounting methodology for CO2 emitions and absorption that is applicable to the territory. We expect that: This methodology will become a tool for planners and designers as well as for territorial emissions trading .- this tool enable planners and architects to apply the knowledge gained in developing a new approach to land planning and architecture for the development of a general trading rules for areas of territory as a whole, in favor of sustainability.

Keywords: low carbon, cities, buildings, planning, design

1. Introduction

In this article a methodology of evaluation for local environmental sustainability to insert in the concept of local Planning.

(Plano Director Municipal). The PDM is in Portugal the most important instrument of territory local management. One of the biggest challenges that currently the humanity faces is the raised CO2 production and emission. It is important to develop techniques and instruments that allow the public and private controllers to implement politics that stop this CO2 excess in the atmosphere.

The problem, face to its scale, only has resolution in the political level of legal regulation, with the elaboration of assertive laws and easy acceptance and application. It increases that this subject in scientific terms is widely trans-disciplinary, enclosing diverse and very distinct areas of the scientific knowledge.

2. Political framing for the proposed methodology

In local and territorial level of planning policies it is necessary to develop urban and municipal plans that incorporate measures and methodologies that minimize or counterbalance the emissions CO_2.

Nowadays, although the local decision makers can be interested and worried in the issues of the CO_2 emissions, due to the lack of public pressure they do not make use of the instruments and the policies that make it possible. Therefore, these policies are not implemented as well as.

It is considered in this proposed methodology of analysis that follows: to create differentiated levels of municipal taxes in order for the city council to encourage planning measures that will allow for a balance of absorption and CO_2 emissions in the county/municipality.

It is also possible to define municipal taxes, in which decision makers and citizen's voters are interested in implementing measures inside the municipal planning policies, who harness low one taxes to pay.

3. Proposed methodology

The proposed methodology intends to establish an accounting of CO_2 emissions in municipal areas, having for objective to verify if the impact of people life, with its equipment, the constant urban and road typology in municipal areas, are superior to the capacity of the existing natural local drains (natural CO_2 absorption).

However, as if it can infer for the accounting methodology and for the presented equations, the literal application of this methodology to the emissions of gases of greenhouse effect in cities or urban zones is not easily practicable.

Taking into consideration that this methodology needs an accounting rigor, to assure justice in the purchase and sales of carbon permits, seems to be difficult to use in environments of great complexity.

For the accounting of the resultant CO_2 emissions due to the production of electric energy in the county, the development of a method is considered that combines specific factors of the territory with some of the factors considered in the Protocol of GEE based on the CO_2 accounting emissions in environments with a higher degree of complexity in human activities can be applicable.

Intention of the Application of the Methodology of Calculation

- Regroup the territory on the basis of the territorial limits of the municipality with quantification of the area of basins of draining in constant it.

- To apply the methodology of calculation of the rocking of the Co2 emissions that is enunciated here in the application example, to follow.

- To verify if the rocking of the emissions, for the area of municipality in study is positive or negative; that is, if these areas are drains or emitting of Co2.

- To apply a new boarding to the planning of the territory and the architecture, being added one tax policy hardwired with the liquid result of the absorption/Co2 emission, with the development of a criterion of fiscal organization to the areas of territory of municipality, in favor of the support.

- This fiscal organization hardwired to the question of the liquid rocking of Co2 in municipality will originate a bigger rationalization of the use of the ground, and will include for this saw penalties for the emitting areas, that will have that to develop in PDM headquarters politics and instruments of territorial management that force the investment in solutions that harness the drains (absorption).

- The cost of the penalties along with the increasing environmental sensibilisation would lead to a holistic and sustainable boarding for the territory.

The county instrument of urban management and territorial PDM (plain municipal director) plays an important role in the game and sink accounting of Co2 emission/. It is this document that defines the typology of the urban occupation (house/building) and delimits the urban perimeters of the populations, with implications in the mobility and the transports of the population. It is this document of management that defines the amount and management of forest, agricultural and urban areas, and is equally in this document that if conceives the management of the drainage basins, namely in the construction of dams. This document has thus a determinant role in the question of the Co2 emissions the county level. In the situations where the positive rocking either, with absorption of superior Co2 to an emission, is considered that autarchic tax IMI, that each proprietor of real properties in the county paid, either inferior to a maximum value of reference in the Country. The IMI are an autarchic tax county function of the value of the property. If the reduction in the value of the IMI will be superior to 40% of the reference value it will initiate a process of pressure of the population next to the city council, so that the PDM may be changed in order to contemplate measures that may correct the negative deficit in the balance between emission and absorption.

4. Delphi method

The Delphi method is a process for gathering information from a group of specialists (Jillson, 1979) to reach a consensus of opinion about a certain subject (Fuller and Jones-Evans, 1994).

The method is used for formalization during a decision-analysis process in order that all the experts (panelists) reach identical opinions or clear differences (Harmanthy, 1982) so that the final result is a consequence of the participation of several experts and not just one person (Shields et al., 1987). With Delphi, Communications between geographically dispersed groups of experts are improved (Linstone and Turoff, 1975).

In the Delphi process a group of specialists, who represent a population of experts, answers several rounds of questionnaires about a certain subject in order to reach a common approach about it (Jillson, 1979). These rounds are repeated until the panel (group of specialists) reaches a consensus on that subject (Fuller and Jones-Evans, 1994).

Before beginning the rounds of questionnaires, a pilot questionnaire should be constructed so that issues like the number of panelists and number of rounds can be fine-tuned (Jillson, 1979).

The Delphi technique is based on three essential features (Dalkey 1969; Perez and Schuler, 1982):

1. **Anonymity.** A face-to-face discussion between experts can lead to a distorted conclusion because experts with dominant personalities can impose their thoughts to others and misguide the process (Shields et all., 1987). Besides that anonymity prevents (Linstone and Turoff, 1975) the following aspects:

    - The unwillingness of individuals to take a position on an issue before. All facts are known

The difficulty of publicly contradicting individuals in higher positions. The unwillingness to abandon a position once it is publicly taken.

- The fear of bringing up an uncertain idea that may turns out to be misconstrued.

2. **Controlled feedback.** The first questionnaire is analyzed, summarized and sent back to the panelists with the second questionnaire, which was developed, based on the results of the first (Linstone and Turoff, 1993). This process is repeated through two to five rounds (Linstone and Turoff, 1993).

3. **Statistical group response.** The use of statistics attenuates the pressure for conformity once it is difficult to have a full consensus between the panelists (Harmanthy, 1982).

The Delphi method was created as a process to predict technological development by a group of specialists (Linstone and Turoff, 1993). Its initial aim was to forecast scenarios through obtaining reliable consensus of opinion of a group of experts by answering a series of intensive questionnaires with controlled opinion feedback (Linstone and Turoff, 1975).

Today, the Delphi technique is applied to issues other than the prediction of scenarios. In fact, this technique can be applied when information is not available or when evaluation models require subjective inputs to the point where they become dominant parameters (Linstone and Turoff, 1975).

Furthermore, Delphi can be used to analyze decisions on subjects that include of extensive numbers of variables or on deficient or even unavailable information in a statistical form (Harmanthy, 1982). This technique is also applied when the subject cannot be approached in an analytical way (Fuller and Jones-Evans, 1982).

Nevertheless the Delphi technique presents several pitfalls that can restrict its field of application (Linstone, 1975):

Space-time discounting. By a longer time horizon it is hoped that additional options or solutions to currently unsolved problems will materialize.

The prediction urge can lead to the suppression of uncertainty, which can mask the real significance of the Delphi results.

The simplification urge. Most human beings exhibit a tenacious tendency to simplistic misjudgments.

- Illusory expertise. The specialist is not necessarily the best forecaster.
- Poor selection of participants.
- Poor interaction between participant and analyst.
- Superficial analysis.
- Basic lack of imagination by the designer.
- Over-pessimism in long-range forecasts and over-optimism in short- range forecasts.
- Overselling the Delphi results.
- The process is not immune to manipulation or propaganda.

- Difficulty in generalizing results beyond the population of panel members.

As referred the use of “case studies” and the Delphi approach are suitable for the analysis of the sort of soft and complex data being studied. However, in edition, they have complementary strengths and to some extent which tend to investigate weakness of the other.

5. Conclusions

Environmental problems have a cause and effect directly related to consumption of resources, whether in terms of energy consumption, or of territory. It is up to the architect and urban planner to play a vital role in reversing the trends and negative consequences that are destroying the biosphere, particularly with respect to climate change and biodiversity.

The perception that there is a serious environmental problem and that this problem stems from human activity, has promoted a series of conferences and agreements, including the Kyoto Protocol, which seek to halt environmental degradation.

However, many of the methodologies and tools necessary to address these issues are not yet available, and there is an excessive compartmentalization of different areas of knowledge. In any case, the size of the problem is so huge that it requires the development of a new intellectual framework based on Trans disciplinary and a holistic platform.

In the process of developing this platform, it is up to architects and planners to assume a role in "the processes of land planning and natural resource planning that must be integrated with an evaluation of quantifiable resources, and a consideration of environmental values, such as aesthetic values, historical-cultural values, and ecological values of the landscape. These are usually intangible in nature (...). It is therefore relevant to the investigation of principles and methods for developing the applicability of this concept, to consider the inclusion of these values in those processes.

It is also important to strive to develop a measurement methodology that is intelligible and can be useful to architects and planners. Therefore, it is appropriate to select which parameters should be addressed for the development of a Trans-disciplinary platform.

To this end, it was necessary to select an area (for our case study) where it would be possible to analyze the way in which the territory was being appropriated for human activities. The criteria behind this selection were based on the logic of a unit area defined by environmental factors, in this case a drainage basin, in which multiple factors coexist that can be analyzed and accounted for.

In order to contribute to a methodology that serves architects, we decided to do a survey and a critique of the legislation for thermal and energy issues in buildings. A range of strategies to reduce energy consumption was then presented showing the underlying concepts advocated by passive solar design. Various systems were shown utilizing solar energy and other alternative energies. Tax incentives for encouraging the use of alternative energy were analyzed, and we reached the conclusion that to ensure the change in patterns of use of conventional energy will require greater commitment on the part of the tax system.

Although the decrease of energy consumption is relevant, as well as the use of alternative energies, it is clear that an assessment of environmental impacts caused by human activities is also needed, particularly those responsible for the emission of CO_2. Therefore, we have outlined a method for the calculation of this gas, as applied to the drainage basin in North of Abrantes. The values obtained by this method were compared with values established for Portugal's emissions under the Kyoto Protocol. The conclusion was that the difference between the values measured for the Watershed North of Abrantes, is only 6% less than the amount stipulated for Portugal by the Protocol.

In short, the contribution that this paper intends to provide for the conceptualization of sustainable architecture and planning was based on 4 pillars:

1) The need for accounting of CO_2 emissions of a specific territory is aimed at assisting the decision-making process in regional and urban development and architecture.

2) The use of equipment and technologies that reduce energy consumption, and placing them in the service of the biosphere in a symbiotic relationship.

3) The review of existing legislation applicable to architecture and planning to suit the new realities of knowledge and technologies that reduce CO_2 emissions. In this paper it is presumed that the next step to be undertaken is the use of the methodologies that have been developed for the case study area, and their applicability to other drainage basins of the counties of Abrantes and Sardoal. The intent is to see whether the balance of emissions for the remaining areas of these counties is positive or negative. That is, if these areas are sinks or emitters of CO_2, and the aim is to check their future use in a scheme of emissions-trading as applied to areas of a territory as a whole, to promote sustainability in land-use planning and architecture (i.e. urban areas, agricultural areas, forest areas and other types of human activity) This scheme of emissions-trading would lead to a greater rationalization of land use, and include penalties for emitting areas, that could then be invested to improve areas of sink.

Through the facts as presented, the environmental degradation of the territory appears to us as a significant challenge, and the objective is to stabilize and reverse this trend, having in mind that planning and architecture must be looked at, thought of, and designed in a holistic manner, where the whole is greater than the sum of its parts, as a social structure, which guides and defines the actions of its people, is greater than the sum of its many individuals. It is demanded from the designers, and from the society at large, that they present a vision of their actions that is more open, more thoughtful, and more generous.

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This Shrinking Island and the Housing Crisis: Unsustainable Sustainable Construction

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Abstract

The position paper focus is predominantly on English housing supply and government intention to intensity production to satisfy population and household culture change with an additional 3 million new houses by 2020. Primary data provides detail on the drivers for house production increase, current housing stock, changes in government policy to speed up the planning and permission process and production enablers including Eco-towns. The author argues that although plans are to be executed to exemplary standards of sustainable construction large mass production on greenfield and greenbelt land does not off set the environmental pillar to sustainable development and is in fact unsustainable causing irreversible damage to the English countryside, devastating habitat and ecology through urban sprawl. Relevant consequences and activity associated with the production increase will ultimately increase carbon dioxide emissions (CO2) jeopardising national targets for reduction. Discussion and conclusion inform that government policy does not properly address the long term effects of sustainable construction off set.

Keywords: house production, sprawl, unsustainable

1. Introduction: Drivers and investment

At present there are plans in the U.K. to construct new houses to meet demand. There are concerns that this will cause environmental damage and urban sprawl as mixed messages are relayed from central government. The Town and County Planning Directive publish in 2005 inform of the ‘inappropriateness’ of development inside green belt and later in the document provides guidance on how local authority should assess and approve planning permission for housing in greenbelt areas (Town Planning Building Directive 2005). Two years later in 2007 the government communicate through their publication Homes for the Future that there will not be fundamental changes to the green belt policy though ‘edge of town’ developments will occur, effectively on greenbelt land (Homes for the Future 2007). At a time when sustainability is high on the political agenda this paper discusses central government housing related policy to establish whether or not potential solutions to meet housing demand are sufficient without placing irreversible strain upon the natural environment through green land development and potential urban sprawl. The following sections review England housing stock, drivers for supply increase, relevant targets and investment before addressing planning policy and the problems associated with the use of land and permissions granted. Subsequent sections discuss changes in government direction and solutions deployed to meet the housing challenge with intent to reduce ‘land take’ and urban sprawl. The author executed a full literature review of relevant primary data inclusive of government policy guidance documents, white paper, green papers, Building Regulations and Acts of Parliament that influence the use of English land in near future.

1.1 Housing production drivers

English Housing demand is a challenge first recognised by Kate Barker in the government green paper ‘Review of Housing Supply: Delivering Stability’ (Barker 2004) that informs of a need for new house production to meet demand. This supply deficit is caused through a serious decline in new house construction which in 2003 was at its lowest since the Second World War with only 21,000 homes built (Building Research Establishment 2003). However, this demand in house production is effectively a dichotomy of population increase and a change in household culture.

1.1.1 Population increase

The Office for National Statistics (ONS) in 2007 reported that there would be a 4.4 million population increase in the U.K. over subsequent years from 60.6 million in 2006 to 65 million by 2016, with an expected increase to 70 million by 2028. Increases over the next 6 years will be through combined fertility and migration with the majority of which taking place in England: with a total 8 % increase from 50.9 million in 2006 to 54.7 by 2016, an increase of 3.8 million. Children under the age of 16 is projected to increase by 4.8% from 11.5 million to 12.1 million by 2016, whilst life expectancy will increase for the oldest age band of over 75s from 4.7 to 5.5 million. New births are expected to make up 2.3 million of the increase with migration making up the other 2.1 million (Office of National Statistics 2007). Also advances in medicine means that people are living to an older age (Eco-town Prospectus 2008) with the ONS informing that the over 75’s will increase faster than other age groups (Office of National Statistics 2007) and the number of people aged over 85 will increase over the next 25 years from 1.3 million in 2008 to 3.3 million by 2033 (Office of National Statistics 2009).

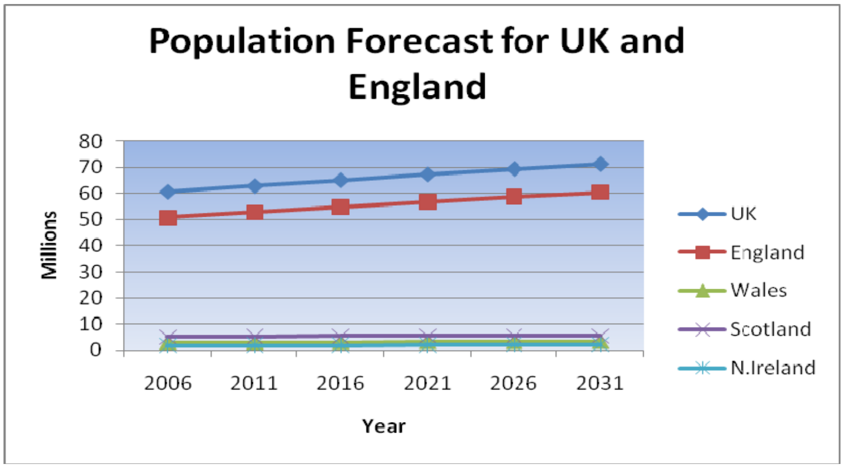

Figure 1: Forecasted population increase to 2031 (ONS 2007)

1.1.2 Change in household culture

The second main driver for the demand is a change in household culture. The U.K. ONS report that in 2006 13% of England's population lived alone and that this number was to increase at a rate of 163,000 households per annum equating to two thirds of the total increase by 2031; increasing single household occupancy to 18% (Household Projects 2009). In 2007 the UK government report that housing stock was growing at 185,000 units a year with expected growth of 223,000 due to people living alone (Homes for the Future 2007). The combined effect means the construction of millions of homes.

1.2 Housing stock and new build targets

In 2005 the government acknowledged a need for major growth increasing housing supply in England from 21.5 million homes to between 2.8 and 3.8 million by 2016, and a further 4.9 to 5.9 million by 2031 (A Sustainability Impact Study 2005). In the 2007 central government green paper 'Homes for the Future' recognised the potential shortfall in housing supply and set a new target to supply 2 million homes in England by 2016 at a rate of approximately 240,000 per annum (Homes for the Future 2007). Following target success the next milestone acknowledged and welcomed by the Housing and Homelessness Charity; Shelter in October 2007 was the commitment to deliver another 250,000 houses per year from 2016 to 2020 amounting in total 3 million homes (Shelters Response 2007).

The Governments Planning Guidance Note 3 (PRG3), issued by the Secretary of State for London Planning Authorities set out objectives for housing capacity studies in regional areas (Planning Policy Guidance 2005). The subsequent London Housing Capacity Study published in 2005 calculated the total capacity from 2007 to 2017 to be 315,327 new homes in London regions. This meant the construction of 31,533 houses per year which was over and above the approximation of between 25,000 and 30,000 set out in the London Plan of 2004 (London Housing 2004). The study set precedent for replica studies throughout England in order to meet housing demand (Planning Policy Guidance 2000). Following industry consultation feedback was made supplement to the London Plan that set out housing development in East London's Lower Lea Valley for the Olympic Games in 2012 (The London Plan 2004).

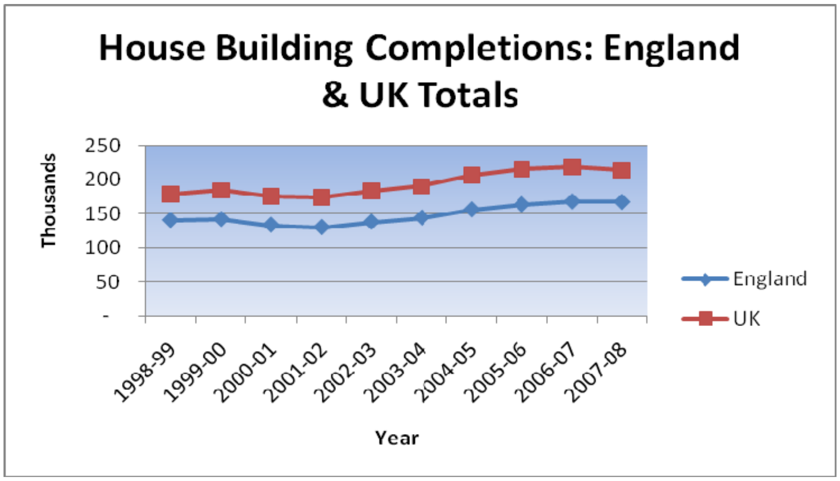

Figure2: Progress on house completions in England (Housing Statistics 2008)

Relevant to housing progress the UK Statistics Authority informed that in 2005 England's housing stock was 21.8 million (total U.K. stock: 27.2 million) (Housing Statistics 2008). By 2007 the amount was 22.189 million with house completions that year amounting to 167,680. In 2008 house completions totalled 168,140 amounting to 335,820 in two years. Were completions to be constant till 2016 the total would be 1,679,100 with a deficit of 320,900. Figures for completions achieved in 2009 are not released, yet the reduction in house starts in the private sector in the first ¾ of 2009 is an indication of at least a temporary deficit due to current economic downturn. Presently targets will not be achieved though central government have plans to speed up the process by the initiation of mass new build production across the nation. This will require huge investment in both the private and public sector if targets are to be achieved.

1.3 New build investment

New build house building projects are funded both publicly and privately. Public investment is directly controlled by the government and private investment is market driven. The current economic downturn has had its effects upon investment hindering the private sector whilst, funds already dedicated to public sector has secured new build developments. Investment in social housing increased from 800 million pounds between the years 2001 and 2002 to over 1.4 billion between 2003 and 2004 with another 50% increase on investment between the years 2007 and 2008 (Housing Statistics 2008). Also the government acknowledge intent to invest 850 million pounds on large scale developments such as the Thames Gateway Project where 200,000 houses will be constructed, in the five year plan outlined in the publication 'Sustainable Communities: Homes for All' (Sustainable Communities 2005). In 2007 the UK Governments Pre Budget Report and Comprehensive Spending Review set out steps to meet the 2016 targets and provide 2 million homes in England by increasing spending on housing specifically from 8.8 billion in 2007-08 to 10 billion pounds for 2010-11. This is inclusive of a 50% investment increase in the construction of new social rented houses to reach 45,000 units per year by 2010-11, with a goal to reach 50,000 in the next spending review period (Meeting the Aspirations 2007). Also in 2007 central government published the Green Paper 'Homes for the Future' that informed of further investment to secure the construction of an extra 70,000 affordable homes and 25,000 shared equity homes by between 2010 and 11 (Homes for the Future 2007). For high growth areas outside of London regions 425 million pounds have been invested for infrastructure and housing developments set out in the publication 'Sustainable Communities Homes for All' of 2005 (Sustainable Communities 2005). Also the Comprehensive spending review of 2007 informed that 500 million pounds was to be invested for new Housing and Planning Delivery Grants to incentivise local authority to improve housing supply and the planning process for housing (Meeting the Aspirations 2007). All demonstrate government commitment to meet housing targets.

1.3.1 Developer investment

Due to recent economic downturn and related housing market deflation the amount of housing being constructed by private developers is unknown. During such climate private production stagnates unlike the public sector where funds committed to build are secure. For certain this financial crisis has led to a lack of mortgage lending. A consequence is that developers are shy to commit to build for fear of high unoccupied dwelling rate taxation and hold back on permissions (Affordability Targets 2005). The Royal Town Planning Institute (RTPI) reports that the top 10 U.K. house builders exercise such tactics for up to approximately 2.7 years (RTPI 2007). This is a reasonable business strategy during economic crisis that is difficult to prove. The situation leads to delay and may play a significant role if 2016 housing targets are not met.

Notably the Barker Review Independent Paper of 2004 estimated that by reducing house prices by 1.8% an increase in house starts of 70,000 per annum would ensue (Barker 2004). If prices are reduced by 2.1% the figure would rise to 120,000 inspiring potential economic recovery as discussed in the government 'Impact Study of Additional Houses in England' (A Sustainability Impact Study 2005). The Housing and Planning Advice Unit warns that if houses are not produced prices will escalate to 10 times average annual earnings.

The following section details the policy change adapted by government to enable ease in the procurement of land for housing developments.

2. Land identification

Land is limited in the U.K., though central government inform local authority of the necessity to build new housing developments across the nation. This pressurises council leaders to commit land for development breaking promises with local communities and organisations. A potential consequence of development onto greenbelt land is known as urban sprawl: the uncontrolled expansion of cities and their suburbs to rural areas. Community response is one of protest. Currently there are 2.6 million hectares of urbanised land in England with an expected minimum increase of 130,000 hectares by 2016 (A Sustainability Impact Study 2005). To put this into perspective the county of Essex would consist of zilch underdeveloped land if all new houses needed were constructed there. Central government have identified the amount of land needed but are unclear as to the whereabouts of potential developments. For example in the city of Salford the council have informed that they will build 33,750 new homes by 2027. Now they are under pressure to decide potential development sites. The sites identified pre 2007 included the high growth areas, all but one located in the South of England (Building More Affordable Homes 2005) including the Thames Gateway development (Thames Gateway Eco-region 2008). Also the Ministry of Defence (MoD) in 2005 provided pockets of land valued at 1.2 billion pounds for such developments, (Building More Affordable Homes 2005) as is the 5,500 homes to be built on ex MoD land in Whitehill-Bordon Hampshire (Bbc4). Together they only slightly reduce the pressure to locate and construct appropriately.

2.1 Planning policy enabling quick permission and housing progress

Intrinsically linked to the supply of homes are the constraints put on planning permission for new housing developments. In the authors experience gaining planning permission in the U.K. is traditionally a long drawn out process varying upon the county council involved. Now local authorities have been instructed to build houses where feasibly possible central government recognised planning constraints and its negative effect on housing targets. The Barker Review (Barker 2004) highlighted such planning restrictions, reporting that the duration of time needed to successfully secure planning permission was the greatest barrier to housing delivery. Section 106 Agreement of the Town and Country Planning Act 1990 (Section 106 1990) known as the 'Planning Obligations', concern legal agreements between local authorities and developers. The Barker Review (Barker 2004) successfully requested the introduction of supplements to the Agreement to overcome restrictions in land acquisition or changes to infrastructure to allow the procurement of land to take place at an accelerated rate, thus encouraging competition. After consultation the government published its response detailing the reform of planning law enabling ease and speed in land procurement, allowing greater investment in infrastructure to support sustainable housing of which housing associations and local authority will play a vital role (Government Response to Kate Barker 2005). Subsequent government legislation outlined in the policy paper 'Sustainable Communities: Homes for All' published in 2005 (Sustainable Communities 2005) details changes to planning law enabling major applications to complete in 13 weeks and minor works to take 8 weeks. Further to this a Community Infrastructure Fund of 100 to 200 million pounds was introduced to overcome blockade caused by infrastructure (Government Response to Kate Barker 2005). The legislation and Policy paper 'Sustainable Communities: Homes for All' of 2005 nominated the first target growth area in the North of England where local authorities identified land for development in which 50,000 homes were built (Sustainable Communities 2005). In 2007 English Partnerships were instructed to work with local authorities to achieve plans releasing surplus public land for affordable housing with the intention to drive down construction costs enabling houses to be sold for less (Homes for the Future 2007).

Evidence indicates that potentially all local authorities are under pressure to provide sites for housing developments, central government stipulate that, 'where development of land occurs it should be executed whilst safeguarding the natural environment' (Building More Affordable Homes 2005). However in construction the footprint of a building destroys habitat in that immediate vicinity so such sustainability claims are contradictory. Therefore it can be argued that greater sustainability would be achieved by either not building at all or considering methods to reduce the amount of land needed for housing developments.

2.2 Build on mass

Recognising the shear volume proposed a solution identified was to build on mass. The innovative solutions would also fit to sustainability criteria set out in 'sustainable communities' ideology. In order of publication the following outlines schemes that were prepared for consultation.

I. The government propose through their 'Sustainability Impact Study' of 2005 that whole new 'settlements': each consisting of between 4500 to 10,000 houses be constructed. The concept is that that the larger the settlement the better the associated local economy (A Sustainability Impact Study 2005).

II. The government paper Sustainable Communities: Homes for All (2005) (Sustainable Communities 2005) set out a 5 year plan to construct neighbourhoods containing up to 3000 homes, that sustain an active local culture that is well run, environmentally sensitive, well designed with good infrastructure and lasting economy. Part of the plan involves understanding the diversity of people with the intent to develop mixed communities.

III. The Government Green Paper 'Homes for the Future' of 2007 inform of Housing Corporation funding to a sum of 230 million for 6,300 villages to be designed for locations across the U.K. (Homes for the Future 2007).

IV. This green paper of 2007 published plans to develop 5 new eco-town schemes consisting each of between 25 to 100 thousand homes (Homes for the Future 2007). Later this year the 'Eco-town Prospectus defined vision for potential Eco-towns consisting of between 5 – 20,000 houses. Private developers would have the opportunity to bid for the work.

V. Later in 2007 the Calcutt Independent Review was published (Callcutt Review 2007). An elemental part of which encouraged developers to build cross commercial residential property. This was due to inner city developments failing to attract customers and being subject to high rate taxation on empty property. Such was the case in Manchester city centre where recent changes in legislation meant a 10 million pounds bill for empty commercial buildings.

In 2008 the publication 'Eco-towns, Living a Greener Future' reports on a diverse spectrum of consultation involving 12,000 respondents who considered Eco-town proposed locations. They influenced relevant policy and the constitution of the Eco-town Planning Policy Statement to achieve the highest standards of environmental protection (Planning Policy Statement 2009). Notably as detailed in Planning Policy Statement 1 where land is developed it should improve life for people through economic, social and environmental issues (Planning Policy Statement 1 2005). The purpose of this statement was to enable planning authorities to recognise that development is possible whilst protecting the natural environment.

The towns will be built to zero carbon standards highlighting at least one display of technological advancement in environmental technology. Between 30 to 50% of the towns will be made up of affordable homes and with the aid of public funding be designed to support local people, business and community services. In July 2008 the Notes and Recommendations from session 2 of the Eco Town Challenge (2008) consultation inform progress of the Eco-town Challenge Panel: an independent group of people with expertise in various aspects of sustainability and urban development. They encourage bidders to develop their proposals with such rigor so that they be regarded as exemplary projects that fit well within their surroundings, demonstrate innovative approaches to sustainable development and represent a step change 'beyond' what would currently be regarded as best practice. It is proposed that a number of these towns be constructed on greenbelt sites, causing devastation to the natural environment as the social pillar of sustainable development offsets the environmental pillar. Have government considered how this will effect English society and countryside in the long term?

2.3 Greenbelt degradation in the U.K.: Setting the scene for protest

There is however a problem with Eco-town development as community protest against granted permission. This is especially the case where locations encroach on green belt land, be it through 'edge of town' developments. In 2006 the local authority promised not to develop the Cutadcre site in Bolton. Now 209 of the 796 acre site is to be developed, much to fierce opposition from the local community who were promised preservation of the site as a country park. Here the land is part of the 'strategic employment land' pool and so extensive woodlands, wetlands, conservation areas and grasslands will be destroyed (Britton 2009). In another protest a petition was presented to the prime minister in January 2008 opposing the construction of 6,000 homes on greenbelt land in South Derbyshire (Bbc1). Similarly villagers in Kellington in North Yorkshire protested against permission for 60,000 houses (Bbc2). At a site in Marple Grove villagers opposed permission granted on a tree preservation site, claiming they were not informed of authority intention and given the opportunity to oppose the site (MEN 2004). A protest in Warrington took place regarding a permission that was part of the 'safeguarded land' plan of 1994 due to rare habitat discovery (Skentelbery D. 2002). Likewise a protest for the protection of habitat in a nature reserve in the Rochdale area on what was once Europe's largest asbestos factory (Dorsett 2005). Other examples include protests against the construction of 1000 homes on a Salford council greenfield site (Keeling 2009) whilst in Cheshire local residents protested against several housing developments proposed in the Warrington area (MEN 2002). Such protests saw Eco-town greenbelt permissions rejected in Hampshire, Oxfordshire and Derbyshire on the grounds that rare habitat would have been destroyed (Bbc5). A campaign spokesperson in South Nottinghamshire informed that local government "are using Eco-town ethos to build houses on greenbelt and destroy the countryside" (Bbc3). The generic reasons for protest span the pillars to sustainable development: social, environmental and economical. These include damage to the natural environment and additional strains put on infrastructure caused through population intensification. Other issues to consider are the long term effects on regional economy and risks applicable during future recession. Many of these protests are fuelled through a change or redirection of local authority and government policy regarding use of green space and green belt land encouraging a potential decline in quality of life for affected community. The general public are also provoked by governments intention when there are empty warehouses, disused industrial land and vacant properties (40,000 social vacant housing in 2007: Housing Statistics 2008) across the nation.

The Code for Sustainable Homes (2006) categorises greenfield protection through their 'Ecology 1' points system devised to encourage development of land that already has a limited value to wildlife and discourage the development of ecologically valuable sites. It appears that in reality as code level 3 becomes mandatory this year substantial areas of green belt land may be utilised for development. The government plan to built 40 Eco-towns around England and have now approved planning permission for 12 shortlisted throughout England. Of the sites 2 are regenerations, 5 are on brownfield and 5 are on greenbelt (Bbc4).

3. Land take reduction enablers

Central government realise the problems they face by building on English countryside, especially as the public community protest openly to such construction. The following subsections consider the solutions put forward by government and their impact on green belt development plans.

3.1 Reduced 'land take' through increased housing density

Before planning applications are approved developers must also provide design information outlining the intended amount of housing units per hectare. In 1997 the average dwellings per hectare was 25. This was increased by 8 units to 33 per hectare in 2003 (Sustainable Communities 2005) with a further 56% increase in new build density of 40 houses in 2004. In 2005 the U.K. government produced a housing Planning Policy Guidance Note 3 to encourage efficient use of land setting a density range of between 30 to 50 dwellings per hectare. Following this 'development plans' for affordable houses were devised in the Government Planning Policy Statement 3 (PPS3) of 2006 requiring constructors to work to standard sizes and a minimum 15 dwellings per neighbourhood plan (Planning Policy Statement 2006).

Lately in A Sustainability Impact Study (2005) government report on both 'infill densities' and 'urban densities'. Infill refer to land in built up urban areas such as high density dwelling apartment buildings consisting of between 84 and 98 units per hectare. Urban density refers to inner cities or towns containing units to usually four storeys high, though where planning restrictions limit the type of design and use of land the housing density ranges between 34 and 44 per hectare (A Sustainability Impact Study 2005). According to Barker (2004) compacting house or dwelling units will reduce 'land take' by 8.5% preserving the natural environment. This amounts to a land saving of 10,400 hectares: a worthwhile saving.

3.2 Alternative brownfield development

In 2007 the government paper 'Homes for the Future' (2007) inform of the intent to build 60% of houses for the 2 million new homes by 2016 targets on brownfield land. This puts quantity to government intention for such development indicated in the 'Sustainable Communities: Homes for All' publication of 2005 (Sustainable Communities 2005). This means a potential greenfield and greenbelt 'land take' saving of 78,000 hectares of land if 2005 estimations for land development were correct (A Sustainability Impact Study 2005. Now the pressure is on for local authority to identify brownfield land suitable for house production, due to the introduction of the Housing and Regeneration Act of 2008 informing houses can be built without conferring with the Secretary of State Department (Housing & Regeneration Act 2008).

4. Discussion: Sustainable construction through a touch of urban sprawl

The more recent supplements to government policy request that new build including Eco-towns and similar initiatives consider brownfield rather then greenfield or greenbelt sites. It seems however that restriction on greenbelt are at present partly lifted as policy provides guidelines on greenbelt application and refers to 'edge of town developments', rather then use the 'greenbelt' terminology. This is an indication that future housing developments needed to meet the 2020 target will encroach on English countryside.

The author understands the concept of sustainable development and the ideology of the triple bottom line of environmental, economical and social pillars. In the U.K. modern construction method tends to trade off one pillar of sustainability for the other. Plans to meet demand and build 3 million houses, some on greenfield and greenbelt land may satisfy the social and economical pillars of sustainable construction, but for how long. According to Hardin (1995) this may last only a short time period because humans will without knowing deplete limited resource including employment, schooling and healthcare. Building Eco-towns across England will as portrayed in his essay 'Tragedy of the Commons' mean more people and an increase in pressure on society. An effect could be irreversible strains upon the natural environment. Where homes are to be constructed at the centre of several villages then the likely outcome is that urban sprawl will occur. Consequences of trade off include the reduction in both arable and stock farmland leading to a reduction in food supply. Grasslands, wetlands and places of natural beauty are destroyed killing carbon sink vegetation and endangered species. Also the amount of material product required including associated waste will be huge. The developments will put additional pressure on infrastructure meaning more noise, land and air pollution. Where an Eco-town consists of 15,000 new properties it can be perceived that this means an additional minimum 15,000 vehicles to strain traffic routes with the related increase in mileage and fuel as communities travel to their place of work and transport children to school. Even if the new houses are constructed to level 6 of the Code for Sustainable Home standard the related increase in carbon dioxide emissions would jeopardise the 2050 targets to reduce CO2 emission by 20%. This being the case if the emission targets are no longer feasible the emphasis should be on conversion and refurbishment. Policy informs how construction will be sensitive in providing necessary environmental protection. In deed there are initiatives in place to secure sustainable practices like the 'polluter pays principle' (Planning Policy Statement 1 2005). However the government does not address the bigger picture and associated long term risks.

Another risk attached to new build progress is establishing the Code for Sustainable Homes level 5 or 6 standards: if defined no doubt the constructor will have to use unfamiliar technologies and products leading to unforeseen complications. This is the nature of the dynamic sector of industry. Notably the government do know that the code cannot be achieved in the refurbishment of existing stock. It seems that target solution options will cause a rise in CO2 emissions regardless.

5. Conclusion: All on this little island

This study has argued that it is not possible to meet housing targets for rising English population without causing a negative effect on the countryside. The amount of land needed to meet the 2016 new build targets is 130,000 hectares (A Sustainability Impact Study 2005). By building on brownfield sites the 'land take' saving is 78,000 hectares (Sustainable Communities 2005). By increasing housing densities there is an additional saving of 10,400 hectares. This means that the amount of greenbelt land in danger has now been reduced to a minimum 41,600 hectares. This is still a large surface area affectively removed from leisure, crop and livestock and lost to development.

The issues discussed should be seriously considered as the Office of National Statistics (2007) forecast the U.K. population to increase from the expected 65 million in 2016 to 70 million by 2028. For England this means from 2006 to 2028 a total increase of 8.1 million; needing sufficient housing. Development would inevitably cut into greenbelt to some degree through what government term 'edge of town' development; in effect urban sprawl.

This paper proposes that as far as mass production of housing is concerned there are elements to the equation for true sustainable construction practice that have not been thoroughly thought through. The author suggests that policy does not address the 'off set' of the pillars of sustainability for the long term. This inaccuracy could cause unsustainable strains on English society leading to an unexpected decline in quality of life. Presently house construction is not on course to meet the 2 million 2016 target. However in this period of economic downturn and present lack of lending coupled with popular protest no doubt alteration may occur to the development plans. Already policy is warming toward restoration, refurbishment and conversion. An indication of this is the amount of funding committed for research in the area of 'retrofit': in effect renovation to reduce CO2 emissions. Also when there is a change in government, solutions, policy and plans change.

At present government policy does not convincingly address these problems. The debate continues.

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Social Enterprise Applications in an Urban Facilities Management Setting: Initial Findings

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Abstract

Public facilities operations in local authorities are facing increased costs each year. The need to move away from the traditional service provider approach is seen as a way of reducing running costs in facilities operations. This brings a new notion of developing a sustainable design for maintaining the public facilities for the benefit of the community. Use of urban facilities management (urban FM) as a mechanism for developing a sustainable design for managing public facilities operations could be a way of achieving this in order to make a difference. The underlying philosophy of urban FM is highlighted in the study conducted by the Public Management Foundation UK (PMF), which describes the use of "social enterprise" as an approach to seek a new organisational form. In this context, the study on which this paper is based, explored relationships between urban FM and social enterprise principles within multiple diverse organisations in order to gain further explanations towards developing acceptable criteria for the suggested new model. Furthermore, with the generalisation of the suggested criteria, this paper looks into the applications of this new model in Malaysia within local government settings. In this context, this paper is an attempt to elaborate on the initial findings that emerged from the pilot interviews.

Keywords: public facilities, social enterprise, urban FM, pilot interviews, conceptual framework

1. Introduction

1.1 Background to the research

It was discovered from the literature, that the theme of urban FM is an emerging concept in finding new and innovative ways to manage public facilities and community assets (Roberts, 2004; Nutt, 2004). Therefore, this study proposes using urban FM as a mechanism for developing a sustainable design for managing public facilities operations, through the approach of developing a new service delivery model that meets the needs of social enterprise. The underlying philosophy of urban FM is highlighted in the study conducted by the PMF (Steele et al., 2003) which describes the use of social enterprise as an approach in which new models of delivering public services are sought. The UK government has highlighted the role of social enterprise as a model for maximising the public good through business solutions, as outlined in the Department of Trade & Industry report *'Social Enterprise: A strategy for success'* (DTI, 2002), published in July 2002.

Accordingly, this study explores the urban FM concept by gaining an understanding of the underlying philosophy of urban FM and this will be based on the premise of the use of social enterprise as a stepping stone in the process of finding a new model for managing public facilities operations, as was suggested in the PMF study (Steel et al., 2003). It could be argued that in seeking a new organisational form which suits an urban FM setting, social enterprise seems to offer this new kind of service delivery model. This direction could be used to provide a flexible 'platform' in which agencies and the private sector can come together in a new and innovative setting for the benefit of the community (urban FM)-(Roberts, 2004). For this reason the link between urban FM and social enterprise needs to be further elaborated in order to have a strong basis for developing this new service delivery model. Hence, urban FM and social enterprise will act as the main concepts identified for this study.

2. Key issues identified from the literature

2.1 Relationship between urban FM and social enterprise

Robert (2004) identifies urban FM as, *"a logical extension of the need to reinvest in community facilities and systems, and provide a flexible 'platform', in which agencies and private sector can come together in a new and innovative setting for the benefit of the community"*. As discussed in the above section, many authors (K. Alexander, 2006; Kasim and Hudson, 2006; Nutt, 2004) have agreed with this initial idea of urban FM. These dimensions have given a new idea for this study in the seeking of new ways of delivering public services. There is for example, the suggestion of urban FM as a possible new service delivery model for managing public facilities operations for urban sustainability. Urban sustainability is needed to ensure that future urban development can be retained regardless of the limited quantities of natural resources. It is the process and development of a sustainable design that could help to retain what is left for future generations. Roberts (2004) also provides some examples that lead to a platform in which agencies and the private sector can come together in new and innovative settings. However, there is no specific guideline on how this platform could work. This platform could be used as a new way of delivering public services, instead of having either the public or private sector as the sole service provider. The need to move away from the traditional service provider's approach is seen as a way of reducing running costs in facilities operations. This could bring about a new notion for developing a sustainable design to maintain public facilities for the benefit of the community. By considering sustainable factors in seeking new ways of delivering public services, therefore, this study is using urban FM as a mechanism for developing a sustainable design to manage community facilities operations.

As the underlying philosophy of urban FM, social enterprise is part of the focus of the exploration, through examining the variety of the service delivery model within its principles. In addition, Alexander (2006) has further explored Robert's idea of urban FM and suggested that the social enterprise organisational form could be used in FM as a 'New Economics'. The information provided by the PMF study (Steele et al., 2003) sought the views of a wide range of senior public service managers about some of the challenges facing the best value agenda of the UK's government. Initially, areas of concern were identified as listed below:

- difficulties in creating partnerships between community service organisations;
- access to capital;
- the need for greater organisational autonomy;
- difficulties in balancing accountability to both service users and the public through the democratic process; and
- lack of capacity to attract high calibre managers.

Potentially, according to Robert (2004), urban FM provides solutions to a number of these problems through the creation of "arms length" organisations with greater autonomy and access to capital. Amongst the advantages would be:

- the introduction of the techniques of business management, in particular efficiency improvement to public services;
- the introduction of market mechanisms and competition into public life; and
- a greater level of service and customer orientation within public services.

Therefore, at the early stage of the literature review, an attempt has been made to identify the links between the concepts of urban FM and social enterprise. The first stage is to try to look at the differences in the definitions, principles and approaches of each concept. Table 1 below, outlines these differences.

Table 1: Contrasts between the concepts of Urban FM and Social Enterprise

Source: (Pearce, 2003; Roberts, 2004; Steele;Tetlow and Graham, 2003; Thompson and Doherty, 2006)

Context	*Urban FM*	*Social Enterprise (SE)*
Term Definition	*Provide a platform for agencies and private sector to work together in an innovative setting to reinvest in community facilities and systems for the benefit of the community*	*The generic term for all trading enterprises which have a social purpose, a non-profit aim and a democratic, accountable and common-ownership structure*
Characteristics/ Principles	*Introduce business management techniques, in particular efficiency improvements to public services;* *Introduce market mechanisms and competition into public life; and* *Introduce a greater degree of service and customer orientation within public services.*	*Having a social purpose or purposes;* *Achieving the social purposes by, at least in part, engaging in trade in the market place;* *No distribution of private profits;* *Holding assets and wealth in trust for the benefit of the community;* *Democratic structure; and being independent organisations accountable to defined constituencies and to the wider community.*
Similarity	*Local development and regeneration;* *Working for the state;* *Managing community assets and public facilities for the benefit of the community;* *Market-driven business*	*Local development and regeneration;* *Working for the state;* *Providing services to the community for the benefit of the community;* *Market-driven business*
Approach by	*The introduction of business management techniques, in particular efficiency improvements to public services;* *Introduction of market mechanisms and competition into public life;* *A greater degree of service and customer orientation within public services*	*Having a social purpose;* *Engaging in trade in the market place;* *No distribution of private profits;* *Holding assets and wealth in trust for the benefit of the community;* *Having a democratic structure;* *Being independent organisations, accountable to defined constituencies and to the wider community*

Although there are differences between these two main concepts, their similarities could be used as a basis for developing a list of suggested criteria for a new service delivery model for managing community facilities operations.

3. Initial criteria for the new service delivery model

Within this context, this study will look into the suggested criteria, which will be discussed in this section. The suggested criteria are identified based on the similarities within and also between, the main concepts. These will act as the initial criteria, developed from the literature review by looking at other settings and other countries in accordance with the underlying philosophy of urban FM and social enterprise principles. Later, these criteria will be expanded by looking at current international practice. By obtaining an understanding of social enterprise principles, the newly created service delivery model will be capable of operating without relying on government funding, and would be both sustainable and at the same time capable of creating a profit. This profit or surplus would then be put back into the company in order to make it self-sufficient. This is a fair assumption to make of the arrangements, as social enterprise is seen as a new form of company that is working towards a social mission. Having a variety of companies as social enterprises might enable interested bodies to choose the most suitable type of company relating to their mission and objectives. This will in particular not restrict them to having to choose a company with a charitable status would therefore be limited in its profit-making but could expand choices by having a variety of profit-making companies that comply with social enterprise principles in an urban FM setting.

Furthermore, drawing on the inter-relationships between the concepts, Table 2 below outlines the initial list of suggested criteria or enablers to be dealt with, within the context of the study.

Table 2: The initial list of suggested criteria for the new model that will be developed

Source: (Pearce, 2003, Ridley-Duff, 2008, Alexander, 2009, ICA, 1995)

Suggested criteria	*Description*
Having a social purpose	*Holding social objectives lying somewhere within the business objectives*
Market-driven business	*This can range from non-profit (charitable status) companies to profit-making companies. By having social enterprise principles, they can partly promote the social economy by making a profit.*
Independent and accountable	*Being independent organisations accountable to a defined constituency and to the wider community*
Initiated by the government	*The organisation need to be initiated by the government in order to gain funding before it can operated independently*
Co-operative values and principles	*At the outset, taking a co-operatives approach seems to be one that is easy to adapt into the foundation of a new organisation/enterprise.* *(This includes voluntary and open membership, democratic member control, members' economic participation, autonomy and independence, education, training and information, co-operation among co-operatives, concern for the community)*
Managing community assets for the benefit of the community	*This tends towards a social mission (it seems to be more social than economic) by delivering services for the benefit of the community in response to local needs.*
Community facilities as a resource	*Facilities used as community resources to be managed and taken care of*
Sense of ownership	*The involvement of the organisation will later verified as their ownership of the facilities as a way of recognising*

	their contribution
Community empowerment	*The giving of confidence, skills, and power to communities to shape and influence what public bodies do for or with them*
Community engagement	*The process whereby public bodies reach out to communities to create empowerment opportunities*
Create local employment	*If communities are given the opportunities and are trusted to set up their own enterprises to manage the community facilities, this will create job opportunities for the local people.*

The following section will discuss the issues related to the pilot study and the initial findings.

4. Pilot Interviews

4.1 Expert opinion

A series of expert interviews were carried out by the researcher to:

- gather views in relation to the link between social enterprise principles and the urban FM concept;
- critically review the initial list of suggested criteria for a new service delivery model that will be developed (issues and enablers for the new model, identifying stakeholders); and
- identify any other areas which could be investigated and addressed when developing the study.

Accordingly, three expert interviews were carried out to identify the stakeholder and the critical issues which need to be investigated in this study. All three respondents are members of academia who are from backgrounds relating to social objectives, community participation, organisation and general management. Furthermore, the conceptual framework developed through the literature review was refined based on the findings from the expert interviews.

4.2 Findings from the pilot interviews

The importance of identifying the right stakeholder to manage public facilities operations was highlighted by the respondents. This will help to further explore and identify the criteria for the new service delivery model. As public facilities are currently provided by the government and used by local people, the community and local government could be appropriate stakeholders in the phenomena being investigated. Moreover, as we are looking at the context of the community within councils of local government, the study needs to clarify the terms used for the study, by clarifying the differences between ‘public’ and ‘community’ facilities.

As derived from the discussion of the research background (Section 1.1), urban FM in the context of this study could be suggested as having a new service delivery model for managing public facilities operations to achieve urban sustainability. Therefore, it is essential to make a clear distinction between the terms ‘public’ and ‘community’ facilities, and whether either is better suited to reflect the context of this study. The definitions of these two terms need to be clarified. According to the Oxford Dictionary, the definition of ‘public’ refers to *‘having to do with the people as a whole, also known as ordinary people in general’*. On the other hand, ‘community’ means *‘a group of people living together in one place or having the same religion, race, etc.’*. Facility is defined as a building, service, or piece of equipment provided for a particular purpose, or a natural ability to do something well and easily. However, (Brackertz and Kenley, 2002) indicates that ‘community facilities’ focus on service-oriented objectives and principles of universality and equity that underpin public provision, rather than ownership status. While McShane (2006) on the other hand suggests the topography of community facilities in Australia are based on religious, philanthropic, trade union, sporting and civic organisations which played a significant role in the provision of social infrastructure such as community halls, libraries and recreational assets, as well as in the management of local environmental features. Derived from the above discussion, ‘community facilities’seems to be a more appropriate terms than ‘public facilities’, as this study is focused on facilities that are used by local people, which is the ‘community’. Therefore derived from the pilot interview findings, the identification of stakeholders involved in community facilities operations towards the new model that is sought would come from two target groups in local councils. Although they are within the same local council, these two target groups are distinct; the first group represents a public sector that is currently running the community facilities operations and holds the ownership of the assets; the second group represents the community, as the council members are chosen by the community to take care of their interests and should know what the community needs. This research will only try to focus on decision maker level/top management in order to gain an insight or understanding of the new model that will be developed.

Furthermore, the researcher needs to map out the requirement of the project based on the literature review findings compared against the stakeholder requirements. Later, those requirements will be matched in order to seek the enabler for a new service delivery model for Malaysian applications in managing community facilities operations.

The following figure maps out the project requirements that need to be met and the enablers for the new service delivery model that could then be developed.

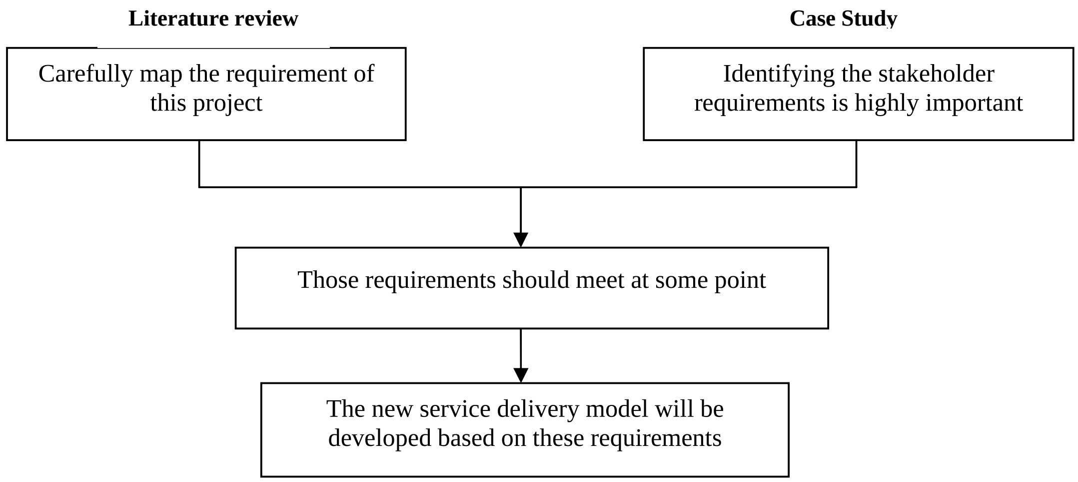

Figure 1: Identifying enablers for a new service delivery model

5. Conceptual framework

5.1 The development

A conceptual framework must be able to explain, either graphically or in narrative form, the main things to be studied – the key focus, constructs or variables – and the presumed relationships among them (Miles and Huberman, 1994). It is a major part of the research process which must be fulfilled before entering the next stages of the study, which are: the research approach and the research techniques to be used for collecting and analysing the data. Conceptual frameworks act as maps that give coherence to empirical inquiry and take different forms depending upon the research question or problem (Kaplan, 1964). In brief, the conceptual framework plays a major role in the research process, as it helps to clarify the main ideas by giving the right routes to take in order to develop the study. The main concepts extracted from the literature review were used to develop an initial conceptual framework. This was done by focusing on the subject area through the identification of the scope or boundary of the study. Subsequently, from the discussion in the literature review section, the constituent parts of a conceptual framework were taken to be the main concepts, the relationship between those concepts and the presence of a boundary within which the concepts and their inter-relationships could be applied. In other words, the conceptual framework comprised three main components, as follows:

- the main concepts;
- their inter relationships and;

- the boundary

Figure 2 below shows an example of a procedure that could be adopted when developing the conceptual framework.

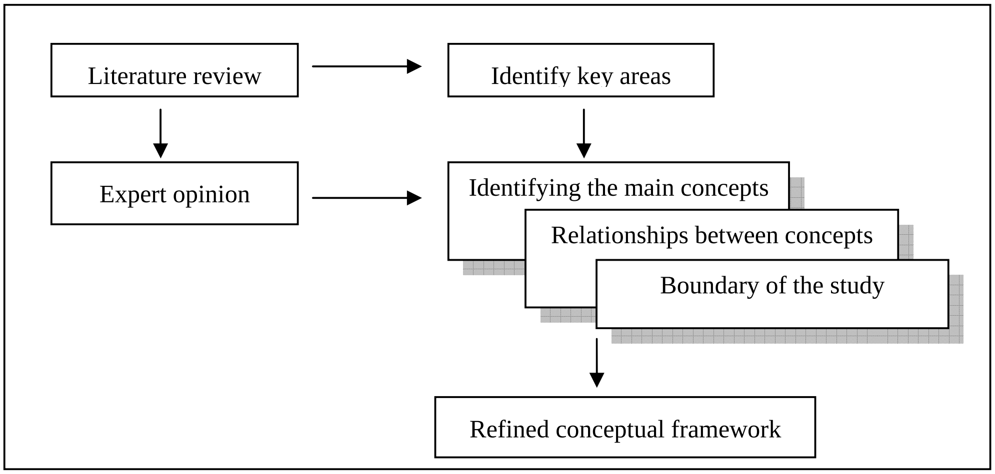

Figure 2: Development of the conceptual framework

5.2 The conceptual framework after the pilot study

This study aims to develop a new service delivery model that meets the needs of social enterprise principles in an urban FM setting in order to manage community facilities operations within the Malaysian context. The primary objective is to understand the applicability and characteristics of social enterprise principles for a new service delivery model in the urban FM setting by learning lessons from other countries and in different setting as well as exploring related theories. Later, this objective will be further developed to test the applicability of such a model in the Malaysian setting through using it as an enabler in managing community facilities operations.

Accordingly, the conceptual framework developed through the literature review was refined by using expert opinions on the issue being studied, in order to understand the relationships between the main concepts and to identify the boundary of the study, as well as to acknowledge the importance of identifying the stakeholders involved in community facilities operations. Moreover this helped in refining the unit of analysis to be undertaken in the case study. In this context, the refinement of the conceptual framework depicted in Figure 3 shows how the research problem is embedded within the scope of the study.

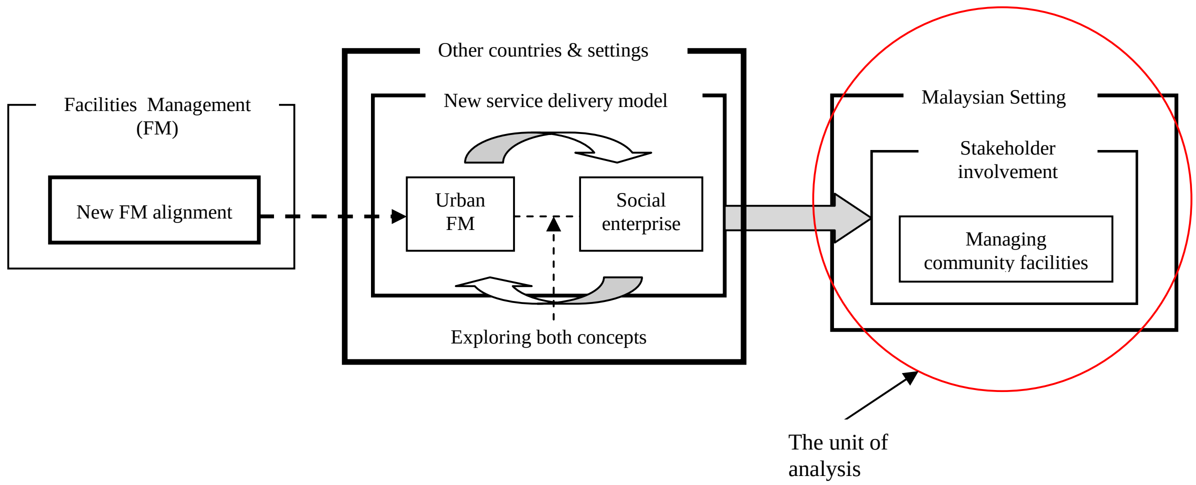

Figure 3: Conceptual framework of the research

At this stage, the conceptual framework will help the researcher to stay on the right track and also guide the progression to the next level of research. It is very likely that the conceptual framework will be changed as the research progresses until the aims are achieved.

6. Conclusion and the way forward

As was revealed in the findings of the literature review and pilot study, the inter-relationships between the principles of urban FM and social enterprise have led to the identification so far of the following:

- a list of the suggested criteria that could be used as an initial basis for this new service delivery model, which need to be further explored and explained in order to gain better understanding of its application;
- the initial findings highlighted the social objective/social mission as an important aspect of this new service delivery model and of having either public agencies or the private sector involved;
- pilot interviews have helped the researcher to identify the stakeholders of this issue, as well as turning the focus of the research towards community involvement for the case study data collection
- the understanding that this new service delivery model could potentially fall under four different types of social enterprise, as established by Ridley-Duff (2008).

It could be suggested that this new organisational form is a social enterprise form developed specifically to suit the urban FM setting which focuses on community involvement. As this study will attempt to taken the approach of developing a new service delivery model that meets the needs of social enterprise principles in an urban FM setting for managing community facilities operations within the Malaysian context, the study will therefore seek a robust finding to come up with a list of enablers for a new service delivery model with the chosen type of social enterprise form. The exploration and explanation towards finding such a model to help better manage the community facilities could later be achieved by using the benefit realisation framework as a contribution to the knowledge used in this context of study.

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Influence of Contemporary Earth Construction on Environmental Sustainability in the United Kingdom

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Abstract

Stabilised earth is an alternative building material which is comparatively cheaper and environmentally sustainable compared to conventional brick and concrete. Although the United Kingdom does have a well structured and effective program to address environmental sustainability through the use of appropriate construction materials, the use of contemporary stabilised earth construction is not widespread. More surprisingly, most construction industry professionals in the United Kingdom do not even know about this technology. This paper aims to identify and highlight the potential of contemporary earthen architecture in the achievement of environmental sustainability in the United Kingdom. A critical literature review method was adopted in this study to investigate how the widespread use of stabilised earth construction in the United Kingdom can reduce carbon dioxide emission and contribute towards the achievement of environmental sustainability.

Keywords: stabilised earth construction, environmental sustainability

1. Introduction

According to Edwards (2005, p3), fifty percent of all resources consumed across the planet is used in construction, making it one of the least sustainable industries in the world; and the World Health Organisation estimated in 2003 that global warming was causing 150000 deaths a year. Edwards (2005, p9) also stated that by 2050 it is anticipated that the human will have four times the environmental impact it had in 2000 (based on a 2% annual economic growth and a global population of 10 billion). The EU estimates that air pollution from traffic is the second biggest killer in Europe, leading to 60000 deaths a year from bronchitis, asthma and heart disease (European Environment Agency, 2001).

According to Easton (1996), rammed earth (RE) construction is a cheap way of providing shelter since earth is an abundant resource. Frescura (1981) writes, “in addition to its political, economic, social and ecological advantages, earth has great cultural and architectural importance.” Construction in earth has the uniqueness of manifesting cultural heritage, and encouraging the continued use of the material helps to maintain and preserve the craftsmanship and cultural values embedded in earth building. According to Morton (2007), earth bricks and blocks can be a substitute for concrete blocks in most internal applications, where it is not suitable for external use due to the severe climatic reasons. However, earth has been used as a construction material in every continent and in every age. The use of earth on site as a building material saves manufacturing cost, energy, environmental pollution and transportation cost (Allinson and Hall, 2007). In order to demonstrate stabilised earth as a sustainable construction material, the experiences and practices of using earth construction can be studied and harnessed from other developed countries (Zami and Lee, 2007) to demonstrate the dynamism of this material suitable for construction in the United Kingdom. Contemporary stabilised rammed earth (SRE) materials have low embodied energy content because approximately 95% of the raw materials are unfired and recently the use of crushed recycled aggregates (demolition waste from bricks, concrete or SRE itself) is increasingly used instead of virgin sub-soil (Allinson and Hall, 2007). The main drivers towards sustainability in UK construction are currently reduction in embodied carbon and waste production (Morton, 2007). Despite the potentials of contemporary earthen architecture in the achievement of environmental sustainability the widespread use of stabilised earth is rare in the United Kingdom as Smith (2000) states, “When I tell people I build cob houses, they often imagine structures made of corn cobs.” This paper aims to highlight the potentials of contemporary earthen architecture in the achievement of environmental sustainability in the UK.

2. Environmental sustainability in the United Kingdom

It is estimated that the construction and the operation of buildings is responsible for around half of all global carbon dioxide emissions, thereby contributing the largest single source attributable to climate change (Allinson and Hall, 2007). According to Edwards (2005, p22), buildings are big users of raw materials and the environmental capital locked in them is enormous, as is the waste footprint:-

- Materials: - 60% of all resources globally go into construction (roads, buildings, etc.).

- Energy: - nearly 50% of energy generated is used to heat, light and ventilate buildings and a further 3% to construct them.

- Water: - 50% of water used globally is for sanitation and other uses in buildings.

- Land: - 80% of prime agricultural land lost to farming is used for building purposes and much of the remainder has been lost through flooding due to global warming.

- Timber: - 60% of global timber products end up in building construction and nearly 90% of hardwoods.

Therefore, environmental damage resulting from current construction practices is clear and this environmental damage in the form of Global Warming needs to be addressed if we want to avoid natural disasters and climate change. The terms ‘Sustainability’, ‘Sustainable Construction’, ‘Material and Sustainable Development’ are some of the terms which deal and address the solution to Global Warming and climate change are used nowadays frequently and need to be demystified.

There are many different definitions of sustainability. To engineers, their definition of working is to maximize uses of materials, skills, and energy for the benefit of mankind (McCarthy, 1998). According to Du Plessis (2002), sustainability is “the condition or state which would allow the continued existence of homosapiens and provide a safe, healthy and productive life for all generations in harmony with nature, local culture and spiritual values”. Sustainability is defined as an interdisciplinary, holistic and integrated process in the way things are thought, measured, implemented and managed. Balance and integration of economic, social and environmental dimensions of life demands changes in patterns of production, consumption, life styles, social relationships among other dimensions and concept of sustainability is not having a “system” in which economy is against ecology but a system in which all human actions are integrated to be effective (Orsatti, 2006, p1). According to Edwards (2005, p1), the definition of sustainability for the architect is a complex concept; a large part of designing sustainability is to do with addressing global warming through energy conservation and using techniques such as life-cycle assessment to maintain a balance between capital cost and long-term asset value. He also stated that, designing sustainably is also about creating spaces that are healthy, economically viable, and sensitive to social needs, respecting natural systems and learning from ecological processes, which is reflected on the three perspectives on sustainable design (Figure 1).

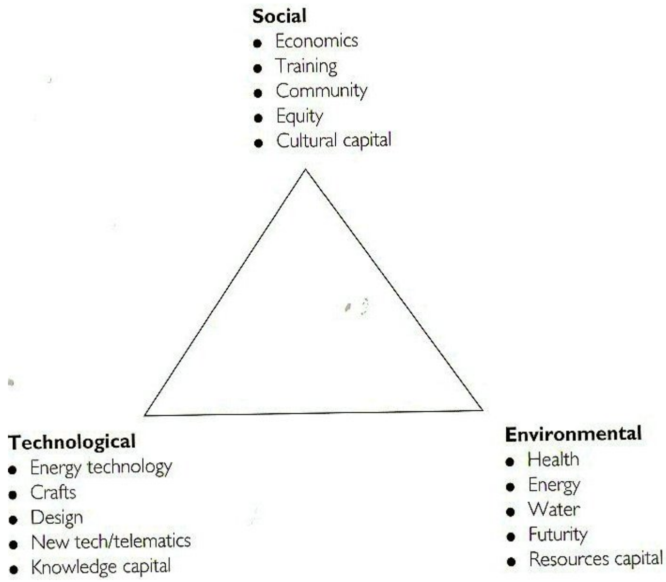

Figure 1: Three Perspectives on sustainable design. (Source: Edwards, 2005, p10.)

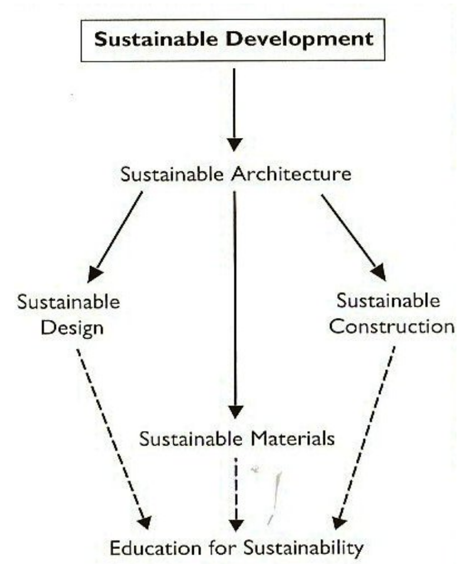

Figure 2: The concept of Sustainable Development spawns several sub-definitions relevant to building design. (Source: Edwards, 2005, p19.)

The Brundtland Commission (1987) defined 'Sustainable Development' as development that meets the needs of the present without compromising the ability of future generations to meet their own needs. This definition has spawned a series of sub-definitions to meet particular sector needs, typical of these is that used by the practice of Foster and Partners (Edwards, 2005, p19, Figure 2). They define sustainable design as creating buildings which are energy-efficient, healthy, comfortable, and flexible in use and designed for long life (Foster and Partners, 1999 cited in Edwards, 2005). Thus, sustainable development focuses on improving the quality of life for all of the earth's citizens without increasing the use of natural resources beyond the capacity of the environment to supply them indefinitely. It requires an understanding that inaction has consequences and that we must find innovative ways to change institutional structures and influence individual behaviour. It is about taking action, changing policy and practice at all levels, from the individual to the international. McLennan (2004) in Philosophy of Sustainable Design states that, sustainable design implies responsibility; and implies a far-reaching respect for natural systems and resources, respect for people and respect for the cycle of life. The opposite of respect is contempt. Our current system of construction, materials manufacturing and design are done in such a way that it may as well be contemptuous of natural systems and if one respects something, he honours it and act as its protector, as a steward or parent. It is in this vein that we describe sustainable design. When one has contempt for something he abuses it, neglects it, ignores it and uses it up. McLennan (2004) also stated that, "of course, the truth is that it is not really contempt for the natural world or any big conspiracy that is behind most environmental degradation but rather it is a by-product of ignorance and the inertia of progress and politics. In the 21st century, we can no longer plead ignorance and innocence for our actions, because we know that our buildings are a big part of the current crisis, inaction and resistance to the sustainable design movement can only be viewed now as contempt." From the definitions of ‘sustainability’ and ‘sustainable development’ (SD) it is understood that, sustainability is the process and its ultimate goal is sustainable development.

The Building Services Research and Information Association (BSRIA, 1996 cited in Edwards, 2005) have defined sustainable construction as the creation and management of healthy buildings based upon resource efficient and ecological principles. Edwards (2004) defined sustainable materials as materials and construction products which are healthy, durable, resource efficient and manufactured with regards to minimising environmental impact and maximising recycling. The draft for consultation of the Urban Thematic Strategy in 2004 saw sustainable construction as: “a process where all the actors involved … integrate functional, economic, environmental and quality considerations to produce and renovate buildings and a built environment that is: -

- Attractive, durable, functional, accessible, comfortable and healthy to live in and use, promoting the wellbeing of all that come into contact with it.

- Resource efficient, in particular with respect to energy, materials and water, favouring the use of renewable energy sources and needing little extra energy to function, making appropriate use of rain water and ground water and correctly handling waste water and using materials that are environmentally friendly, that can be readily recycled or reused, that contain no hazardous compounds and can safely be disposed of.

- Respects the neighbourhood and local culture and heritage.

- Competitively priced, especially when taking into account longer term considerations such as maintenance costs, durability and resale prices.”

The profession of architecture has defined “the dimensions of sustainability” from a variety of perspectives. According to Jones (1998), in the 1970s, solar cabins in the woods were associated with the counter-culture and alternative lifestyles, and in the 90s, parallel but uncoordinated efforts at sustainability have developed between approaches more aligned with urban design or with engineering. Jones further stated that, in the former, dimensionality is associated with the kind of broadening of perspective brought on by a systemic environmental approach and architecture’s sustainability is judged in relation to its role in urban and regional systems. The latter approach works at the scale of the individual building and its precisely detailed components designed to minimize energy use or maximize energy production. In this case, the dimensions of interest are the quantifiable measures of the building’s self-sufficiency. Ideal performance is represented by the “stand alone” building and able to produce its own power, recycle its own waste, the stand-alone building seemingly does not contribute to environmental degradation (Jones, 1998).

Human history shows that the early generations intuitively recognized the importance of utilizing the resources provided by nature carefully and had practical experience of the fact that humans are dependent on the earth’s life support systems for survival (Mead, 1964; Van der Post and Taylor, 1984). Therefore, the concern of the traditional societies and most of the developing world is not sustainability because as far as they are concerned they have contributed very little to this problem.

Instead, their main concern is mere survival using as many natural products and resources as possible. Ngowai (2000), also stated that, as time goes, it seems that humans lose their relationship with the environment, and the necessary feeling for its protection and, possibly, enhancement. In construction, the spread of modern ways of building and the use of materials without reference to context, climate and culture is a legitimate target of the effort to attain sustainability. A closer look at the traditional building practices will reveal that the main materials that were used were either stone or soil in one form or another. These materials can be considered sustainable because of the possibility of recycling them (Ngowi, 2000).

3. Environmental benefit of contemporary earth construction

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

Energy consumption
4.9 times less than wire cut bricks
15.1 times less than country fired bricks

Pollution emission
2.4 times less than wire cut bricks
7.9 times less than country fired bricks

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.

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

Product and thickness	***Number of units (Per square metre)***	***Energy consumption (MJ per square metre)***	***Carbon dioxide emission (Kg per square metre)***
CSEB – 24 cm	*40*	*110*	*16*
Wire Cut Bricks – 22 cm	*87*	*539*	*39*
Country Fired Bricks – 22 cm	*112*	*1657*	*126*
Concrete blocks – 20 cm	*20*	*235*	*26*

Adam and Agib reported that compressed stabilised 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 as required in 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 metre 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 as follows: -

- The energy required to construct a house and
- The 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.(Source: Vroomen, 2007.)

	Energy required in MJ/ Kg	*Carbon dioxide emission in Kg carbon dioxide per Kg material*
Gypsum (NBVG, Herpen)	*1*	*0.01*
Cement (Adobemachine)	*4.8*	*1.25*
Soil (Adobemachine)	*0.028*	*0*
Fired bricks (Houben)	*3.16*	*0.19*

The resulting totals are given in Table 3.

Table 3: The totals of the environmental computation. Source: Vroomen, 2007, p69.

	Adobe	*CSEB*	*Fired brick*	*Hollow concrete blocks (HCB)*	*Gypsum stabilised earth wall in sections*	*Gypsum stabilised earth massive blocks*
Energy required (MJ/ fu)	*36*	*233*	*1026*	*390*	*191*	*161*
Carbon dioxide emission (Kg/ fu)	*0*	*55*	*118*	*98*	*2*	*1*

Vroomen (2007) identified the following conclusions on the energy requirement and carbon dioxide emission from the above tables: -

- The energy requirement of Gypsum Stabilised Earth is about half of the energy requirements of HCB.
- Adobe is indisputable as the most environmentally friendly material.
- The firing of bricks is a very energy consuming process.

- Both cement stabilised products (CSEB and HCB) cause a large carbon dioxide emission. Due to their lower Wet Compressive Strength and high amount of gypsum required, the CSEB is no better alternative than HCB.

- A lot of carbon dioxide is released in the production of fired bricks.

- The release of carbon dioxide is almost nil in the production of Gypsum Stabilised Earth walls.

It is notable from this section that stabilised earth construction is environmentally sustainable compared to the conventional (fired brick, concrete) building materials. Promotion and adoption of earth as an alternative construction material is worthwhile and significantly helpful in achieving environmental sustainability (less carbon dioxide emission and less energy used). It is also notable from this section that stabilisation of earth doesn't only mean using cement stabilisation. Gypsum is also one of the stabilisers discussed in this section proved to be more environmentally sustainable than cement stabilised earth.

4. Contemporary earthen architecture in the United Kingdom

According to Smith (2000), exactly when and how cob (earth) building first arose in England remains uncertain, but it is known that cob houses were being constructed there by the 11th century and cob houses became the norm in many parts of Britain by the 15th century, particularly in South western England and Wales, where the subsoil is sandy clay and other building materials are scarce. An estimated 20000 cob homes and as many more outbuildings remain in use in the country of Devon alone (Smith, 2000). Furthermore, the advent of industrialisation and cheap transportation made fired brick available throughout England in the mid 1800's. By late last century, cob building was declining its popularity. There was virtually no new cob construction in England between World War-I and the 1980,s and its traditional builders took much of their specialised knowledge with them to the grave (Smith, 2000). The first construction project of the England cob revival was a bus shelter built by Alfred Howard in 1978. Since then, cob building has enjoyed an upswing in popularity in England, particularly in Devon (Smith, 2000).

According to Morton (2007), earth masonry has the realistic potential to break out of the niche of eco-building to make significant gains in reduction of CO2 emissions and waste production. The development of contemporary mass construction using earth materials in the UK has the potential to revive lost cultural traditions, while contributing to the development of a progressive sustainable construction industry. Furthermore Morton (2007) mentioned that the clay brick manufacturing industry in the UK has been in long-term decline for many years. There has been little innovation in the design of products, while production has been increasingly centralised into fewer, but more efficient, brickworks. Key markets, such as for internal partitions, have been lost to concrete block construction. The rising cost of energy, carbon taxation, and insecurity of gas supplies further contribute to a climate of uncertainty for the brick industry. In this context, the brick industry in the UK is looking for opportunities to diversify into more sustainable clay products, which could create new and growing markets while requiring less energy to produce. Two main producers of bricks in the UK, each responsible for 1/3 of national production, are currently developing earth products.

According to Morton (2007), the attraction of developing unfired clay masonry products include: -

- Materials are essentially non-hazardous and non-polluting in production.
- Raw materials are mainly those currently used the industry, with secure long term supplies. Possible additives are mainly cheap waste by-products of other industries.
- Existing, under-used production capacity can easily be used to produce simple unfired clay products with little investment required in new technology.
- Marketing and distribution of the new products can follow established patterns.
- New earth products have the potential to reduce energy used in production by 80-90%, with efficiency increasing with scale of production.
- The market for new 'green' construction materials is a growing one, with an image of future promise in contrast to the very traditional image of brick products
- Unfired clay products can compete with internal concrete and framed construction to build new markets, complementing rather than competing with existing fired clay products.

Earth bricks, mass produced in a typical UK brickwork process, built with a clay mortar, were assessed as having an embodied energy of 146 KWh/ tonne and an embodied carbon of 25.1 Kg CO_2/ tonne (Morton et al, 2005). For a three bedroom house of 92 square meter where earth masonry forms the internal partitions and inner face of the external walls, these figures represent a saving of about 24.9 MWh or 7 tonnes CO_2 over common bricks, and 14.5 MWh or tonnes CO_2 over lightweight concrete blocks (Morton, 2007). Construction and demolition in the UK annually produces 90 million tonnes, 19% of all waste and three times that produced by all households; 13 million tonnes of this is materials delivered to site and never used (Environment Agency, 2006). According to Morton (2007), earth masonry is effectively zero waste in production and any construction waste is benign and easy to dispose of. Earth masonry can also consume other construction waste in its production. Therefore, the notion of adoption of contemporary earth construction in the United Kingdom is worthwhile to reduce the CO_2 emission.

5. Conclusions

It is notable from this paper that there has been increasing levels of CO_2 emission in Europe due to the traffic and mass industries contributing to the severe air pollution, which will in some way affect every individual person on earth. On the other hand, it is evident that stabilised earth is environmentally sustainable compare to the conventional (fired brick, concrete, steel etc.) building materials and would be appropriate in the case of urban building construction. Promotion and implementation of earth as an alternative urban construction material is worthwhile and significantly helpful in achieving environmental sustainability (less fossil fuel is used, therefore, less carbon emission). It is also notable from this paper that stabilisation of earth doesn't only mean the cement stabilisation. There are other stabilisers which is more environmentally sustainable than the cement stabilised earth. An awareness and understanding by people to environmental issues such as air pollution, deforestation, land degradation, climate change and energy conservation would help the users and the professionals to change their attitudes and views towards earth building. As a matter of fact, earth building conserves energy during construction or during other lifecycle stages. Rammed (Stabilised) earth construction, due to their low thermal conductivity and higher thermal mass as opposed to conventional Brick-Block or RCC construction, is more thermally comfortable. Hence, it consumes less energy during operation. Operational energy use is important to tackle and mitigate the impacts of climate change. It is generally accepted that if lifetime energy consumption of a building is 100 units, approximately 15 units are consumed during construction and the rest 85 units are during operation. This is why, tackling operational energy use is essential for ensuring energy security of a nation as well as to reduce CO2 emissions from buildings. Besides, in earth construction individuals and community as a whole can easily participate in building their own homes in affordable ways addressing their moral obligation to climate change.

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Inhibitors Influencing the Adoption of Contemporary Earth Construction in the United Kingdom - State of the Art Review

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Abstract

Stabilised earth is an alternative building material which is comparatively cheaper than using conventional brick, concrete and steel. In addition, it is also well recognised that stabilised earth construction reduces CO2 emission, therefore, environmentally sustainable. Majority construction professionals in the United Kingdom do not know about contemporary earthen architecture, despite the enormous potentiality of stabilised earth construction. In fact there are potential inhibitors which is making contemporary earthen architecture unpopular in general and specifically in the United Kingdom. This paper aims to identify and highlight these inhibitors in the light of its use on site, performance, image in the societies and cultures, institutional and administrative acceptability. A critical literature review method was adopted in this paper to investigate the inhibitors influencing the adoption of stabilised earth construction in the United Kingdom.

Keywords: earth construction, sustainability, inhibitors

1. Introduction

According to Morton (2007), the development of contemporary mass construction using earth materials in the UK has the potential to revive lost cultural traditions, while contributing to the development of a progressive sustainable construction industry. In our current pursuit for sustainable development, earthen structures hold enormous relevance and potential in providing solutions for environment-friendly buildings that are energy efficient, comfortable and recyclable (Reddy and Mani, 2007). The use of mechanical air conditioning to control the interior environment (temperature and humidity) of buildings within comfortable levels for the occupants is now commonplace in the UK and stabilised rammed earth (SRE) walls can be used as a building integrated source of passive air conditioning (Allinson and Hall, 2007). Despite all these benefits of contemporary earthen architecture recognised by the empirical evidence, earth construction still not widely adopted to construct urban structures in the United Kingdom. Therefore, it is pertinent to analyse the inhibitors influencing the adoption of this technology. After a critical review of the literature, it seems to appear that there is a lack of well structured research so far carried out to establish the inhibitors influencing the adoption of stabilised earth construction in the United Kingdom. A critical literature review method was adopted in this paper to investigate the inhibitors.

2. Why contemporary earth construction?

According to Easton (1996), rammed earth (RE) construction is a cheap way of providing shelter since earth is an abundant resource. Frescura (1981) writes, “in addition to its political, economic, social and ecological advantages, earth has great cultural and architectural importance.” Construction in earth has the uniqueness of manifesting cultural heritage, and encouraging the continued use of the material helps to maintain and preserve the craftsmanship and cultural values embedded in earth building. According to Morton (2007), earth bricks and blocks can be a substitute for concrete blocks in most internal applications, where it is not suitable for external use due to the severe climatic reasons. The benefits of earth construction are multiple and complementary and are summarised in Table 1. It is important to mention here that the benefits of stabilised earth construction depends on the context and situation of particular countries and it seems the benefits of stabilised earth construction in the United Kingdom is not identified with the help of a structured research.

Table 1: Benefits of contemporary earth construction. (Source: compiled by author, 2009)

Benefits (summarised from the literature review)	*Author*
1. Earth construction is economically beneficial.	*Lal, 1995; Easton, 1996; Minke, 2006; Zami and Lee, 2007; Morton, 2007; Kateregga et al, 1983; Cassell, 1993; Walker et al, 2005; Hadjri et al, 2007; Morris and Booysen, 2000; Adam and Agib, 2001, p11; Maini, 2005;*
2. It requires simple tools and less skilled labour.	*Kateregga, 1983; Easton, 1996; Minke, 2006, p15; Hadjri et al, 2007; Morris and Booysen, 2000; Adam and Agib, 2001, p11; Maini, 2005;*
3. It encourages self-help construction.	*Kateregga, 1983; Minke, 2006, p15;*
4. Suitable for very strong and secured structure.	*Lal, 1995, p119; Houben & Guillaud, 1989; Walker et al, 2005;*
5. It saves energy (low embodied energy).	*Morton, 2007; Lal, 1995, p119; Minke, 2006; Hadjri et al, 2007; Adam and Agib, 2001, p11; Maini, 2005;*
6. It balances and improves indoor air humidity and temperature.	*Cassell, 1993; Howieson, 2005; Alphonse et al, 1985; Minke, 2006; Kateregga et al, 1983; Lal (1995, p119); Walker et al, 2005; Hadjri et al, 2007; Adam and Agib, 2001, p11;*
7. Earth is very good in fire resistance.	*Alphonse et al, 1985; Walker et al, 2005, p43; Hadjri et al, 2007; Adam and Agib, 2001, p11;*
8. Earth construction is regarded as a job creation opportunity.	*Adam and Agib, 2001, p11;*
9. Earth construction is environmentally sustainable.	*Minke, 2006; Easton, 1996; Walker et al, 2005; Hadjri et al, 2007; Adam and Agib, 2001, p11; Maini, 2005; Ngowai, 2000.*
10. Loam preserves timber and other organic materials.	*Minke, 2006, p15; Möhler 1978, p. 18*
11. Earth wall (loam) absorbs pollutants.	*Cassell, 1993; Minke, 2006;*
12. Easy to design with and high aesthetical value	*Morton, 2007; Houben and Guillaud, 1989; Walker et al, 2005; Hadjri et al, 2007.*

13. *Earth buildings provide better noise control.*	*Kateregga, 1983; Alphonse et al, 1985; Hadjri et al, 2007;*
14. *Earth construction promotes local culture, heritage, and material.*	*Frescura, 1981.*
15. *Earth is available in large quantities in most regions.*	*Adam and Agib, 2001, p11; Easton, 1996; Lal, 1995; Hadjri et al, 2007; Morris and Booysen, 2000; Adam and Agib, 2001, p11;*

In the light of the benefits mentioned in Table 1 one can posit that the use of earth as a construction material with an innovative approach would apply well and can be considered as a sustainable solution to the energy efficient urban construction in the context of United Kingdom.

3. Inhibitors influencing the adoption of earthen architecture

Section 2 stated the benefits of stabilised earth construction in general. It is evident from the literature review that experimental stabilised earth construction projects are a success in many developing (Sudan, Zimbabwe, South Africa) and developed (Australia, Germany, France) countries (Mubaiwa, 2002; Zami and Lee, 2008). Thus the question remains, why is stabilised earth construction not yet widely adopted to address CO2 emission in the United Kingdom? To investigate the reason, it is logical to review the literature and find out whether there is any structured research so far carried out to identify the inhibitors influencing the widespread adoption of contemporary earth construction. In Devon (England) there are 40,000 cob buildings still in everyday use (Abey and Smallcombe, 2007). Lack of standardised earth-based materials, rapid urbanisation, changing lifestyles and increased adoption of energy-intensive modern construction materials have lead to a steep decline in adoption of traditional/ vernacular earthen structures (Reddy and Mani, 2007).

According to Baiche et al (2008), various earth-building awareness initiatives and performance-enhancement studies were undertaken in a number of African countries. In Nigeria, tests to improve the durability and affordability of earth building, which has been promoted as an alternative for low-cost housing for the poor, were carried out (Olotuah, 2002). It has also been reported that compressed stabilised earth blocks were 'successfully' used in low income housing in Sudan (Adam and Agib, 2001); users' perceptions were however not recorded. Similarly, the potential of earth building in Botswana has also been studied, with the aim of developing a suitable material mix for a compressed earth block technique and recommendations were put forward on the proportions of the block mix; mixing methods; stabilisation; strengthening and transport. The study concluded that further work was required to establish the wider use of earth blocks and it encouraged earth block use for housing in Botswana, Namibia, and Zimbabwe, given the similarity in their soils (Longfoot, 2003). Under pressure for modernisation, the Zambian government has so far neglected the promotion of vernacular construction methods and materials (Tyrell, 1996). Furthermore, the Zambian Institute of Scientific Research and the Copperbelt University carried out research on traditional construction technologies, but the dissemination of their findings has not been implemented effectively (Mususa and Wood, 2004). A study identified several barriers to earth building in Uganda, including the need for new legislation, technical training, public awareness of sustainability, and knowledge-sharing (CRATerre, 2005).

Baiche et al (2008) carried out a research project that examined the viability of earth construction as a building material and technique for urban housing in Zambia. It was anticipated that this might give indications of the reasons for residents' attitudes. According to Baiche et al (2008), a twofold quantitative and qualitative research methodology was used to collect data for assessing attitudes towards earth building amongst end users, building designers and contractors in the Zambian construction industry.

- First, a case study was carried out to gain insights into users' views on living conditions in earth houses. Qualitative information was collected through surveys and semi-structured interviews with twenty (20) residents in two (02) selected sites: earth homesteads in Chief Nkana's area and Musonda compound; and conventional buildings in the Riverside area of Kitwe. This case study provided the basis for the formulation of a questionnaire.

- Second, a questionnaire was used to collect data for a baseline overview of the Zambian construction industry's attitude to earth construction. It also examined the levels of support and involvement of building designers and contractors in promoting the use of earth for housing.

Sixty (60) questionnaires were randomly distributed to architects, structural engineers, and contractors specialising in housing. Out of the sixty (60) questionnaires circulated to design practices and contracting companies, 22 were completed and returned, a response rate of 37%. Responses from the survey were analysed using the Statistical Package for Social Sciences (SPSS). Analysis of the five point Likert scale answers was carried out by comparing the means by 'one sampling T test'. Respondents were asked to rate a number of limiting factors that impede the use of earth in the Zambian construction industry. The majority (69%) strongly believed that structural weakness (mean value of 4.50) was the key constraint in specifying earth in their projects, followed closely by lack of interest by clients, with a mean value of 4.31. Additionally, respondents rated equally (3.50) the lack of technical knowledge regarding earth construction and the perception of earth as not suitable in up-market development as critical barriers. Similarly, poor water resistance and the perception by society of earth as a sign of unattractive old architecture were seen as serious impediments to its wider use. Figure 1 shows the inhibitors that impeded the use of earth in the Zambian construction industry.

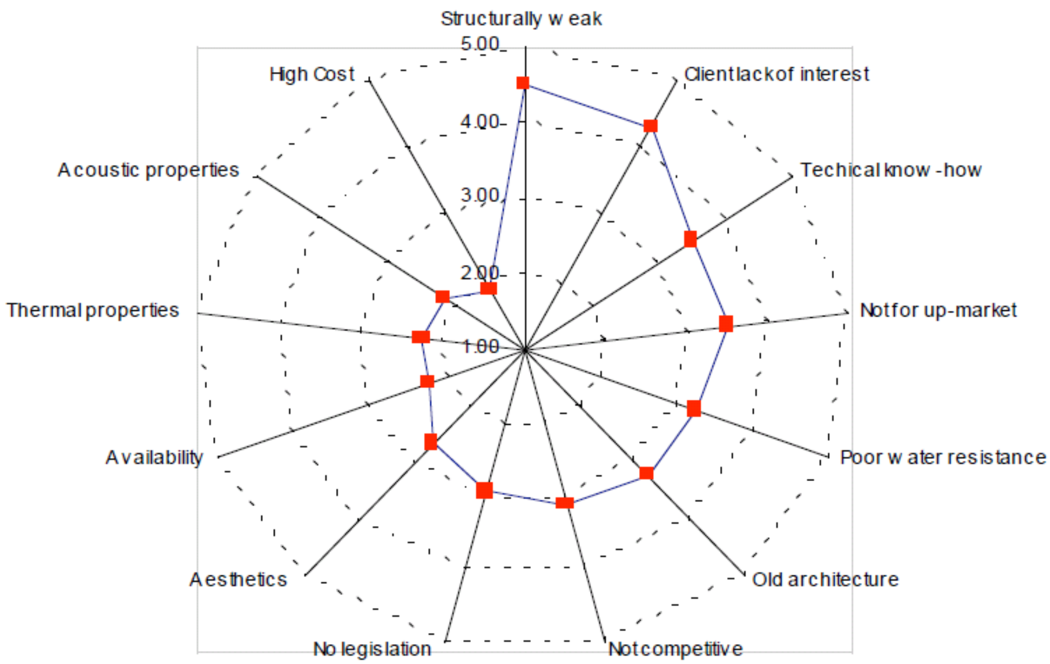

Figure 1: Inhibitors of earth construction in Zambia. (Source: Baiche et al., 2008)

However, Baiche et al's (2008) research lacks appropriateness of methodological design. First, no critical literature was reviewed before executing this research. In addition, there was no basis justified for the case study approach and to formulate an interview questionnaire in the first place to get insights into users' views on living conditions in earth houses. Furthermore, the one or other technique was adopted to collect data in Baiche et al's (2008) research, which was not justified and compatible to investigate user's and professional's perception. The problem under investigation in this research is directly related to people's perception, literacy, educational background, attitude, culture and belief. According to Baiche et al (2008, p6), "*The case study shows that earth buildings are **perceived** as not durable and aesthetically unpleasant; and are **believed** to be a sign of poverty and backwardness. Additionally, designers and contractors were **reluctant** to specify and select earth materials due to their technical and performance limitations*". Therefore, the research methodological design and in particular the research techniques adopted, are not appropriate to collect data from construction professionals and users.

Baiche et al's (2008) research shows that, there are many inhibitors that influence the widespread adoption of stabilised earth construction and inhibit this technology being universally accepted by the clients (users) and practicing professionals. The experience of the last three decades has thrown up considerable information on the process of dissemination of stabilised earth technologies and it must be admitted that the spread of earth technologies has not been a smooth process (Jagadish, 2007, p25). Moreover, earth materials and techniques are perceived as 'substandard' or 'second class', while modern construction methods and materials are seen as 'civilised' or 'symbols of affluence' (Sojkowski, 2002). Table 2 lists the inhibitors from the intensive literature review. It is worth mentioning here that the inhibitors influencing the adoption of stabilised earth construction depends on the context and situation of particular countries and it seems the inhibitors in the United Kingdom are not identified with the help of a well structured research.

Table 2: Inhibitors influencing the adoption of contemporary earth construction. (Source: Author, 2008)

Inhibitors *(Summarised from the literature review)*	*Authors*
1. *Peoples mistaken perceptions and cultural problems.*	*Morton, 2007, p377; Norton, 1997, p8; Chaudhury, 2007; Kateregga, 1983; Blondet and Aguilar, 2007, p8; Jagadish, 2007, p26; Hadjri, 2007; Maini, 2005; Adam and Agib, 2001, p11; Minke, 2006, p18; Baiche et al, 2008; Sojkowski, 2002.*
2. *Lack of knowledge, skills, and understanding amongst professionals, government, donors, and users.*	*Jagadish, 2007, p26-27; Houben et al, 2007; Morton, 2007, p383; Hadjri, 2007; Maini, 2005, Baiche et al, 2008.*
3. *It requires extra money, labour and time.*	*Morton, 2007, p379; Blondet and Aguilar, 2007, p8; Cassell, 1993; Kateregga, 1983*
4. *Lack of technologies and resources.*	*Jagadish, 2007, p26-27; Maini, 2005.*
5. *Lack of courses and trainings in the universities.*	*Jagadish, 2007, p26 -27; Houben et al, 2007, p39 ; Castells & Laperal, 2007; King, 1996, p5*
6. *Lack of care and focus for the environment, aesthetics, and comfort.*	*Jagadish, 2007, p27; Houben et al, 2007, p39 ; Elizabeth, 2005 ; Adams, 2005*
7. *Lack of building codes, policies to adopt earth construction.*	*Morton, 2007, p377; Lal, 1995, p124; Eisenberg, 2005; Hadjri, 2007, p143;* *Adam and Agib, 2001, p11.*
8. *Professionals make less money from their customary percentage on total cost of earth construction projects.*	*Robinson, 1939.*
9. *Housing credit and insurance are difficult to obtain from financial institutions.*	*Norton, 1997, p8.*
10. *Low technical performance of earth as a construction material.*	*Maini, 2005; Hadjri, 2007; Adam and Agib, 2001, p11.*

All the inhibitors identified in Table 2 of contemporary earth construction lack empirical evidence and it would seem from a thorough review of the literature that sparse research to date has been undertaken to substantiate whether the inhibitors in Table 2 are real or mere speculation. It is questionable whether they are the author’s perception, and thus lack empirical data to substantiate the findings. Therefore, a well structured research is pertinent to substantiate the inhibitors influencing the widespread adoption of contemporary stabilised earth construction.

4. Inhibitors influencing the adoption of earthen architecture in the United Kingdom

Despite the loss of traditional earth construction, there are estimated to still be 500,000 inhabited earth buildings in the UK (ICOMOS UK, 2000 cited in Morton, 2007). Limitations in the widespread adoption of earth-based techniques for buildings include lack of standardised engineering methodologies, poor seismic resistance, lack of strength upon saturation, poor resistance against rain impact, uncertified products, lack of sustained research and development efforts, education and training, and poor regulatory mechanisms (Reddy and Mani, 2007). According to Heath et al (2007), low embodied carbon, ease of recycling, thermal mass and passive moisture regulation qualities are just some factors that have stimulated a recent revival in the interest and use of unfired clay masonry in the UK. Morton (2007) stated the following inhibitors influencing the adoption of contemporary earthen architecture in the United Kingdom: -

- The most significant technical barrier, the lack of a recognised earth building standard, could best be tackled by a British Earth Building Association. A key barrier that has been tackled in countries such as Germany and New Zealand, and which will need to be addressed in the UK is the issue of standards. The quality control and marketability that an industry-recognised standard for earth construction would give is the gateway through which the sector can move from one-off demonstration projects to everyday use in everyday buildings. Only once this has been achieved, will earth masonry really begin to deliver on its potential to improve the sustainability of construction.

- Currently no British standard is directly applicable as a control on construction quality. While standard-testing procedures that were developed for fired clay or concrete products need to be modified and the results interpreted for earth materials. This can make demonstration of compliance with building regulations and certification of products by independent bodies less easy than with conventional products.

- A UK earth building standard will not be achieved quickly and would need wide industry backing to bring about. The long overdue establishment of a British Earth Building Association to promote the conservation and development of earth building in the UK would act as a focus for the dissemination of good practice in earth construction, while promoting the technology more broadly than individual manufacturers are capable of.

- Lack of appropriate skills is another potential barrier. While bricklayers commonly require minimal introduction to earth materials and quickly achieve rates of construction comparable to conventional products, the application of finishes can be more problematic. Clay plasters, in particular, require different skills than the ubiquitous gypsum plasters, which set quickly by chemical action and are usually polished with a steel float. Job specific training, organised by materials suppliers, is currently used to ensure good quality in such projects.

The above inhibitors mentioned by different practitioners and authors are not substantiated by any empirical evidence and research, therefore, these essentially need to be substantiated by the empirical evidence and a well structured research.

5. Conclusions

This paper has investigated and analysed the literature and argued that the adoption of stabilised earth as an alternative material in the construction of urban structure is beneficial in general and specifically in the United Kingdom. Stabilised earth is an affordable, locally available, environmentally sustainable building material and would be an appropriate alternative to conventional building materials, such as fired brick, concrete and steel. In addition, this paper also investigated the inhibitors influencing the adoption of contemporary earth construction in general and specifically from the context of United Kingdom. It was found that there is lack of structured research, to date carried out to identify the benefits and inhibitors. Therefore, it is imperative to empirically substantiate the findings of the literature review and validate them through an appropriate research technique.

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The Environmental Impact of Recycled Concrete

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Abstract

Concrete is a building material used worldwide and consumes large amounts of raw materials. The concrete structure is cheaper than steel structures; the raw materials can be found in almost anywhere and can be moulded easily. Nevertheless, the concrete industry produces a lot of waste and the old concrete many times goes to landfills. The aim of this work is identify, in a critical way, the aspects related to the concrete used in the 'sustainable' architecture developed nowadays. Concrete has many advantages respect other materials, but can not be recycled in the same way if compare to metals, for instance. Actually, it occurs a downcycling, because the old concrete is transformed in recycled aggregate and the new concrete made with this recycled aggregate needs new cement. Sand, gravel, limestone and other materials many times are extracted from nature on a destructive way. The recycled aggregate production is about 5% of the total aggregates needed to supply the construction industry. As other industries, the transformation activities to produce concrete generate waste. The standards are mostly conservative and the amount of recycled concrete aggregates used normally does not exceed 20% in weight on coarse aggregates. Furthermore, there is always a residual concrete which is located at the concrete mixer truck at the end of each day. This concrete is treated as a waste and many times is discarded with no or little environmental control. These and other factors contribute to reduce the natural resources and to increase the amount of waste. From the development of this paper it can be noticed that the actual recycled concrete can not be characterized as sustainable, because there are many issues that must be solved until it becomes a real sustainable material.

Keywords: sustainability, concrete, recycling, waste

1. Introduction

Concrete is a compound material many used in buildings, mainly in multi-storey buildings. Cement is a material that needs 1 to 1.5 metric ton of lime; uses a lot of energy for its production, around 4000 MJ/metric ton and releases 0.8 to 2 metric ton of carbon dioxide to the atmosphere to produce the clinker (Kumar et al, 2006). A building made of reinforced concrete structure is demolished at the end of its lifecycle and its residues are normally sent to the landfills. Nevertheless, all the concrete mass treated as waste can be incorporated into new concretes in the form of aggregates. Another issue that helps to increase recycling aggregate is the difficult to find natural aggregates locally (Topçu and Günçan, 1995). The higher price of natural aggregates contributes to increasing the concrete price and decreasing the materials resources available for next generations. Transport of such aggregates is a problem of costs too, because aggregates are heavy and low-price products.

2. Recycled aggregates

Natural aggregates are products made of sand and crushed stone; and recycling aggregates are made mainly of crushed concrete and asphalt pavement (Goonan, 2000). According to the same author, natural aggregates corresponded to 36% of total raw materials produced by United States in 1900. There was a growth in production along six decades, which increased the proportion of natural aggregates up to 70% respect to the total raw materials. Since these years the percentage of natural aggregates is more and less steady, around 70 to 73% of all raw materials demand.

Aggregates are the most used materials in the world, because they are available in almost sites on the planet, which makes their price is very low. Only in United States are extracted 3,000 million metric tons of coarse and fine aggregates per year. It has started to study the applications of recycled aggregates in concrete in the way to diminishing the environmental impact caused by natural aggregate extraction, due to the enormous quantity of natural aggregate used in buildings construction. Normally, the decision of sending the construction and demolition wastes to the landfills or to a recycling plant is responsibility of a firm contracted to demolish the building (Goonan, 2000). In this case, the firm studies economic aspects and local laws. Goonan (2000) argues that the recycled aggregates market in The United States correspond to 5% of the total aggregates market of that country and are used in low cost applications. One of the causes of this low percentage is the fact that recycled aggregates of construction and demolition wastes do not have uniform quality. From this, test results can be very different, which decreases the confidence of architects and engineers for using recycled aggregates. However, many researches have been made in this area to create standards and recommendations with the aim to encourage the use of recycled aggregates.

Some of the limitations in using recycled aggregates are respect to transport, the quality of aggregates and the raw materials availability which in this case is highways and buildings that will be demolished. Transportation cost has to be low and the demand for demolishing structures must guarantee a constant supply of aggregates and force the market to stay at large cities. The growing urbanization, mainly after The Second World War has created a great demand for new buildings and the demand for natural aggregates too. Nowadays, these same buildings do not comply with the new standards and many are demolished to take place to new ones. Therefore, large cities now are converted into urban deposits of recycled aggregates. The production of recycled aggregates in The United States is around 140 million metric tons per year, which correspond to 5% of total aggregate market (Taylor, 2007). The machinery normally used for natural aggregates transformation can not be used for recycled aggregates due to the metal content in the concrete; and metal must be sorted from aggregates (Wilburn y Goonan, 1998). Concretes that will be recycled are previously sorted to remove products which are not concrete or masonry at building site. From this point, there are basically two methods to obtain recycled aggregates from concrete. One is crushed the concrete at a recycling plant facility and the other one is with a mobile plant. Each method uses basically the same procedures.

The quality of materials which arrives at the recycling facilities is the part that recyclers have little or no control, due to the wide range of variety of materials transported from different sources. Construction and demolition wastes contain non metallic materials, such as wood and plastic that must be collected. The energy types employed to processing and transporting the recycled aggregates are electricity and diesel. Wilburn y Goonan (1998), estimated that the energy necessary to process one metric ton of concrete into recycled aggregates is 34 MJ, for processing one metric ton of recycled asphalt aggregate requires 16.5 MJ and to process one metric ton of natural aggregates is 5.8 MJ. The high difference in energy consumption between recycled and natural aggregates is due mainly to the labour in identify and remove materials like wood, plastic and glass from construction and demolition wastes for further processing. Energy values for transport are 2.7 MJ/metric ton-kilometre for fine aggregate and 3.8 MJ/metric ton-kilometre for coarse and recycled aggregates (Wilburn y Goonan, 1998).

3. Carbonation of CO_2

Carbonation is a chemical reaction in which calcium hydroxide present in cement reacts with carbon dioxide in the air and the result is calcium carbonate. Carbonation increases concrete resistance with the past of the years. However, when steel is used as reinforced concrete carbonation can be a problem, because carbonation decreases concrete pH. This can cause oxidation of steel and hence structural problems. Dodoo et al (2009) investigated the carbon cycle of a building with reinforced concrete and wood-frame structure. The work demonstrates that construction phase releases the most carbon dioxide of all building life-cycle. These authors made calculations to determine the amount of carbon dioxide absorbed by concrete through carbonation during the building life-cycle. Recycled concrete has a high CO_2 absorption rate respect the same concrete used as structure (figure 1). Carbonation in wood-frame structures showed in figure 1 is due to the concrete used as foundations. The carbonation rate of concrete in wood-frame structure is low because concrete is underground land and reacts slowly than concrete exposed to air.

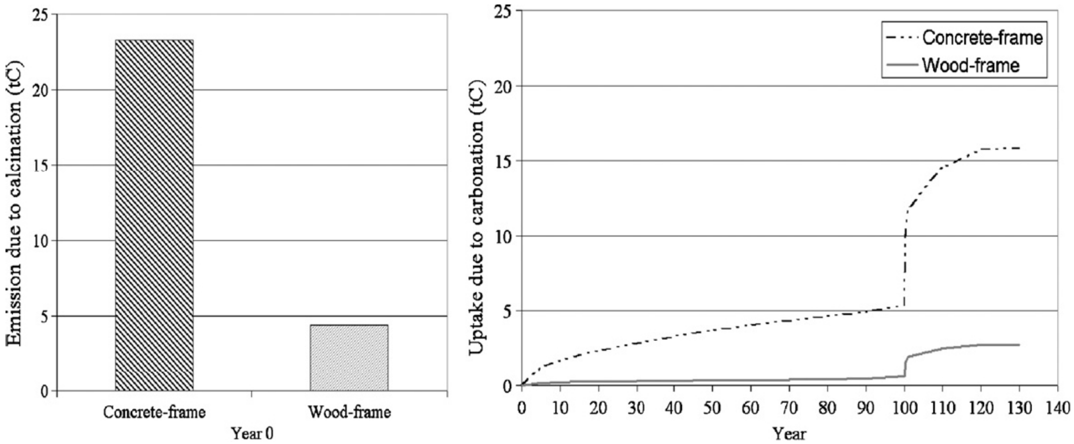

Figure 1 Carbon flows through cement calcination (left) and carbonation of concrete and cement mortar during the service life and after demolition (right) for the concrete and wood-frame buildings (Dodoo et al, 2009)

Carbonation presented in figure 1 is due mainly to the exposed area of crushed concrete which is higher at recycling facility yards or building sites than the interiors of buildings. The most marked difference in carbonation is in the first 4 months of demolished concrete. Concrete can absorb up to 68% of carbon dioxide released in concrete calcination, for a building service life of 100 years and subsequent recycling of this concrete. However, non-renewable energy resources used to crush and transport concrete to recycling plants do not allow high gains of carbonation. Steel structure recovered during crushing and separation operations of concrete contribute to the carbon cycle because steel recovered from structure can be recycled.

4. Characteristics of recycled concrete aggregate

The international literature provided numerous works at recycled concrete aggregate area, mainly from the beginning of 1980 (Hansen, 1992). The topics most investigated are durability and mechanical characteristics. The quality of aggregates made of recycled concrete affects directly the properties of new concrete mixes. Some recycled aggregate properties, such as dimensions, resistances and water absorption are investigated. Aggregates influence directly porosity and mechanical resistance, among other characteristics because the proportion content of aggregates in concrete varies around 70 to 80% in mass and therefore affects the quality of concrete. Investigations in this area are divided in two types: one type is with natural fine aggregates and coarse recycled aggregates; another group is with fine and coarse aggregates partially or totally made with recycled concrete. The percentage of recycled aggregates has influence on the new concrete properties too. Absorption is an aspect that is investigated a lot, because water is the primary agent which can degrade materials. Water transports aggressive agents to concrete and it can cause chemical and physical problems in concrete structures and this affects concrete durability (Levy y Helene, 2004).

4.1 Aggregates absorption

Water absorption of masonry recycled aggregates, concrete recycled aggregates and the mixtures of two ones must be a maximum of 20%, 10% and 3% respectively in mass of aggregates (Rilem, 1994). Sagoe-Crentsil et al (2001) investigated the relation between fine natural aggregates and coarse recycled aggregates and they shown that coarse recycled aggregates have 5.6% of water absorption and that fine natural aggregates have 1% of water absorption. The authors argue that de difference is due partially to mortar wastes which are presented in the recycled aggregates. Gómez-Soberón, (2002) observed in his investigation that water absorption in recycled concrete aggregates varies from 5.8 to 6.8%, while water absorption in natural aggregates varies from 0.9 to 1.1%.

Katz (2003) investigated the compressive strength of concrete which was crushed to serve as a source of aggregate for new concretes. In the investigation it can be noted that as smaller is the crushed aggregate as higher is the water absorption. Coarse aggregates among 9.54 to 25 mm had absorption of 3.3% in 28 days. Medium aggregates (2.36 to 9.5mm) had 8% and fine aggregates (less than 2.36mm) had 12.7% of water absorption. These differences in porosity are due to the high cement content presented in fine aggregates. The percentage of old cement in aggregates is 6.8% to coarse, 13.2% to medium and 24.5% to fine aggregates. In comparison, natural aggregates have low porosity and its absorption percentage varies from 0.5 to 1.5%. Mortars are less dense and more permeable to water then natural aggregate, because it is function of concrete age and the quality of mortar presented in the concrete (Gómez-Soberón, 2002). Levy y Helene (2004) measured the water absorption of natural, concrete and masonry aggregates. Natural aggregate has absorption between 0.8-1.8% for coarse and fine respectively. Recycled concrete aggregate has 5.6% for coarse and 7.9% for fine aggregates. Recycled masonry aggregate obtained 7.9% for coarse and 13% for fine aggregates. The researchers recommend that recycled aggregates must be saturated before put them in the mix in the way to not reduce the workability of fresh concrete by high absorption rates.

4.2 Compressive, tensile and flexural strengths

Respect to the compressive strength, tests with concrete with coarse recycled aggregates carried out by Sagoe-Crentsil et al (2001) demonstrated that there is no difference superior to 5% with a coarse recycled aggregate content up to 23%. On the other hand, Gómez-Soberón, (2002) founded a reduction about 11% in the compressive strength between specimens made of 100% recycled aggregates respect to specimens made of natural aggregates only. However, when it was a 30% replacement of natural aggregates, the compressive strength decreased 5%. Tensile strength of a concrete with recycled aggregates has 10% lower strength that concrete made of natural aggregate and it maintained steady up to 90 days of tests.

Katz (2003) obtained different results. According to his investigation, the values of compressive strength of concrete made of with 100% recycled aggregates are 24% lower in comparison to concrete made of natural aggregate. Etxeberria et al (2007) tried to obtain concrete mixes with recycled aggregates with the same strengths to concretes made of natural aggregates. The mixes studied have natural aggregate replacement rates between 25%, 50% and 100%. The results shown that concrete with 25% replacement obtained practically the same compressive and tensile strengths then the control concrete. However, concretes with 100% natural aggregate replacement must have its cement content increased in 12% and diminishing its w/c ratio in 20% in order to obtain the same resistances to those conventional concretes. For the same cement content and w/c ratio, the compressive strength of concrete with 100% natural aggregate replacement drops 20 to 25% respect concretes made of natural aggregates only. (Etxeberria et al, 2007).

Ajdukiewicz y Kliszczewicz (2002) analyzed high performance concrete made of recycled aggregate. The aggregates used were recovered from high performance concrete structures demolished from 2 to 7 years. The authors tested six different groups. The first group is the control specimens with natural aggregates only; the second one is formed by 2-16mm recycled aggregates and natural quartz sand. The third group is made of 100% recycled aggregates. The tree last groups are the same of anterior groups with the addition of 3% of plasticizer and 10% of silica fume in mass of cement. The w/c ratio in all groups was 0.3-0.4. The test results shown that the addition of plasticizer and silica fume increases compressive strength 50% respect to the group of control. Concretes with 100% recycled aggregates and with those additions obtained superior resistances respect to the group of control.

4.3 Other factors

Creep is affected by the young's modulus. Gómez-Soberón, (2002) calculated the young's modulus for a concrete which uses recycled aggregates only and is 10% lower than concrete made of natural aggregate. The difference of young's modulus increases to 18% for tests carried out at 90 days. This means that concrete with recycled aggregates can be more suitable to long term deformation forces. Retraction of concrete with recycled aggregates was measured by Katz (2003) and the results show that this concrete has retraction around 0.7mm/m in comparison with 0.32mm/m encountered in conventional concrete. Li (2008) explains that the superior retraction observed in concrete with recycled aggregates is due mainly for two factors. The first one is that the old cement paste has superior retraction respect natural aggregates and the second one is that the water content necessary to adequate the mixture to the slump test is higher, which creates voids and therefore much more retraction.

Investigations are carried out to recycle the waste wash water produced in ready-mixed concrete plants and ready-mixed concrete trucks. According to Sandrolini y Franzoni (2001), each day exists an amount around 200-400 kg of concrete inside of concrete trucks. This fresh concrete is washed out and aggregates can be removed mechanically with the addiction of 1000 litres of water for reuse in new mixes. However, this water can not be discharged in the environment without previously treatment, due to high amount of solid particles and its extremely high pH. The authors comment that the practice to recycle water at ready-mixed concrete plants is thought sedimentation basins and sediments are disposed of in authorized landfills. Concrete made with recycled water has 28-day compressive strength 4% lower then concrete made with distilled water. As reported by Šelih y Žarnić (2007), the EN 1008 standard affirms that the solid matter content in water can not exceed 1% in mass. The result of the investigation showed that the effect of recycled water in concrete mixes tested is minimum.

One of the problems that affect the utilization of recycled aggregates is the variation in performance and the availability of buildings that will be demolished for continuous concrete supply. Another factor is the proportion of contaminants in recycled aggregates, for instance, gypsum, wood, organic matter, among others. Gypsum presented in large quantities in concrete can affect the durability of steel reinforcement; because gypsum has high sulphate concentrations (Khalaf and DeVenny, 2004). Organic matter such as papers and wood reduce the mechanical properties of concrete, due to its lightness. Concrete and masonry recycled aggregates are classified in tree groups, according to the Rilem Recommendation (1994). The type I is classified is aggregates made of masonry rubble; type II aggregates referees to concrete rubble and type III is aggregates which contains both concrete and masonry rubble. This classification is for aggregates with 4mm diameter or higher. Additional requirements for group III are the following: The natural aggregate content must be at least 80% in mass of total aggregate content and the maximum content of group I is 10%.

The Real Decreto 1247/2008, of the Ministry of Public Works of Spain about structural concrete (EHE-08) provide data about the use of concrete containing recycled aggregate in its composition. The standard informs that both natural and recycled coarse aggregates must have maximum water absorption of 5%, when the aggregate proportion is superior to 20%. However, the water absorption can rise up to 7% if the aggregate content does not exceed 20%. This standard is not prohibitive for proportions above 20% of recycled aggregates; however specific tests must be made to ensure a good quality concrete with these higher percentages. The concrete produced with recycled aggregates can be employed either in plain concrete or reinforced concrete up to 40kN/mm^2. Nevertheless, the standard prohibits its use with prestressed concrete. The maximum content of impurities is 5% for ceramic materials, 1% for light particles and 1% for other materials such as glass, metals and plastics. The durability of concrete made of recycled aggregate is a much discussed theme. The instruction EHE-(08) argues that the durability of concrete with 20% addition of recycled aggregates has similar performance to conventional concrete. At higher levels of recycled aggregates it should be take some measures to reduce the attack of some atmospheric agents, with the reduction of the w/c ratio, increasing cement content or using plasticizers.

4.4 Other types of wastes

Many investigations have been made with the aim to incorporate wastes of other industries in aggregates for concrete. The most investigated materials are glass, tires, marble wastes and PET bottles. The incorporation of crushed domestic glass as aggregates into concrete mixes is possible, as informed by Polley et al (1998) and Park et al (2004). According to Polley et al (1998) the mechanical characteristics are significant altered at 20% of addition of crushed glass in fine natural aggregate. On the other hand, Park et al (2004) argue that the incorporation of 30% of crushed glass in fine natural aggregate does not affect significantly the mechanical properties of concrete. In fact, the compressive, tensile and flexural strengths decrease respectively 0.6%; 3.4% and 3.2% respect to the conventional concrete. They report that "recycling waste glass as an aggregate is effective for environmental conservation and economical advantage." (pp 2181-2182). On the contrary, bottle glass should be recycled into glass again and not transformed into aggregate for concrete. Glass used as fine concrete aggregate can not be extracted from cement paste, due to its particle dimension which is around

0.6mm in diameter after crushed. In this case it can be noted that this crushed glass is not effective to conserve the resource materials, because it will be necessary more raw materials to make new glass bottles. Polley et al (1998) emphasize that the primary concern about the use of such glass is that the silica present in the glass reacts with the alkalis contained in the cement paste. This alkali-silica reaction expands the concrete and it can cause structure deterioration. The studies carried out show that after a 730 days period the glass content aggregates can expand 10 times higher than the maximum acceptable requirement. Tawfiky Eskander (2006) investigated the effects of crushed PET bottles and marble wastes in GRP (Glass Reinforced Plastics) with the aim to salve costs more than environmental concerns. The work made by Ghaly y Gill (2004) utilizes plastics in coarse aggregates for concrete. The results show that the compressive strength is 29% lower for a 15% replacement of natural coarse aggregate respect the concrete made of natural aggregates only.

The ideas are interesting from a point of view, because industrial waste can be reduced. Another good point of these applications in new concretes is the smaller amount of natural aggregates require as well as the transport of then, since the aggregate extraction occur far from urban centres. However, all of these applications do not reach the closed-loop. On the contrary, the materials cycle still opens because cement will be produced continuously in large quantities, as well as the extraction of raw material for other industries.

5. Methods of recycling used concrete

Construction and demolition wastes are formed by a various types of materials, such as masonry, concrete, wood and plastics that should be sorted to keep the rubble as more uniform as possible and according to the standards. The sorting methods of such wastes can be made manually or automatic, in recycling plant facilities or in mobile plants.

In the recycling plant facilities the construction and demolition wastes can be reclaimed from building site and sorted by dimensions, density, magnetic and material type. In manual sorting there is a group of workers which collects and sorting the materials in distinct containers. On the other hand, mechanical sorting can be made by water or air jets. In manual separation, the materials are transported to a finger screener which classifies the input materials by size; fine, medium and large. After this, fine materials are conducted to sorting stations where people select the materials and direct then to specific containers. Magnetic belts put on conveyor belts collect objects that contain iron and deposit then in specific containers. In the sequence, wastes are transported by conveyors and workers separate materials such as wood, non ferrous metals, cardboard, among others. It can be noted that this process creates a high amount of dust, mainly in the finger screen. Workers must use masks to avoid dust inhalation and earplugs due to high noise levels emitted by conveyor and materials movement. As a result of high amount of dust and to provide higher productivity it can be use a sorting station partially or totally automated. Basically there are two automatic methods to sorting the heavier particles to the lighter particles using water or air jets. The method with water separates wastes when water entries and fills partially a container. The container starts to turn, the lightweight materials float and the heavy materials sink. The materials are then separated and can be sorted again or be deposited in a specific local.

One alternative to recycle construction and demolition wastes is doing it on the building site with a mobile plant. The advantage more evident with this equipment is salve CO_2 emissions with the transport of such wastes to the recycling plant facility. CO_2 emissions are related only to the mobile crusher plant. Wastes that are not suitable to be transformed into aggregates are sent to a recycling plant facility. Mobile plants are mainly used in large buildings, because the large amount of wastes makes possible move a mobile plant to the building site. Other advantage is that mobile plants cost less than a recycling plant facility and there is the possibility to transport then easily which depends on demand. The crushers must be compact to permit easy transport by conventional trucks. Construction and demolition wastes are deposit in the crusher feeder and under the feeder there is a screener which takes the smaller particles without the necessity to crush them. The larger particles are crushed and pass through conveyor belts where exists a permanent magnetic belt which reclaims particles that contains iron from the others. The disadvantage of this machine is the elevated wear in comparison with recycling plant facilities, because crusher grinds many materials and this can damage the machine.

Aggregates produced by ready-mixed concrete plants and transported by concrete trucks can be recycled too. The percentage of concrete which remains in concrete trucks is approximately 3%. The principle is basically simple and separates fine and coarse aggregates from cement paste. Concrete trucks deposit fresh concrete in hoppers on the ready-mixed concrete plants and concrete is washed. A screener inside the hopper together with water separates the aggregates from cement paste. Particles larger than 0,2mm are sorted and transported by a screw conveyor. Aggregates can be transported to a deposit or accumulated in containers. The smaller particles and water are conducted to a container which maintains the particles in suspension for use this water on future mixes. Another function of water deposits is utilizing it to wash the concrete trucks with posterior dump in the hoppers. Aggregates are used in future mixes too. The precast industry has equipments to recycle fine and coarse aggregates as well as the water used in the concrete mixes. The sorting operation is basically the same of that encountered in ready-mixed concrete plants. However, there is a difference in the water cleaning. The idea is that grew water be treated to be used in the concrete production.

6. Final considerations

From the previously exposed it can be observed that the only renewable part of recycled aggregates is the urban deposit, that is, old buildings that can be demolished. Many types of the equipments produced for this industry use fossil fuels and most of the electricity is generated by non-renewable energy resources. Furthermore, it is used more energy to transform the construction and demolition wastes into aggregates than to transform natural stone in aggregate. The recycled aggregate production is very little in comparison to aggregate demand. Currently, it is very difficult the total replacement of natural aggregates by recycled aggregates, due to the differences in recycled aggregate characteristics and standards restriction.

The high costs of equipments many times are not a good alternative, because the demand can be limited. Furthermore, the type of equipment will take into account if it is a recycling plant facility or a mobile plant. The quality of recycled aggregates can vary a lot, depending on the type of the old concrete and the impurities presented in the rubble. Other issue is the high amount of steel and energy required to manufacturing equipments used in this industry. This leads to iron ore extraction and the production of large amounts of wastes from the steel industry.

Many investigations have been made to produce new concrete mixes from old concretes. Glass, tires and other materials were used to replace the natural aggregates. However, the results reached until now can demonstrate that concrete made with recycled aggregates is not sustainable. In fact, it can be said that these initiatives reduce the environmental impact because less amounts of natural aggregates are extracted. On the other hand, many virgin materials are continuously extracted form the earth's crust to produce cement in large quantities. Despite a change in the type of energy used for the cement calcination, which consumes almost 50% of the total concrete life-cycle energy, it still contaminates atmosphere with carbon dioxide. Not even studies about concrete carbonation can bring an effective solution of CO_2 absorption by the demolished concrete. This is due to the consumption of fossil fuels of demolished equipment, crushers and transport of concrete which releases a lot of the CO_2 in the atmosphere. The diversity and the mixes of such wastes made in the recycling plants difficult the implementation of recycled aggregates and concretes produced with these aggregates are used in lower performance concretes respect to concretes made with natural aggregates. In conclusion, there are many issues that must be solved until concrete becomes a real sustainable material.

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Life Cycle Assessment of Building Materials Used at External Wall Systems

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Abstract

Due to lack of information about environmental regulations, assessment tools and methods, environmental impacts of external wall systems and their components are mostly neglected during the design process by architects and other construction professionals in Turkey. Presently, a Master of Science thesis is conducted to develop several sustainable external wall system design alternatives according to performance approach by considering environmental performance of related components, which have particularly proved to be efficient. The aim of this paper is to present environmental performance of external wall system components, which consist of core, waterproofing, thermal insulation and cladding materials. Life cycle assessment (LCA) was used as a method to assess the environmental performance of the components. Initially, survey system of Environmental Resource Guide, which is designed by American Institute of Architects in a framework of LCA, was reorganized in a simplistic format. The survey consisted of three parts, one of which was the definition of aim and scope of the study, where research boundaries were set by particular materials and geographical positions, and the other was inventory analysis where data was collected for observing environmental footprints from cradle to grave. The final part included the impact assessment, where collected data was evaluated by different impact categories. According to LCA survey, building materials are compared between same functional component groups in regard to related impact category, such as environment and ecosystem effects, human health and welfare effects, energy effects and building operation factors. Life cycle assessment survey has guided to evaluate environmental performance of external wall system components manufactured in Marmara Region of Turkey. Subsequent to the preparation of the survey, external wall system component manufacturers in the Marmara Region of Turkey were compiled and sorted in a list. Thereafter, surveys were filled out by visiting manufacturing facilities, where controlled interview was conducted with facility managers in response to enquiry. Consequently, environmental performance of related components was assessed to present their environmental impacts. Reliability of survey data could not be validated depending on unverified vague replies of manufacturers.

Keywords: Life cycle assessment, sustainability, environmental performance, external wall systems, building materials

1. Introduction

After Industrial Revolution, beyond any doubt to say that, easy, fast, durable and highrise construction techniques were developed as a new concept for modern construction (King 2009). However, challenge for climate change has been showing that, environmental impacts of modern buildings with conventional materials are ignored or underestimated by architects and building professionals. Therefore, for last decade's, new sustainable design solutions such as, environmental building codes, assessment systems, tools and methods have been developing globally and locally to evaluate and improve environmental performance of buildings, building element systems and building materials. LCA method is one of the most commonly accepted methods that evaluate materials environmental impacts throughout their life cycles.

In Turkey, environmental performance of building element systems and building materials is an emerging challenge. In history of Turkish architecture, traditional materials, such as adobe, wood and stone were commonly preferred and used at external wall systems. Besides in contemporary architecture, some designers are encouraged to use of local materials with environmental design principles. As a case for this, Aga Khan Award winning B2 House is one of the contemporary sustainable design projects, in design of which, some parts of external wall systems were constructed with local materials and construction techniques.

In despite of good efforts on sustainable building element systems, environmental impacts of these systems and their components cannot be assessed reliably, as building materials can only be monitored by guidance of sustainability rating and labelling systems, tools or standards and there is no certification system and tool in Turkey. Additionally, manufacturers have environmentally standards, such as ISO 14001 Environmental Management Systems Standard, which determines only the environmental impacts of their facilities. However, ISO 14040 Environmental Management- LCA is necessary for reliable assessment of the environmental performance of building materials. Due to lack of information about environmental regulations, assessment tools and methods, environmental impacts of external wall systems and their components are mostly neglected or underestimated during the design process by architects and other construction professionals in Turkey.

Presently, a Master of Science thesis is conducted to develop several sustainable external wall system design alternatives based on performance approach by considering environmental performance of related components, which have particularly proved to be efficient. Along with the other performance criteria, such as, structural, waterproofing, thermal performances environmental performance of the materials is necessary to design sustainable external wall systems.

The aim of this paper is to present environmental performance of external wall system components, which consist of core, waterproofing, thermal insulation and cladding materials. In terms of environmental performance, energy and material inputs from environment and material outputs to the environment are determined as building materials environmental footprints, which are evaluated to put forward their environmental benefits and handicaps.

Life cycle assessment (LCA) was used as a method to assess the environmental performance of the components. Life cycle assessment survey has guided to evaluate environmental performance of external wall system components manufactured in Marmara Region of Turkey. Subsequent to the preparation of the survey, manufacturers of building materials used at external wall systems in the Marmara Region of Turkey were compiled and sorted in a list. Thereafter, surveys were filled out by visiting manufacturing facilities, where controlled interview was made with facility managers in response to enquiry. Results of the survey were interpreted next to show present situation about the environmental performance of building materials used at external wall systems.

2. Life cycle assessment survey

2.1 Structure of the survey

LCA survey was configured on LCA method, which is compiles and evaluates the environmental performance of the building materials throughout its life cycle in terms of raw material acquisition, manufacturing, transportation, and use, maintenance, and disposal stages (ASTM 2005). Designed survey system was advanced by LCA survey on Environmental Resource Guide (ERG), which was designed by American Institute of Architects. In the survey of ERG, ISO 14040 standard requirements from cradle to grave were underlined well in a simplistic format.

In this study Turkish format of the ERG survey was redrawn with more compacted design. To avoid negative reactions about the timing of the surveying process, layout of the survey was compacted. Thus, the Turkish format has fewer pages than original copy in ERG.

The survey consists of three stages, which are goal definition and scoping, inventory analysis and impact assessment, respectively. Initially, problems at the past and forecasts for present and future works are guided to define goals for the development of the study. Subsequently, scope of the study is defined, where research boundaries were set by particular materials, geographical positions, local access opportunities to facilities and occupational positions of participant people in the facilities. The scope of the study is important to lessen difficulties of implementation.

In the next step of the survey, environmental footprints of the building materials are defined from cradle to grave by inventory analysis. Inventory analysis gives quantitative information about; (i) energy and material inputs and outputs for all life cycle stages, (ii) effects of building materials on building operation energy and (iii) building materials' afterlife potentials, such as reusability, recyclability and disposal options.

At the last step of the survey, building materials are graded by manufacturers. This part of the survey is called impact assessment, which shows the entire result of survey by graduation of different impact categories for all related life cycle stages. Impact categories are defined as ecological and environmental effects, human health and welfare effects, energy effects and building operation factors.

2.2 Goal and scope

Acquiring from earth, manufacturing, and installation, using and disposing of the building materials without thinking of their environmental impacts comprises the main problem of this LCA survey. While environmentally design actions are getting more necessary in a climate of change, it is also necessarily required to monitor life cycle of building materials to show how they act mutually with their environment. Furthermore, there is lack of knowledge about the definition of “environmentally friendly” products, which are not declared transparently in terms of their environmental performance. Therefore architects and building professionals cannot compare and choose sustainable building materials with reliable and sufficient data. Therefore, this survey is aimed to get aware not only architects, but also building material manufacturers about environmental performance of building materials used at external wall systems. Moreover, it is aimed to prompt and guide manufacturers to improve environmental performance of their products. Thus, architects and building professionals can design and build sustainable external wall systems with sustainable materials.

Scope of the LCA survey was limited with local manufacturers in Marmara Region of the Turkey. Besides, the survey was completed only for core, waterproofing, thermal insulation and cladding materials. Fixing materials that are used at installation and intermediate products that are not manufactured in the same facility with final products were excluded from the scope. External wall systems in Istanbul were selected as case studies for measuring transportation energy data for installation stage.

After defining the goals and scopes, building materials, that are manufactured in Marmara Region of Turkey such as, core, waterproofing, thermal insulation and cladding materials were sorted and listed separately. Following to the list of thirty three different types of building materials, the manufacturers of related materials in the Marmara Region of Turkey were determined. Eventually, appointments were made with production managers of regional manufacturers. Sixteen of the manufacturers accepted to fill out the survey. In conclusion, two core materials, three waterproofing materials, one thermal insulation material, and ten cladding materials were assessed according to LCA survey.

2.3 Inventory analysis

Inventory analysis data were gathered by manufacturers. Table 1, 2, 3 and 4 show lists of materials and manufacturers for each component group. Manufacturers have either accepted or refused to attend the survey, where bold font letters represent positive and grey colour font letters represent negative responses. Missing data about the manufacturing process of inventory analysis can also be observed in the given tables. Missing data were abbreviated in capital letters such as “R” for raw material acquisition, “E” for embodied energy and “N” for natural resource depletion. Manufacturing of some materials is not processing in Marmara Region. Therefore, manufacturers for related materials were shown as “N/A” in given tables.

2.3.1 Results for core materials

As a result of the study, six different types of core materials and nine manufacturers were determined in the Marmara Region of Turkey (Table 1). C7 and C8 are manufactured out of region. Therefore, they couldn't covered by the scope of the study. The survey was completed only by two manufacturers of two core materials.

Table 1: List of core materials and inventory analysis results

Codes	*Core materials*	*Manufacturers*	*Missing data*
C1	***Horizontal perforated clay bricks***	***A***	
C2	***Autoclaved aerated concrete (AAC)***	B_1, B_2	***E / N***
C3	*Concrete masonry unit (CMU)*	*C*	
C4	*AAC panel wall*	B_1	
C5	*Cement based panel wall*	E_1, E_2, *C*	
C6	*Light gauge steel frame*	D_1, D_2, D_3	
C7	*Wood frame*	*N/A*	
C8	*Pumice block*	*N/A*	

Table 1 indicates that, inventory information was completely achieved for **C1** only. On the contrary, energy consumed by raw material acquisition is not known for **C2**; thereby embodied energy data is missed. Additionally, manufacturer of **C2** didn't provide any information regarding the types and amounts of depleted natural resources.

2.3.2 Results for waterproofing materials

Among seven types of waterproofing materials and seventeen manufacturers listed on Table 2, appointments could only be made with three manufacturers of three waterproofing materials.

Table 2: List of waterproofing materials and inventory analysis results

Codes	*Waterproofing materials*	*Manufacturers*	*Missing data*
W1	***APP modified bituminous membrane***	F_1, F_2, F_3, F_4, F_5	***R / N***
W2	***Polysulfide based liquid***	G_1, G_2, G_3, G_4	***R / E / N***
W3	***Solvent based silicon reinforced liquid***	H_1, G_1, G_2	***E / N***
W4	*Solvent based bituminous liquid*	I_1, I_2, I_3, F_3	
W5	*Polymer reinforced bituminous membrane*	*J*	
W6	*High density polypropylene membrane (HDPP)*	K_1,K_2, K_3	
W7	*Oxidized bituminous membrane*	*N/A*	

Table 2 shows that, quantity of raw material is not provided by manufacturers for the survey of **W1** and **W2**. Besides, raw materials used by **W2** and **W3** are imported from abroad. Liquid waterproofing materials have only mixing process, while manufacturing in local facilities. Thus, energy consumed by raw material acquisition and preparation couldn't be obtained by manufacturers of **W2** and **W3**. Additionally, information about quantities of natural resource depletions was not supplied by all participant manufacturers.

2.3.3 Results for thermal insulation materials

Table 3 shows that, among the all types of material manufacturers in Marmara Region of Turkey, thermal insulation material manufacturers provided the least information. Only six manufacturers were determined for five thermal insulation materials. Only one manufacturer participated to the survey. Therefore, EPS is the only material that represents thermal insulation materials.

Table 3: List of thermal insulation materials and inventory analysis results

Codes	***Thermal insulation materials***	***Manufacturers***	***Missing data***
T1	***Expanded polystyrene (EPS)***	***L***, M_3	***R / E / N***
T2	*Extruded polystyrene (XPS)*	M_1, M_2, M_3, F_5	
T3	*Glass wool*	M_1	
T4	*Mineral wool*	M_1	
T5	*Polyurethane foam*	*N*	

According to results of Table 3, **T1** has deficient information for its further evaluations on survey. For instance, amount of raw materials, amount of natural resources and type of natural resources used in a unit of product were not informed by the manufacturer of **T1**.

Due to lack of technological potential of chemical industry in Turkey, raw materials for stren based thermal insulation, such as EPS imported from abroad. Manufacturer of **T1** does not know well about environmental impacts of processes for acquiring and preparing the raw materials. Therefore, they cannot provide information about embodied energy of **T1**. In order to solve this problem in another way, LCA survey was sent to foreign supplier to gather more information; however they refused to fill out the survey.

2.3.4 Results of cladding materials

According to list of cladding materials used on external wall systems in Istanbul, thirteen different types of cladding materials and fifteen regional manufacturers were determined. At the end of the study, nine manufacturers for ten cladding materials were accepted to join to survey.

Table 4: List of cladding materials and inventory analysis results

Codes	*Cladding materials*	*Manufacturers*	*Missing data*
L1	***Metal sheet***	***O***	***R / E / N***
L2	***Glass reinforced plastic sheet***	***L***, F_5	***E / N***
L3	***Paper reinforced bituminous sheet***	F_3	***R / E / N***
L4	***Glass reinforced cement facing***	P_1, P_2	***E / N***
L5	***Cellulose reinforced cement facing***	***R***	***E / N***
L6	***Clinker facing***	***S***	***E***
L7	***Mineral wool insulated metal laminated composite board***	***T***	***R / E / N***
L8	***Polyurethane insulated metal laminated composite board***	***O***	***R / E / N***
L9	***Acrylic based outdoor paint***	G_3	***E / N***
L10	***Calcite adulterated cement based powdered plaster***	G_3	***E / N***
L11	*Expanded polystyrene reinforced outdoor paint*	*U*	
L12	*Natural stone facing*	V_1, V_2	
L13	*Wood and composite wood facings*	W_1, W_2	

The amounts of raw materials used to produce final products are not defined by manufacturers of **L1, L3, L7** and **L8**. All participated cladding material manufacturers have one or more imported raw or intermediate materials in their manufacturing process. Due to lack of knowledge and know-how confidential procedures, manufacturers couldn't provide any data for any of all cladding materials about acquiring and manufacturing energy of raw and intermediate materials to calculate embodied energies. Besides, except for **L6** all other cladding material manufacturers imported their raw materials from other facilities. Therefore, they couldn't give any information about what kind and how much natural resources depleted when the raw materials were acquired.

2.4 Impact assessment

Impact assessment has a graduation system for materials. Based on this system, environmental performance of the materials are defined on a chart with a cell matrix by grades from one to four, where one stands for poorest and four stands for best environmental performance (Figure 1-4). The materials, which weren't assessed by LCA survey didn't have part on impact assessment chart.

Each life cycle stage has different environmental problems. Precaution of the environmental impacts based on some specific emission of different life cycle stages may require prior action than others. Therefore, weighting factors, which determines the matter of priority for environmental burdens, are required to achieve most reliable final grades. Such LCA tools as, LCAiT, PEMS, SimaPRO, and TEAM are assessing the impacts of different environmental burdens, which are calculated depending on their own weighting factors (Menke, Davis & Vigon 1996). Weighting factors are depending on local economical, social and environmental conditions. According to conditions of each nation, national environmental agencies have to decide for parameters and methodologies of their calculations (Demkin 1998). In this paper, due to lack of national parameters about environmental priority of emissions and their life cycle stages, weighting factors couldn’t be integrated to calculation. Hence, they are not considered on impact assessment chart. Thus, the environmental performance of the materials concluded without final grade.

Some impact categories were assessed for one or more life cycle stage. For instance, ecological and environmental effects are considered for all life cycle stages, where building operations is not.

	Impacts \ Codes	C1	C2	W1	W2	W3	T	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10
Ecological/ environmental effects	Air quality/ atmospheric impacts	4	4	3				4		3		4	**1**	4	**1**		
	Water quality/ availability	4	4	4				**2**		4		4					
	Land and soil quality/ availability	4	3	4				4		4		4	**2**	3	4		
	Virgin resource depletion	**1**	**1**	**1**				**2**		**1**		**2**	**2**	**2**	**2**		
	Biodiversity/ habitat loss	4	3	**2**				4		**2**		4		4	**2**		
Human health/ welfare	Worker/ installer health	3	3	3						3		3	**2**				
	Building occupant health																
	Community health and welfare	4	4	3				4		3		4		4	4		
Energy effects	Production/ manufacturing energy	4	**2**	3				**1**		**2**		4	**1**	**1**	**1**		
	Transportation energy	4	4	4				4		4		3	3	4	4		
	Impact on operation energy use																
Building operation factors	Life expectancy/ durability																
	Maintenance requirements																
	Reusability/ recyclability																

Figure 1: Impact assessment chart for materials acquisition and preparation stage

Some materials presents poor performance on material acquisition and preparation stage, such as core materials, which were graded by one, according to their great diverse impacts on virgin resource depletion. Besides, **W1** is graded by two for its impact on biodiversity and habitat loss, which means that, its impact is unstable. That could be even less or more.

Graduation by three means intermediate performance, which also means that that material has some stable impacts not necessarily to be cared for short period. For instance workers health is affected by some hazardous wastes for **C1**, which is accepted by health regulations. However, that wastes have to be neutralized for better health conditions.

When materials were graduated by four, they must have good or excellent performance. For instance, raw material resources of **L8** are transported in very short distance between their facilities for acquiring process.

Some materials such as waterproofing liquids, thermal insulation material and some of claddings have imported raw and intermediate materials. Final products manufacturers of related materials don’t have sufficient information to assess impacts of their products, while their acquired from earth and prepared to be manufactured.

Impacts	Codes	C1	C2	W1	W2	W3	T	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10
Ecological/ environmental effects	Air quality/ atmospheric impacts	4	4	3	4	4	4	4	3	4	4	4	**2**	4	3	4	4
	Water quality/ availability	4	4	4	4	4	4	4	4	4	4	4	**2**	4	4	4	4
	Land and soil quality/ availability	4	4	4	4	4	4	4	**2**	4	4	4		4	4	4	4
	Virgin resource depletion	**1**	**1**	**2**	4	4	3	4	**2**	**2**	3	3	**2**	4	4	4	4
	Biodiversity/ habitat loss	4	3	4	4	4	4	4	4	4	4	4		4	4	4	4
Human health/ welfare	Worker/ installer health	3	3	**1**	4	4	4	4	3	**1**	3	4	**1**	4	4	4	4
	Building occupant health																
	Community health and welfare	4	4	4	4	4	4	4	4	4	4	4		4	4	4	4
Energy effects	Production/ manufacturing energy	4	4	3	4	4	4	4	3	3	4	3	3	4	4	4	4
	Transportation energy	4	4	3	**2**	3	**1**	4	3	4	3	4	**1**	3	4	4	4
	Impact on operation energy use																
Building operation factors	Life expectancy/ durability																
	Maintenance requirements																
	Reusability/ recyclability																

Figure 2: Impact assessment chart for manufacture

Impact assessment for the manufacturing of materials is almost completed for all materials except for **L6** which has some missing data. The most significant diverse impacts of this stage are shown for virgin resource depletion, because manufacturing energy for some materials are even high and also gathered by non-renewable energy sources. On the contrary, all materials have low manufacturing energy, which were graded well in assessment chart.

Impacts	Codes	C1	C2	W1	W2	W3	T	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10
Ecological/ environmental effects	Air quality/ atmospheric impacts	4	4	4	4	4	4	4	4	4	4	4		4	4	4	4
	Water quality/ availability	4	4	4	4	4	4	4	4	4	4	4		4	4	4	4
	Land and soil quality/ availability	4	4	4	4	4	4	4	4	4	4	4		4	4	4	4
	Virgin resource depletion																
	Biodiversity/ habitat loss																
Human health/ welfare	Worker/ installer health	3	3	4	4	4	4	4	4	4	3	3		3	3	4	4
	Building occupant health	4	4	4	4	4	4	4	4	4	4	4		4	4	4	4
	Community health and welfare																
Energy effects	Production/ manufacturing energy	4	4	4	4	4	4	4	4	4	4	4	3	4	4	4	4
	Transportation energy	4	4	4	4	4	4	4	4	4	3	3		4	4	4	4
	Impact on operation energy use	**2**	4	**1**	**1**	**1**	4	**1**	**2**	**1**	**1**	**2**		3	3	**1**	**1**
Building operation factors	Life expectancy/ durability	4	4	3	4	3	4	4	4	3	3	4	4	4	4	3	3
	Maintenance requirements	4	4	4	4	4	4	4	4	4	4	4	**1**	4	4	4	4
	Reusability/ recyclability																

Figure 3: Impact assessment chart for installation, use and maintenance

Impact assessment of installation, use and maintenance stages were presented in one chart, where use stage has more specific categories under building operation factors. As a result of Figure 3, impacts on operation energy use are mostly poor when considering the impacts for other categories, because claddings and especially waterproofing materials didn’t produced to reduce thermal conduction at external wall systems.

Impacts	Codes	C1	C2	W1	W2	W3	T	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10
Ecological/ environmental effects	Air quality/ atmospheric impacts	4	4	3	4	4	3	4	**2**	3	4	4	**1**	4	4	4	4
	Water quality/ availability	4	4	3	3	4	4	4	4	3	4	4		4	4	4	4
	Land and soil quality/ availability	4	4	4	4	4	4	4	4	4	4	4		4	4	4	4
	Virgin resource depletion																
	Biodiversity/ habitat loss																
Human health/ welfare	Worker/ installer health	4	4	4	4	4	4	4	4	4	4	4		4	4	4	4
	Building occupant health	4	4	4	4	4	4	4	4	4	4	4		4	4	4	4
	Community health and welfare	4	4	4	3	3	3	4	3	4	4	4		4	3	3	4
Energy effects	Production/ manufacturing energy	**2**	**2**	4	3	3	4	4	3	3	3	3		3	3	3	3
	Transportation energy	4	4	4	4	4	4	4	4	4	3	3		4	4	4	4
	Impact on operation energy use																
Building operation factors	Life expectancy/ durability																
	Maintenance requirements																
	Reusability/ recyclability	**1**	**1**	**1**	**1**	**1**	**1**	4	3	**1**	3	3	4	3	3	**2**	**1**

Figure 4: Impact assessment chart for reuse, recycling and disposal

Reusing and recycling of building materials used at external wall systems are the most significant impact category for the last stage of life cycle. According to reports of manufacturers, despite having potential of reuse and recycling, most part of the materials is used for land filling when they are disposed. Therefore, they show poor performance as can be observed at Figure 4. Furthermore, the process of incineration of the non recycled materials was not defined by manufacturers.

3. Interpretation

While the answers in the survey were gathered from production managers, at the last part of the study, interpretation of the survey was made by the authors. At the interpretation of the survey, building materials were compared with each other in the same functional component groups, which are core, waterproofing, thermal insulation and cladding materials.

Assessment of the environmental performance of building materials was done by commentaries. Literature readings were used to compensate for the lack of expert review. As a result of inventory analysis, most contacts were established with the manufacturers of waterproofing materials. However, only three of them accepted to fill out to survey. This suggests that the remaining manufacturers do not have sufficient information regarding the environmental performance of their productions. One group of components, such as thermal insulation material has only one assessed specimen. Results of this material are required to present its drawbacks, which are necessary for its manufacturer to improve environmental performance of their material. However, without any other specimens, while designing sustainable external wall system alternatives; there will be no alternative to compare and choose for thermal insulation material with least environmental performance.

Transportation distance for acquiring raw materials to manufacturing and production facilities and also supplying products to building sites is important parameter for evaluation of materials' environmental impacts. While some of the materials have short transportation distances during their life cycles, others are transported inter continentally by ships. Thus, the energy consumed by their transportation has negatively affected their environmental performance.

As a result of survey, it can also be interpreted that, Turkey has a low recycling and reusing potential for most of the assessed materials. Lack of technical opportunities is one of the reasons, which the other is inefficient executions to conduct the processes.

Missing data of related surveys affect adversely to the comparison of materials. Without holistic assessment, comparison between building materials cannot be carried out to specify their environmental performance during the design period of external wall systems. A holistic environmental assessment is not only required for architectural design process, but also necessary for the environmental building codes to evaluate environmental performance of building element systems such as external wall system, when integrating their environmental performance to whole building performance. Additionally, parameters about the prior impacts of wastes on environment have to be defined by national organizations to draw most reliable conclusions for the impact assessment.

All materials have both environmental benefits and drawbacks, such as metal sheet coating preferred for its recyclability potential; however it requires too much energy to be embodied while acquiring from earth and prepared for manufacturing. When benefits and drawbacks for all materials are defined well, architects can compare the environmental performance of materials according to environmental requirements of external wall systems. After, they can choose most appropriate ones for their designs. For example, metal sheet coatings are preferred to acrylic based outdoor paints, when recyclability potentials are more important for design requirements.

4. Conclusion

LCA is a key tool to present environmental performance of building materials from cradle to grave. In this study, environmental impacts of building materials used at external wall systems were assessed by LCA method to show current possibilities to design sustainable external wall systems with sustainable materials and also the awareness of manufacturers in Marmara Region of Turkey about environmental performance of their materials. In Turkey, in order to develop LCA to achieve more reliable results by more manufacturers, it is important to modify regulations for implementation of environmental assessment tools. Additionally, well developed interdisciplinary audit commission is required to develop national parameters for the methodology of LCA. Therefore, architects and other building professionals may choose more environmentally friendly building materials for their external wall system designs.

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Built Environment: The Sustainability of Heritage

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Abstract

Different sustainable evaluation tools can provide a way to certify the building`s performance during its life cycle: raw material depletion, production of materials and components, construction, use and demolition. In this process, several variables that analyze common components, such as the reduction of resources consume, the reuse and recycle potential, flexibility and adaptability, the pollution components generated during the process, are involved. Some examples of these tools are the systems like SBTool, BREEAM, BEE or LiderA that are used to evaluate a specific context according to specific conditions. Meanwhile, the existing evaluation systems are oriented to the building´s design phase or have under consideration patterns adapted to the 21st century reality. This work was developed due to the need to analyse and evaluate the built environment, specifically in what concerns the urban settlements in Portuguese cities, with more than three hundred years old, and that are not enclosed in the new construction's reality - both at materials and techniques levels. The knowledge gathered about the built environment allows the creation of a sustainable grid capable of guide-lining rehabilitation actions. The evaluation of these urban areas was carried out based on an exhaustive work of collecting the building's characteristics, in an area with around 770 buildings, allowing the creation of a built environment sustainability evaluation grid and adapted to socio, cultural, heritage, economic and environmental contexts. The grid mentioned before was designed after a set of parameters were analyzed, such as: i) the existent materials and the constructive solutions adopted; ii) the urban mesh and the meeting of the construction resources to the built environment; iii) the contemporaneous patterns and the possibilities of reusing; iv) the heritage and cultural values; v) the social and economic values. The evaluation grid presented in this work shows a set of different parameters, where the criteria that are related to the external environment are reassessed according to the existent urban possibilities and where the criteria related to internal environment are adapted to the existent spaces' possibilities.

Keywords: sustainable construction, evaluation systems, historical city centres, sustainable criteria

1. Introduction

1.1 Urban constraints

Urban growth consists in the main constraint of the issues related to sustainable development. The growth rhythm of several urban agglomerations, where a great and sudden increase of the inhabitant's number has occurred, without the proper improvement of the urban structures with capacity to support these changes, has led to the existence of ghettos located within the urban periphery. The impact of the sustainable development has been subject of several levels of intervention: global, regional and local ones, from the city to housing buildings. This intervention must be carefully planned, not only in terms of new buildings and urban space, but mainly to be renewed and invigorated in order to promote less use of resources and less production of waste.

The sustainable urban renewal consists in a way of recycling some city areas, sometimes with historical characteristics, disconnected in relation to existing social, economic and political needs. This renewal must always have in mind the features of the current built environment and the load that it represents in the environment, namely the issues associated with energetic waste (United Nations, 1992; Rogers and Gumuchdjian, 2001).

1.2 Urban rehabilitation

The urban rehabilitation is characterized of a complex intervention because it acts upon an existing structure with specific cultural and social characters that are usually consolidated. In historical zones these factors are amplified, for the resident population or for the cultural and architectural values of the sites. The city, attending to its urban image, tells its own history and these areas are its beginning (Wolf, 1974).

The intervention must be worked out based on the resident population and all the social impact that it will produce. This work is not based on sociological issues, but is unmistakable in its preponderant role as a factor of social integration and equality to access opportunities as it is praised in the United Nations Agenda 21 (1992), in its Rio Conference.

The main goal towards sustainability is the definition of strategies for buildings rehabilitation in consolidated historical zones, considering its impact in the environment and never as an isolated element. In these areas, the rehabilitation has become all the complex due: i) the characteristics of the structure and the impossibility of change, ii) the requirements of the building and its unsuitability to modern standards of habitability and comfort iii) the cultural importance of these areas that take a leading role the image and memory urban iv) the complex cultural and social. Faced with these constraints is important to rethink these areas in order to reintegrate them into the city, promoting their self-support through policies that boosting economic activity and renew social relations.

2. Sustainable evaluation systems

2.1 Systems approach

In this work we have analyzed different systems of sustainability, including some implemented as formal tools that support designers and decision-makers in the management of the construction. These systems address the most important issues of sustainability in buildings, with different organizations, and are focused on four key issues (Graham, 2003):

- Resource management - consumption compatible with the natural replacement capacities by minimizing consumption, maximizing the use of renewable and recyclable resources and efficient use of resources (to do more with less);

- Create systems which maximize the consumption in terms of the energy / quality binomial - use of solar resources, efficient distribution of energy and minimization of waste;

- Production of materials which results in nutrients or raw materials for the production of resources - reduction / elimination of pollutants, use of biodegradable materials and reuse of components and systems of the construction;

- Improve the adaptability and functional and biological diversity - conscious analysis of the life cycle, allow access to easily recyclable materials without destruction of the materials difficult to recycle, protect and improve biodiversity.

According to Kibert (2003), the design process is very similar to the management of an adaptive ecosystem: they both need to learn from past experiences and anticipate the future, knowing that the world cannot be fully understood. In this sense, the implementation of sustainable solutions involves the perception of the life cycle of buildings and hence the various phases that the building must meet, each one with specific levels of requirements and targets. This complexity of factors, similar to an ecosystem, results from the interaction between the building and the environment.

Table 1, adapted from Graham (2003) and Newman & Jennings (2008), presents some overall strategies for sustainable communities and shows the extent of sustainability.

Starting from this overall assessment, is possible to understand the approaches outlined in the considered assessment systems, including the SBTool developed by the International Initiative for a Sustainable Environment (iiSBE), the system developed by the Building Research Establishment (BRE) entitled as BRE Environmental Assessment Method (BREEAM), the Leadership in Energy and Environmental Design (LEED), under the responsibility of the United States Green Building Council - USGBC (USGBC, 2008; Yudelson, 2008), and LiderA - Sustainability Assessment System, developed by professor Manuel Duarte Pinho (Instituto Superior Técnico, Lisbon Technical University). These systems have different approaches and different degrees of coverage: the SBTool is a system that seeks a global scope, participating in its development several teams from various countries (Cole and Larsson, 2002); the BREEAM is a system developed for use in the United Kingdom with the possibility of application in other countries through the International version of BREEAM (BRE, 2006, BRE, 2006a); LEED is a system designed in the United States of America and has several variants which allow the assessment of different situations (USGBC, 2008a); the LíderA is a portuguese system that is being applied increasingly in the country.

Table 1: Strategies for sustainable communities

Feature	***Strategy***
Health	*Characteristics of atmospheric environment; renewable energy use; environmental monitoring; local needs; preservation of ecosystems; food production system with embedded strategies (sustainable ecosystems); low fuel consumption and waste production.*
Self-regulation	*Communities located in order to allow its self-regulation through a closed loop; population under local capacity.*
Permeability and renewal	*Adaptive learning; democratic structures; small communities with streamlined institutional structures; control of environmental impact.*
Flexibility	*Democratic; decentralized communities.*
Ethics	*Respect for land use and people, sustained by the emotional connection to the site through a continuous interdependence.*
Mobility	*Access, public transport, alternative transport.*
Psychology	*Historical and cultural value of the built environment; history, rituals and interaction with the place.*

The SBTool and LiderA systems present a comprehensive framework that allows its application to various types of buildings. The LEED system includes tools specifically adapted to buildings with different occupations and in accordance with the phase of its life cycle (design, construction, use). The BREEAM system presents a larger number of specific assessment tools covering buildings with different occupations and urban areas and provides analysis during various stages of their life cycle (design, construction, renovation / expansion).

2.2 Common approaches

Starting from the work developed in the previous paragraphs was possible to establish a common matrix to allow comparability between the various systems. This comparative analysis was possible by defining key areas of performance, defined from the existence of common criteria and / or assessment or analysis methodologies similar or equivalent. These key areas are based on the analysis of the Local Sustainability, Transportation, Resources Management – Water, Resources Management - Energy, Resources Management - Materials, Exterior Environment - Emissions, Interior Environment, and finally, the Use Sustainability - Control, Flexibility and Suitability.

This common structure led to the need to reorder the criteria of each system within these areas, which were organized in different structures and in similar topics or classifiable those defined for the matrix. Table 2 presents the original structure of the systems.

Table 2: Comparative table between the systems

SBTool	*BREAM (Ecohomes)*	*BREEAM (Ecohomes XB)*	*LEED (New Buildings)*	*LEED (for existing buildings)*	*LiderA*
Location, design and development	*Energy*	*Energy*	*Local Sustainability*	*Local Sustainability*	*Local*
Location	*Transport*	*Transport*	*Construction activity and pollution*	*Efficient water mamagement*	*Land*
Design	*Pollution*	*Pollution*	*Efficient water mamagement*	*Energy and atmosphere*	*Ecology*
Urban planning	*Materials*	*Water*	*Energy and atmosphere*	*Management best practices for energy efficiency*	*Landscape*
Energy and resource consumption	*Water*	*Waste*	*Ensure that energy systems have the expected performance*	*Establish a minimum energy performance*	*Amenities*
Life cycle and non-renewable resources	*Land use and ecology*	*Health and welfare*	*Establish a minimum energy performance*	*Non use of equipments with CFCs*	*Mobility*
Máximo consumo eléctrico para utilização	*Health and welfare*	*Managemen t*	*Non use of equipments with CFCs*	*Materials and resources*	*Resources*
Energias renováveis	*Managemen t*		*Materials and resources*	*Policies for sustainability*	*Energy*
Materials			*Storage and collection of recyclable waste*	*Management of solid waste*	*Water*
Drinking water			*Indoor environment quality*	*Indoor environment quality*	*Materials*
Environmental loads			*Minimum performance of air quality*	*Inflation outside air and exhaust systems*	*Environmental loads*
Greenhouse gases emissions			*Control the environment – smoke*	*Control the environment – smoke*	*Effluent*
Other atmospheric			*Innovation and design process*	*Policies for green*	*Atmospheric emissions*

emissions				*environment*	
Solid waste			*Regional priority*	*Innovation and design process*	*Waste*
Rainwater and sewage					*Noise outside*
Impact of location					*Thermal pollution*
Others local and regional impacts					*Indoor environment*
Indoor environment quality					*Indoor air quality*
Indoor Air quality					*Lighting*
Ventilation					*Acoustic*
Air temperature and relative humidity					*Controlability*
Natural light and lighting					*Durability and accessibility*
Noise and acoustic					*Durability*
Service quality					*Accessibility*
Safety during operation					*Environmental management and innovation*
Functionality and efficiency					*Environmental management*
Controlabillity					*Innovation*
Flexibility and adaptability					
Cooperation of designers in the definition of systems with critical functions					
Maintenance of performance in use					
Social and economic					

aspects						
Social aspects						
Costs and economics						
Cultural aspects						
Culture and heritage						

Besides different systems, we have analyzed the variants for the assessment of new buildings and interventions in the built environment. These realities reflect two systems with different evaluation purposes, in the former case there is the possibility of evaluation at the project level which reflects a broad level of intervention, the second reflects the improvements made on existing systems and provides the optimization of resources and adaptation of solutions. This second reality limits the intervention and requires a meticulous knowledge of the characteristics of the built environment.

The reorganization of the criteria in the key areas set resulted in nine groups of parameters and in the recognition of parameters that are not common, including social, economic and cultural factors that are central themes of sustainable development. Table 3 shows an example of the groups formed, notably in the Resources Management - water.

Table 3: Sustainability in the Resources Management - water

Sustainability in the management of resources - water (supply and drainage)					
SBTool07	LEED - New Buildings	LEED - Existing Buildings	BREEAM - Ecohomes	BREEAM EcoHomes XB Existing housing	LiderA
Location, design and development / Energy consumption and resource / Environmental loads	Sustainability of the place / Efficient water management	Sustainability of the place / Efficient water management	Pollution / Water	Water	Resources / Environmental loads
Design	Construction activity and prevention of pollution	Rainwater Management - capture and reuse / evapotranspiration	Curtailment of surface runoff - covered surfaces and roofs	Internal use of potable water - water consumption in the various activities	Water
Use of renewable resources	Rainwater Management - monitoring the quantity	Efficient water management	Internal use of drinking water	External use of potable water - the collection of rainwater for outdoor use	Consumption of drinking water (indoors)
Existence of a management system of surface water	Efficient water management	Reduction of losses in water facilities of buildings supply	External use of potable water - the collection of rainwater for outdoor use		Consumption of water in outdoor spaces
Availability of system water treatment	50% reduction in the consumption of drinking water for irrigation	Verification of water consumption and system performance			Control of consumption and losses
Availability of water supply systems separate for drinking water / gray	Only use non-potable water for irrigation or without irrigation	Increasing the efficiency of the building water supply			Use of rainwater
Drinking water	Waste water treatment on site and its reuse into the building	Reduce the consumption of drinking water / groundwater [illegible]			Management of local waters resources
Use of drinking water for irrigation	Reduction of water consumption of the building - 20% reduction	Reduce the use of water in cooling towers			Wastewater
Use of water for the needs of occupation	Reduction of water consumption of the building - 30% reduction				Flow of wastewater
Rain water and sewage					Type of wastewater treatment
Liquid waste discharge					Flow of wastewater reuse
Collection of rainwater for reuse					
Rain water not collected					

The systems approach is similar, although with significant differences in the organization of its structure analysis. Aspects related to construction and the life cycle of buildings appears in all systems. Those who evaluate the built environment variables are not related to land use. The economic, social and cultural issues are sparse and are named only in the SBTool. The importance of the quality of life inside the house is relevant and it’s, in fact, taken into account, whether in the health and well-being concern or the indoor environment quality.

In terms of results, these systems are based on establishing an overall grade for the building, in some cases to assign weights to the different areas and criteria in order to take into consideration problematic issues regarding specific places or regions.

3. Evaluation of the built environment

3.1 Building the model

After defining the main areas involved in the assessment of sustainability, discussed earlier, it were defined the analysis’ parameters for each one of them, based on the characteristics of the historical areas of portuguese cities, the sustainability principles and the strategies outlined by the Urban Rehabilitation Corporations that exist, such as in Lisbon, Porto and Coimbra. The particularity of these urban areas requires detailed knowledge of its evolution, the constraints and potential impacts of their specificities. While the physical conditions of buildings, the age of residents, the conditions of infrastructure and urban space constraints are important, the historical and cultural value, the urban memory urban, the economic activities and the built environment are key factors that characterize the enormous potential of these areas. Figure 1 shows some images of the historic area of Coimbra’s downtown.

Figure 1: Historical Coimbra city centre images

The images show the advanced degree of degradation of some buildings in Coimbra's downtown. This area is in the outskirts of the city of Coimbra, built from the X Century and it was occupied by the full population of the less wealthy and with a strong commercial element. Nowadays, it is an important commercial hub of the city, with a diversified economic activity, and especially, an area of great historical value and heritage. It is currently the target of interest through the initiatives of urban regeneration driven by policy initiatives, such as the creation of Rehabilitation Corporations consisting of support structures to the owners for the preparation and implementation of rehabilitation.

Given these factors, it is necessary to conduct the processes of intervention in encouraging activities that promote local sustainability, through initiatives that promote social relations, environmental quality, economic activity, self-support, recovery and optimization of the built environment, cultural heritage and history as part of urban memory.

3.2 Evaluation model of sustainable rehabilitation

The evaluation model of sustainable rehabilitation is designed to lead the process of intervention as a tool to support decision. This model addresses various parameters of analysis and evaluation grouped into nine areas defined above.

Through the analysis performed was possible to define an evaluation system with the following objective:

- To direct the activities of intervention in historic areas;
- Safeguard the cultural and historical interest of the area and its memory;
- Promote the generation of jobs and activities that develop the area and respects its neighbours;
- To create conditions to return a part of the urban fabric that values the city existence;
- Promote social spaces and rest areas, open spaces and its relationship with the interior;
- Apply the principles of sustainability, which have been properly identified in Table 1;
- Return to the dialogue between the habitat and the environment that has existed since the dawn of human existence, as a way to reduce its impact.

The criteria defined analyze issues related to the land use and the impact on the surrounding environment, the consumption of resources at all stages of the life cycle of the building, in this case in comparison with the current situation and the improvements incorporated through the intervention operations. They also evaluate the support for the mobility of users, both in relation to the provision of services such as the existence of alternative traffic routes and conditions for use of automobile alternative means of transportation. Also appreciates the quality of indoor and outdoor environment, showing the natural relationship between these spaces. The improvement of living conditions are also analyzed to improve existing conditions and to make urban space more attractive to newcomers.

The flexibility of the building is valued according to its adaptability, a key factor that allows a versatility that follows the changing social and area needs. Finally, is taken under consideration the architectural, social and cultural value of the building as a way to maintain the existing characteristics and adapting the use.

Table 4 presents the general structure of the evaluation model.

Table 4: Evaluation Model of sustainable rehabilitation

Sustainable place		
	SL1	*Density*
	SL2	*Exterior spaces*
	SL3	*Type of occupation*
	SL4	*Exterior ventilation*
	SL5	*Exterior thermal conditions*
	SL6	*Impact on surrounding environment*
Sustainable Transport		
	ST1	*Availability of public transport*
	ST2	*Conditions for use of alternative transport*
	ST3	*Need to travel to access services*
Sustainability in the Management of Resources - Water		
	Supply	
	SA1	*Consume of Drinking water*
	SA2	*Efficiency of the building water supply*
	SA3	*Different interior supply water systems*
	SA4	*Use of rainwater for irrigation and non-potable uses*
	Drainage	
	SA5	*Waste water treatment for reuse*
Sustainability in the Management of Resources - Energy		
	Efficiency	
	SE1	*Definition of minimum performance levels*
	SE2	*Types of equipment used*
	SE3	*Types of lighting inside and outside the building*

SE4	Monitoring of energy consumption
Renewable Resources	
SE5	Use of renewable resources
SE6	Strategies for maximizing the potential passive solar
Sustainability in the Management of Resources - Materials	
Consumption	
SM1	Reuse of the main existing structure
SM2	Use of local materials
SM3	Use of materials with recycling potential in rehabilitation operations and maintenance
Production and Collection	
SM4	Availability of devices to collect waste
SM5	Reduction of waste resulting from operations of rehabilitation and maintenance
Recycling	
SM6	Recycling of household waste
SM7	Recycling of waste from the operations of rehabilitation and maintenance
SM8	Management of non-recyclable waste
Sustainability in the Exterior Environment - Emissions	
SAE1	Control of annual CO_2 emissions
SAE2	Emission control greenhouse gases, acid or photo-oxidants
SAE3	Monitoring of outdoor air quality
Sustainability in the Interior Environment	
SAI1	Control of indoor air quality
SAI2	Use of indoor coating materials with low emission
SAI3	Air renovation
SAI4	Temperature and relative humidity
SAI5	Levels and quality of lighting
SAI6	Privacy and outside views
SAI7	Acoustic comfort
SAI8	Articulation and minimum areas of the interior spaces
Sustainability in the use	
Controllability	
SU1	Controllability in the building's systems
SU2	Document the principles and practice of building

Flexibility	
SU3	*Usability for new features*
Adaptability	
SU4	*Adapting to new energy sources*
SU5	*Interior adaptability*
SU6	*Technical systems adaptability*
Sustainability Cultural, Economic and Social	
CES 1	*Patrimonial valorization of the building*
CES 2	*Architectonic valorization of the building*
CES 3	*Social valorization of the building*
CES 4	*Stimulation of local economy*

The model also evaluates the intervention according to a hierarchical structure as follows (Figure 2):

Area: is the subject of ongoing study and results from the analysis of various criteria involving the approach itself.

↓

Parameters: in some cases, the area is divided into two parameters that typify the input of resources and waste.

↓

Criteria: these are the covered items and are evaluated according to indicators of measurement. The evaluation of measurement indicators will be the evaluation criterion.

↓

Indicators measure: they are the adopted alternative and measured with a given score.

Figure 2: Structure of the evaluation model

The results of applying the model are presented in graphical and report form, as the marks awarded shall be duly justified. The performance seen in the chart will make it possible to visualize the effectiveness in each area evaluated, which identifies the improvements to be introduced, at the building itself level or at the urban management model used level.

4. Conclusions

The fundamentals issues for the creation of an array of assessment of existing buildings, in this case with specific characteristics and a net asset value and cultural value, consist of:

- The fact that these areas constitute part of the urban fabric with little flexibility or low changeability, defined by a consolidated urban mesh;

- The existence of a network of mobility defined and shaped by a constrained urban environment, usually with distinct patterns of occupation;

- The high value patrimonial and cultural heritage;

- The representation of the heritage of a people with values and customs that make up its story;

- The tourism potential of these areas and the possibility of forming an economic powerhouse, with a significant representation in the productive fabric;

- The feasibility of becoming a nerve center for employment and business opportunities.

In this sense, the system draws a set of lines that clarify the actors involved in the various stages of the life cycle of the building. The model has been designed considering, as starting point, the existence of a building, in this sense there is an initial performance and the model assesses the improvements implemented to address this performance. The assessment is always carried out in relative terms, working on a percentage basis compared to the existing.

There has been a great effort to implement sustainable systems and methodologies; however, there is a need to change the current context of construction, to guide decision-makers and active agents in the process of design and construction. This model includes this component and helps to clarify the best strategies.

The score of the criteria allows the setting of a final rating that promotes comparability between some rehabilitation activities, reflecting the improvement implemented. Some of the criteria are presented as urban management; they must be analyzed attending to local policies and highlights the need for joint efforts to achieve the desired outcomes.

There are several initiatives aimed at building sustainable level of new buildings, or even intervention in the built environment, where the historical areas consist of critical areas. These areas have been marginalized, even in regulatory terms, and due to lack of existing conditions and difficulties of intervention, have been exonerated of responsibilities about their performance. This part of the built heritage should take their part in environmental responsibility and alternatives must be found to regulate their effectiveness and measure their impact. The complexity of the intervention should not cause an "urban autism" and these areas must communicate and relate to the town, as well as must respond adequately to the environment.

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Indicators for a Sustainable Built Environment

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Abstract

The sustainability of buildings has become a headline topic in recent years. Several schemes have been developed to define sustainable or green buildings, and “brand” them based on their achievement of some set of predefined sustainability criteria. Buildings do not exist in isolation from their environment, however, but are integrated with infrastructure. In defining sustainable buildings, the issue arises how to incorporate the influences of not only user behavior, building design and technologies, but the associated infrastructure that comprises the entire built environment. The built environment considered here includes all buildings and infrastructure, and in this context, comprises approximately 10% of global GDP. The building and construction sector alone is not only the largest consumer of natural resources, in terms of both land use and materials extraction, but is responsible for 30-40% of global primary energy use and greenhouse gas (GHG) emissions. An important element in the implementation of sustainability goals in the built environment is the availability and dissemination of quantified knowledge about the effects that the construction, use, maintenance, and decommissioning of buildings and infrastructure are having on the environment. One approach to making that knowledge available and useful in the pursuit of sustainability is through the use of indicators. Indicators can be defined as variables that have been chosen for their ability to describe specific characteristics in the state of a system. Many sets of indicators have been developed, and then utilized independently or aggregated into indices to assess different components or aspects of sustainability. While many of these indicator sets and indices incorporate segments of the built environment into their analyses, none of them incorporate a complete and specific set of indicators. This paper presents an initial inquiry and literature review to determine the current state of research into the development of indicators for sustainability, sustainable development, and specifically the assessment of sustainability in the built environment. The review focuses on the built environment at the sectoral level, but as a basis for preliminary discussion of the topic, includes the development of indicators for relevant subsets and categories.

Keywords: sustainability, indicators, infrastructure, built environment

1. Introduction

During the last few decades, sustainable development and sustainability have become crucial issues globally. The terms were highlighted in 1987 in the report Our Common Future by the World Commission on Environment and Development, where sustainable development was described as: "…development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987, p.54). While there is a general agreement on this description of sustainability, there is no consensus on a path to implementation. From the somewhat vague description emerges a plethora of different interpretations, as "…various stakeholders and institutions configure a fairly malleable idea to fit their own agendas (Allenby et al. 2009, p.10)." This leads to a large variability between the different understandings, methodologies, and intentions regarding sustainability. The proper path to implementation of the concept of sustainability, then, is influenced (or wholly determined) by the existing paradigm. Regardless of the path to be chosen, an important element is quantified knowledge about the effects that human activities are having on the environment, and the effects of the environment on human activities. One approach to making this knowledge available and useful in the pursuit of sustainability is through the use of indicators.

1.1 Indicators, frameworks and indices

Indicators are generally quantitative measures or variables chosen for their ability to describe specific characteristics in the state of a system (Mayer 2008), "that can be used to illustrate and communicate complex phenomena simply, including trends and progress over time" (EEA 2005, p.7). There are many existing frameworks for the development and presentation of sustainability indicators. Most of these focus on indicators for sustainable development, and were developed to allow comparisons between nations. These indicator frameworks are generally designed more for simplicity of comprehension for non-scientific policy makers in government than for true quantitative assessment. Some result in a relative ranking of nations against each other, while others display less aggregated results. Frameworks in use for indicator development and presentation include:

- The Pressure-State-Response (PSR) framework (Segnestam 2002)

- Expanded versions of the PSR framework (Segnestam 2002):
  - Pressure-State-Impact-Response (PSIR)
  - Driving Force-Pressure-State-Impact-Response (DPSIR)
  - Driving Force-Pressures-State-Exposure-Effects-Actions (DPSEEA)

- Flow or input-output based frameworks, relying on:
  - Material Flow Accounting (MFA)
  - Life Cycle Assessment (LCA)
  - Energy Flow Accounting (EFA)
  - Exergy Analysis

- Other specialized methodologies and frameworks, such as the Ecological Footprint.

Many sets of indicators have been developed, and then utilized independently or aggregated into indices to assess different components or aspects of sustainability (see (Hak et al. 2007; Singh et al. 2009; Böhringer & Jochem 2007). While many of these indicator sets and indices incorporate segments of the built environment into their analyses, none of them incorporate a complete and specific set of indicators.

1.2 The built environment, buildings and infrastructure

The built environment "encompasses all of the buildings, spaces and products that are created or significantly modified by humans" (Health Canada 1997, p.12) and in this context is understood to comprise: buildings and structures, facilities and networks for communication, facilities and networks for transport, plants, facilities, and networks for water supply and wastewater treatment, plants, facilities, and networks for solid waste treatment, and plants, facilities, and networks for and energy production and distribution.

The building and construction sector alone is responsible for 10-40% of countries' GDP, as well as 10% of employment (UNEP 2009). The sector is not only the largest consumer of natural resources, in terms of both land use and materials extraction, but is also responsible for 30-40% of global primary energy use and greenhouse gas (GHG) emissions (Huovila et al. 2007). While there are many current initiatives that aim to reduce the impact of the built environment on the natural environment, according to the United Nations: "…there is still a clear lack of initiatives aiming at addressing global issues from a life-cycle perspective of the built environment" (Huovila et al. 2007, p.1).

While buildings and infrastructure are responsible for a major share of negative impacts affecting sustainability, they are also a large provider of positive services affecting sustainability. According to the United Nations, the building and construction sector "literally builds the foundations for sustainable development" (Huovila et al. 2007, p.1). Any indicator framework assessing the sustainability of the built environment must take this important feedback cycle into account.

2. Sustainable buildings and infrastructure

While the sustainability of the built environment has become a headline topic in recent years, the majority of the attention, especially by the public at large, has been towards green or sustainable building. Several schemes have been developed to define sustainable or green buildings, and "brand" them based on their achievement of some set of predefined sustainability criteria. The rating system that has garnered the most attention, especially in the United States, is the LEED (Leadership in Energy and Environmental Design) certification scheme developed by the United States Green Building Council (USGBC).

Regardless of its popularity, emerging research is showing that LEED is not living up to its expectations. In fact, a recent paper (Scofield 2009) presents a critical review of LEED certification and the continuing lack of evidence supporting its effectiveness in reducing building energy consumption. The USGBC commissioned the New Buildings Institute (NBI) to study energy use in LEED certified commercial buildings (Turner & Frankel 2008), and the results of the study have been used by other authors as proof of the effectiveness of the LEED scheme. Scofield points out the methodological inconsistencies and flaws in the NBI analysis, however, showing that on average, based on a re-examination of the same buildings presented in the NBI study, there is "no evidence that LEED certification has collectively lowered either site or source energy for office buildings." Such qualitative approaches to assessing sustainability may be useful, or they may present an ineffective distraction from valid attempts to progress toward sustainability.

Buildings do not exist in isolation from their environment, however, but are part of a larger infrastructure. In defining sustainable buildings, the issue arises how the equation should incorporate the influences of not only user behavior, building design and technologies, but the overall built environment, with all of its feedbacks and synergies.

An initial inquiry into the infrastructural requirements of buildings was performed by Deilmann et al. (2007). The authors utilized a GIS analysis to compare the land consumed by infrastructure as a function of the density of urban development. They specifically considered the "surface area of roads and sidewalks per gross floor space" (2007, p.160). The results show that over 1/3 of the areas analyzed utilized more than "one m^2 of road per m^2 of floor space" (2007, p.162) with an inverse correlation between paved area and urban density. In addition to the material resource demands of transport infrastructure, Kennedy et al. (2009a; 2009b) have reported that per capita energy use and emissions from transport are inversely correlated with population density.

It can be inferred that building attributes regarding sustainability should not be considered irrespective of their infrastructural burden – including not only the physical surface area considered in the Deilmann et al. study, but the environmental and health impacts (materials use, energy consumption, CO2 and pollution emissions, etc.) associated with their production and maintenance, operation and end-of-life. Focusing on a single aspect of the built environment, while ignoring the inherent influences and interdependencies, will not solve the problems of energy consumption, CO2 emissions, material consumption, and waste generation, nor allow the measurement of true progress toward sustainability. One approach to properly exposing and identifying all of the environmental, social and economic interactions attributable to buildings is to expand the system boundaries to include buildings and their associated infrastructure: the entire built environment.

3. Literature review

3.1 Indicator development and frameworks

An early inquiry into some of the issues involved with developing indicators for sustainable development by Custance and Hillier (1998) acknowledges the need for more than just "aspirational" definitions of sustainability (like the Brundtland definition). The authors present a comprehensive discussion of the methodological and statistical issues encountered when attempting to develop a set of indicators. They consider the definition of sustainability (and sustainable development) itself, attempts to measure it, ways to treat the trade-offs between quality of life and environmental impact, choices of indicators and framework, aggregation and representation.

Regarding indicator development, Hennicke (2003) argues that we already know enough to proceed on a safe path, and that we should not wait for new or better ecoindicators. The author discusses the division between differing views of measuring sustainability, and emphasizes the need for both monetary and physical indicators – that neither alone can tell the whole truth.

Hukkinen (2003) presents a criticism and commentary on the inherent gaps in the ability of the existing indicator frameworks, such as the PSR model. The author identifies and recommends the development of better indicators that would be able to incorporate functional linkages between indicators, use alternative sustainability scenarios to develop indicators for carrying capacity instead of relying on an absolute notion of carrying capacity, and address "path dependence" or the constraints on future options resulting from current decisions.

Alfsen and Greaker (2007) present a comprehensive history of the different approaches taken around the world to developing indicators of sustainable development. The authors are critical of the methodology and analytical basis for many approaches to sustainable development, noting that the goal is not "about preserving some particular development pathway, but about protecting development options for the future" (2007, p.606). They outline the process by which the Norwegian Ministry of Finance Commission developed their approach to indicators of sustainable development, accepting the theory of marginal trade-offs between services and resources, but ultimately rejecting total aggregation into a single index, and presenting an initial set of indicators.

Wilson et al. (2007) compare six nation-level sustainable development indices (SDIs) and discuss the reasons behind the large variability in results. "A significant reason as to why the SDI metrics present differing assessments of sustainability is that underlying the metrics are different theoretical understandings of sustainable development. There is no consensus about what constitutes sustainability" (2007, p.311).

Singh et al. (2009) provide a comprehensive review of 70 different indicators and composite indices, with a description and overview of the different approaches and frameworks. The authors assume that the goal of composite indices is some sort of country level ranking. The authors present a critique of the "degree of arbitrariness" as well as lack of transparency regarding assumptions. The paper bemoans the fact that of the plethora of indicators and indices, very few take an integrated approach to addressing the environmental, social, and economic aspects of sustainability.

3.2 Sustainability indicators and indices

Vanegas (2003) defines a sustainable built environment through general overlapping paradigms (or visions) and then presents a hierarchical approach, with strategic, tactical, and operational levels. The author focuses on the project level, taking a life-cycle approach from project definition and implementation through to end-of-life. Consideration of the text, diagrams and flow charts highlights one of the biggest obstacles to actual implementation. There are a myriad of factors that different stakeholders will claim fits within the overall rubric of sustainability, but an equitable approach to their inclusion results in an operational framework so unwieldy it becomes useless in its complexity.

Böhringer and Jochem (2007) conduct a survey and critical review, scrutinizing 11 country level sustainability indices. They consider that lack of transparency and scientific rigor in the choice of variables, normalization, and aggregation renders them "useless, if not misleading" with respect to concrete policy advice, and attempt to expose the hidden value judgments along the many levels of index design (2007, p.2). The choice of variables, and approach to normalization and weighting are "matters of substance to be decided by natural science and/or policy" (2007, p.2).

Atkinson (2008) presents an overview of the capital approach to sustainability and a discussion of its application at the sectoral (built environment) level. The capital approach to sustainability considers non-declining overall wealth (including substitutable natural capital) as "the basis of future well-being" (2008, p.242). Weak sustainability considers full substitution of different forms of wealth or capital, while strong sustainability considers some provisions of the environment to be irreplaceable and nonsubstitutable. The author makes note of the lack of inclusion of land (space) as a "complex asset that has possibly multiple (social) values under different uses" (2008, p.245) deserving a larger role in discussions and debates regarding the sustainability of the built environment.

Mayer (2008) presents an overview and explanation of sustainability, its definition, and factors that are necessary to assess sustainability within a system. The author compares a diverse set of sustainability indices based on approach to aggregation, interpretation of sustainability, and the inclusion of trade and flow effects, or "leakage". The author mainly considers indices that are used to compare or rank countries, and provides reasoning and criticism for the inconsistency of index results. Methodological bias and lack of transparency are considered, along with the need for direct and explicit conveyance of the methodological approach and issues.

3.3 Sustainable infrastructure

The Canadian InfraGuide (2003) presents a framework, applicable to "roads, water, wastewater, and sewers" (2003, p.ix), to assist Canadian municipalities in their own development of "basic indicators, benchmarks, and performance measures" (2003, p.ix) in order to prioritize resource allocation, prolong asset life cycle and identify optimum interventions. The proposed methodology involves a hierarchy of indicators mimicking the organizational structure of municipalities, using aggregation to form higher levels of indicators. The guide provides a set of examples of the relationship between the different levels of indicators, and presents a list of qualities that chosen indicators should have: manageable, relevant, meaningful, measurable, well-defined, and aligned with objectives.

Wright (2007) describes the sustainability of infrastructure as “essential to a sustainable society” (2007, p.1) and presents an assessment methodology based on performance indicators. The author describes the characteristics that these indicators should have, but does not attempt to develop the indicators, or describe how, or at what level they should be implemented (macro/micro/project).

3.3.1 Project level

Dasgupta and Tam (2005) approach the consideration of sustainable infrastructure from a project perspective. Indicators are developed and presented to assess project sustainability of Civil Infrastructure Systems (CIS) in all life stages, including preproject planning, project implementation & ongoing operations. Noticeably absent from “all life stages” is the consideration of end-of life. The authors concede that there are “many cases where the post-use stage also becomes significant” (2005, p.31) but have chosen to put end-of-life outside of the system boundaries for sake of simplicity. The indicator system does not attempt to actually address the sustainability of the system, but only compare given alternatives and makes a determination of which is less bad. “…the discussion is limited to comparing modification options with similar sets of project specific issues of concern” (2005, p.34). No attempt is made to reconcile the trade-offs between the negative environmental and potential positive societal goals of the project schemes.

Ding (2005) presents the methodological basis for the development of a sustainability index incorporating economic, social, and environmental criteria with both monetary and non-monetary approaches. The system allows trade-offs with a multicriteria algorithm, ranking projects and facilities based on their “contribution to sustainability,” and choosing the most efficient option among competing alternatives. The author uses an “industry survey of professionals in the construction industry” (2005, p.6) presented in a prior paper to identify important criteria that are then ranked and aggregated, resulting in a sustainability index consisting of four criteria. The author accepts that changing the weighting would change the results, but does not explain the rationale behind the choices made in the case study, nor conduct a sensitivity analysis to explore the impact.

Ugwu and Haupt (2007) use a survey to develop a set of indicators for project-level sustainability appraisal, based on an interpretation of goals related to the sustainability of infrastructure. The survey is a convenience sample of 49 “industry stakeholders attending a series of national health and safety workshops and seminars” (p. 668) with a 100% response rate. The study does not attempt to define or clarify the actual meaning of sustainability at the macro or project level, though it discusses both in detail. The paper does not attempt to discern whether any of the options present a truly sustainable option, only which of the project alternatives is the better option, using a sustainability index derived from the indicators as criteria. The sustainability index itself is subjective in its weighting and methodology, and depends entirely on a subjective choice of indicators.

3.3.2 Buildings

Zimmermann et al. (2005) present an approach to defining and achieving sustainability in the construction sector, specifically focusing on buildings. The authors take a life cycle approach, including construction, operation, and end-of-life, to the assessment of three factors: environmental loads, greenhouse gas emissions, and energy use. The authors present an approach to defining benchmarks for critical limits of the three factors based on population and housing area. A sector functioning within these limits would be considered sustainable. The paper is unique in its attempt to actually quantify the limits of a sustainable society and in the presentation of an approach to achieving sustainability within the building sector.

San-José et al. (2007) focus on the sustainability of industrial buildings, making note of the fact that the notion of “sustainable building” in the industrial sector is traditionally more concerned with the production processes occurring inside the building rather than the building itself. The authors recommend taking a life-cycle approach, using the existing 3 “pillars” of sustainability: economic, social, and environmental, but adding three more: safety, aesthetics, and functionality. The paper presents an approach using a hierarchy of requirements, criteria, and indicators, and a mathematical model for multicriteria assessment, but ultimately is an empty framework, with a consideration of some of the methodology.

ALwaer and Clements-Croome (2009) present a methodology for the development of a list of key performance indicators for sustainable “intelligent” buildings through literature review, and then a survey of “selected stakeholder” (n=20) opinions and recommendations from a provided list of choices. These indicators were then weighted (n=11) in the same manner. From this a model (Sustainable Built Environment Tool SUBETool) for comparative measurement was developed. The result is a subjective tool where the definition of sustainability is completely dependent on the group of selected stakeholders.

3.3.3 Roads and transport

Gudmundsson (2003) conducts a review of transport indicator sets, and addresses some of the core problems and issues at the foundation of the indicator development. He notes that evaluating sustainable mobility “clearly depends on what is implied by the concept” (2003, p.199). When considering different indicator systems: “it matters which interpretation of the sustainability concept itself (if any) each indicator system adheres to or embodies (2003, p.200). He sums up the multitude of problems with the concept of sustainable mobility: “There is little agreement if and how sustainability in a strict sense is at all meaningful and measurable at a sectoral level” (2003, p.202). There is also generally a lack of analytical justification for the chosen definition of sustainable mobility. The author notes the need for relative indicators to measure various aspects of efficiency in relations between the economy, transport sector, and the environment “to incorporate purely environmental indicators within an extended set of indicators of: socioeconomic activities, driving forces, supply chains, and life style patterns” (2003, p.205). The author argues that the “lack of sustainability targets in the indicator systems seems like a major omission. With no benchmark, how would we know if systems are sustainable or not?” (2003, p.209).

Jeon & Amekudzi (2005) provide an overview of the state of the art (in 2005) for addressing sustainability in transportation systems. The authors note that there is no “standard definition for transportation system sustainability” (2005, p.31) resulting in a myriad of different approaches depending on the “unique definition of sustainability adopted” (2005, p.33). They mention the seemingly obvious, but usually overlooked, idea that a working definition of sustainability is a “critical element in the development of indicators and metrics” (2005, p.33) and that currently “there is no standard framework for evaluating progress toward sustainability” (2005, p.42). The authors give a review of the different categories of indicator frameworks found in the literature for assessing transportation system sustainability. In the absence of definite measures, the authors lament that sustainability in transportation systems is “largely being measured by transportation system effectiveness and efficiency as well as the environmental impacts of the system.” (2005, p.49) and that “…if there is no consensus on what would constitute a sustainable system state, how can one plan for such a system?” (2005, p.48).

Amekudzi et al. (2009) assess the impact of transport through modification of the existing Ecological Footprint (EF) system, while acknowledging its limitations. The authors’ methodology provides spatial and temporal flexibility, and an initial attempt at reconciliation of the trade-offs inherent to the provision of infrastructure systems (quality of life contributions vs. environmental impacts). They derive a “sustainability footprint” using the EF in an equation with rate of change of quality of life, which is intended to be a measure of the efficiency of the environmental impact of development on improving quality of life. An intentionally simplified case study is presented that highlights some of the limitations of this approach. In the example, one indicator is chosen from each of the three categories (quality of life, resource, waste) to be compared. The choice of units has a tremendous impact on the analysis; the results seem only applicable in a direct comparison, and have no inherent ability to determine movements toward or away from sustainability. Like many other approaches to indicator systems, the framework presented can be used to determine some measure of the efficiency of resource use and waste generation in promoting quality of life, but not sustainability itself.

3.3.4 Water

Sahely et al. (2005) use a modified LCA approach in assessing the sustainability of urban infrastructure. This approach includes problem definition, inventory analysis, impact assessment and decision analysis. Their assessment relies on existing environmental standards, energy and chemical use norms, assuming they properly define what is “sustainable” while admitting and recognizing the pitfalls inherent in this approach.

Sahely & Kennedy (2007) develop an urban water system model, “considering water production, distribution, and end-use through to wastewater collection and treatment” (2007, p.551). The model allows for scenario analysis to consider the effects of various approaches to reduce environmental impacts (energy and water use), including demand management, pipe renewal, and pipe relining. Interventions at earlier life cycle stages have “greater positive downstream impacts” (2007, p.557)

3.3.5 Energy generation and transmission

A. Evans et al. (2009) use a life-cycle approach to rank renewable energy generation technologies (PV, wind, hydro, geo) based on a set of seven key sustainability indicators. The choice of the indicators considered is justified but nonetheless subjective, and has major ramifications for the resulting sustainability assessment. The summed ranking system is controversial in its simple design, failing to differentiate between small and large score variations, and masking similarities or differences in the results. The indicator framework is designed to neglect regional variability when ranking technologies (using “international conditions”), rendering the results of this system ineffective at best, and likely misleading.

4. Discussion and conclusions

The current approach to the development of sustainability indicators is hampered by a lack of willingness to define and measure sustainability. Assessment of sustainability can only be successful with a quantitative approach, defined benchmarks, and a clear definition of sustainability. This underlying interpretation of sustainability should be explicit and transparent. Of the many sources considered, only the Zimmermann et al. (2005) paper attempts to define sustainability quantitatively, and then actually present an approach to its implementation. The paper considers only buildings, however, and not the implications of building design and location to direct and indirect interactions with the built environment and the overall sustainability of a society. The best way to achieve that would involve expanding the scope and folding in the rest of the built environment, with all of its feedbacks and synergies. As Sahely & Kennedy (2007) showed with regard to the sustainability of water systems, intervention in the provision of services through infrastructure upstream from buildings can have greater impacts than intervention at the end-user.

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Linking Energy and Maintenance Management to Improve Knowledge Transfer within Building Operation and Management

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Abstract

Smart, sustainable buildings often utilize sophisticated mechanical and building controls systems to provide energy efficient strategies to meet comfort conditioning requirements and sustainability organizational expectations. To ensure mechanical and building control systems operate as designed and align with best practices, an integrated operations and maintenance approach must be understood and applied. The integrated approach must recognize and apply the interdependencies between energy and maintenance management. To study the interdependencies between energy and maintenance of mechanical equipment and building control systems, three case studies were conducted. The case studies consisted of a community college district, a university laboratory building and a medical center renovation. Using the findings from the case studies, a framework to link energy and maintenance management decision making for mechanical systems, building automation systems (BAS) and computerized maintenance management systems (CMMS) is being developed. The framework will provide a question-driven structure to help stakeholders manage and transfer knowledge between four technical thrusts and the human factor. The end goals of the framework are:

- Help promote best practice sharing across the industry
- Provide a method for knowledge transfer
- Promote the understanding and use of smart and intelligent building technologies

Keywords: case studies, energy efficiency, facility management, maintenance, mechanical systems

1. Introduction

Maintenance management and energy consumption are two key focus points of facility managers. Building automation systems (BAS) and computerized maintenance management systems (CMMS) are complex and fully utilizing such systems can be challenging. It has been documented that although a large amount has been written on the value of energy management and control systems, for every building control system that is operated successfully, there are hundreds that are underutilized and incapable of achieving basic energy savings (Rios 2005). Brambley, Haves et al. (2005) find that a lack of systematic information exists to address the causes, find solutions and determine the financial payback of possible solutions. These statements are quantitatively supported a study of 60 commercial buildings by Piette and Nordman (1996): more than half of the 60 buildings studied had temperature control problems, 40 percent had heating, ventilating and air conditioning (HVAC) equipment problems and about 33 percent had improperly operating sensors.

Similar findings exist within the literature about maintenance management, although maintenance management literature, especially academic maintenance research, is uncommon. For example, although CMMS can provide many benefits for maintenance management, industry experts find that successful implementation of CMMS is a continued challenge (Sapp 2008). In fact, about 50 percent of CMMS implementations are not successful (Berger 2009). Ring (2008) finds that it is not uncommon for commercial buildings to suffer from insufficient proactive maintenance, erroneous maintenance work, unsound and non-institutionalized maintenance practices, unnecessary preventative maintenances, inability to track and visually find maintenance problems, blind acceptance of Original Equipment Manufacturer (OEM) recommendations, variability of preventative maintenance practices between like or similar units, and the use of ineffective preventative maintenance technology.

Although often viewed as independent challenges, an important interdependency exists between energy performance and maintenance of building mechanical systems. As shown in Figure 1, proper maintenance is necessary to achieve optimal energy performance, while energy performance data is needed for effective maintenance management. When the tensions between energy performance and maintenance practices are balanced, buildings operate efficiently. Efficient operation of buildings will result in decreased energy and maintenance costs and reduced environmental emissions.

Understanding the link between maintenance management and energy performance is also important to meet sustainability goals. To meet aggressive energy goals, such as zero energy buildings, it is important that processes are in place to fully utilized BAS and CMMS.

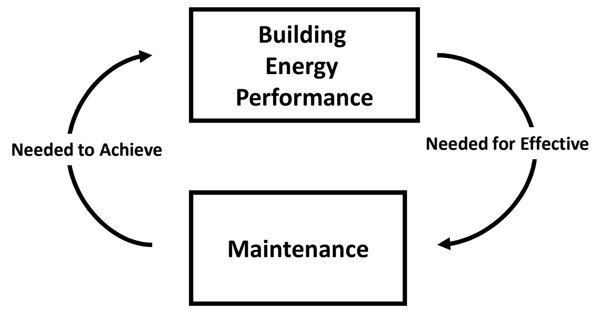

Figure 1: Link between building energy performance and maintenance

1.1 The link between energy and maintenance management

Without proper maintenance, even the most efficiently designed building with high reaching energy efficiency goals will not reach its energy goals. As mechanical systems are used to heat and cool the building over the building life, system performance degrades and sensors and meters drift out of calibration. If the systems are not maintained, they begin to consume more energy due to equipment wear and the data collected by the meters and sensors will become of little value as sensors and meters drift out of calibration. Despite a general understanding of this topic, many buildings do not have effective maintenance programs in place. Ring (2008) has found that it is not uncommon for commercial buildings to suffer from insufficient proactive maintenance, erroneous maintenance work, unsound and non-institutionalized maintenance practices, inability to track and visually find maintenance problems, and variability of preventative maintenance practices between like or similar systems. Although many commercial buildings have computerized maintenance management systems (CMMS) to assist with maintenance management decisions, data collection and record keeping, many industry experts find that CMMS are underutilized and not effectively used (Sapp 2008).

Building automation systems (BAS) are also often underutilized and not effectively used (Piette and Nordman 1996). A BAS is the 'heart' of a building mechanical system, providing computerized logic to command system components on/off, cycle at different speeds, trend and manage operations and performance data, and maintain comfortable conditions within buildings. Rios (2005) has found that for every BAS that is operated successfully, there are hundreds that are underutilized and incapable of achieving basic energy savings. A study of 60 commercial buildings by Piette and Nordman (1996) found that more than half of the buildings studied had temperature control problems, 40 percent had mechanical system problems and about 33 percent had improperly operating sensors. BAS have extensive capabilities to collect, trend and report energy performance data. Unfortunately, BAS typically operate at extremely elementary levels of control (Hartman 2000).

The challenge of underutilization of both CMMS and BAS strengthens the need to further understand the interdependencies between energy performance and maintenance. It is clear that a current lack of structured methods inhibits facility managers from effectively managing buildings and reaching their maintenance and energy performance goals. This increases building energy consumption and operation costs. When facility managers have an increased understanding of the relationship between energy performance and maintenance, they will be able to better utilized BAS and CMMS effectively and economically to improve building operation.

2. Case studies

Three case studies were conducted using an action research approach. Action research is an inquiry based process, grounded in qualitative techniques, to gather information about professional practice and the practitioner's thoughts about the practice. It provides a systematic method to find effective methods to problems practitioners encounter in their daily professional lives by focusing on specific or localized situations. It requires a collaborative approach of inquiry and building relationships between the researcher and the practitioner. The goal of action research is to make a difference for the practitioner and the practitioner's clients (Stringer 2007), often with a goal of resolving organizational issues. Action research also sees to have implication beyond the immediate research case, being able to provide solutions that inform other contexts (Saunders, Lewis et al. 2007).

The role of the researcher in action research is to be resource person, taking a facilitator or consultant role, opposed to an expert. Finally, when using an action research approach, the researcher must start where the people are, not where someone else thinks they are (Stringer 2007).

Given this approach, it is very appropriate that the research started with a question from a practitioner. A mechanical system contractor and service provider asked, "Why is it that when our firm goes into the field to perform maintenance on a BAS installed one year ago, it is being used as a time clock?" In other words, why is the BAS no longer functioning as it was after it was commissioned one year earlier?

Building on this question, the researcher was given the opportunity to work with three of the contractor's clients to conduct three case studies. The three case studies included a community college district, a laboratory building on a college campus and a medical facility BAS upgrade, all located in California, United States. These three facilities were selected because:

- They are three of the best customers of the fourth largest mechanical contractor in the United States, which has 400 customers.

- The facilities represented green, forward thinking facilities management groups, as demonstrated by having a strong commitment to LEED® and are committed improving building management practices.

- The State of California also has taken a more aggressive approach to energy management policy than many other states (such as Title 24). As a result, California building owners have sought out more advanced energy management practices.

2.1 2.1 Case study #1, District Level Study: Los Angeles Community College District

The Los Angeles Community College District (LACCD) is the largest community college district in the United States. It encompasses 884 square miles (2290 square kilometres) within metropolitan Los Angeles and serves over 115,000 students. The LACCD Facilities Planning and Development team, of about 175 maintenance technicians and about 45 Facilities Administrators, manages over 5 million square feet (0.5 million square meters) of classrooms spread across 9 community college campuses, including several completed Leadership in Energy and Environmental Design (LEED®) projects. LACCD is currently completing $5.7 billion (US dollars) of renovation and construction projects, many which include renewable energy optimization, demand-side management and central plant construction.

Figure 2: Los Angeles Community College District: Campus Buildings

2.1.1 Case study goal

The goal of the LACCD case study was to document current maintenance and building energy management practices and current challenges across the 9 campuses. The results of the case study were documented in a case study report completed August 2008. The report contained a summary of maintenance practices used, the frequency of each maintenance practice used, methods used to collect and analyze energy data, current challenges faced by the facility directors and recommendations to align strategic facility management goals with current practices.

2.1.2 Data collection

To collect the data, phone interviews were conducted with 8 facility directors, 1 lead HVAC technician, the Director of Facilities Planning and Development, the Executive Director of Facilities and an engineering management consultant. Each phone interview lasted about 1 hour and included standard series of open ended questions asked of all interviewees.

2.1.3 Results and feedback

The results of the case study found:

- Reactive maintenance practices were the most commonly used maintenance approach across the District.
- The use of preventive and predictive maintenance techniques was minimal.
- Most commonly collect maintenance records were work order requests submitted by faculty and staff.
- Building energy performance measurements was generally limited to the review of utility bills.
- The largest challenges faced by the facility directors were: lack of staffing and funding, and lack of properly commissioned building automation systems.

After sharing the case study results with the facility management team, LACCD hired the researcher to work with the team to determine the criteria for a sophisticated computerized maintenance management system. The work done after completion of the case study demonstrated that LACCD is committed to transitioning from reactive to proactive maintenance and energy management practices.

2.1.4 Lessons learned

The following lessons were learned during the case study and the CMMS selection criteria determination:

- Transitioning from a reactive maintenance program to a proactive maintenance program is a complex process that requires changes in both technologies and process used. The time required for educating and seeking buy-in from stakeholders who will use the new technologies and processes can take several years. Process changes are often take more time and stakeholder engagement than the technology implementation.
- The understanding of the value of documenting maintenance information, such as parts used and labor hours to complete a maintenance activity varies greatly between the facility director and the facility executive. Facility directors generally concluded that documentation takes too much time and reduces the time technicians can be in the field performing maintenance. Whereas, the facility executive concluded that documentation is critical to the efficiency maintenance management.

2.2 Case study #2, Single Building Study: University of San Francisco, Mission Bay Campus Rock Hall

Rock Hall, a highly instrumented laboratory building at the Mission Bay campus of the University of California: San Francisco (UCSF), United States, was selected for the single building case study. The 176,000 square foot (16,400 square meters) building was completed in November 2003. A retro-commissioning project for the building was completed in 2005. The building is managed by the

UCSF Facilities Management Group.   The Group manages about 3 million square feet of laboratory, office and classrooms.

Figure 3: University of San Francisco, Mission Bay Rock Hall Building

2.2.1 Case study goal

At the time of the case study, the Facilities Management Group was pursuing certification for certification for Leadership in Energy and Environmental Design for Existing Buildings (LEED-EB®).   The goal of the case study was to determine the requirements for a semi-automated building performance score card. The score card was to support LEED-EB Energy and Atmosphere credits EA5.1 and EA5.2: Performance Measurement Enhanced Metering. To earn these credits requires that quarterly metering reports be submitted to the United States Green Building Council (USGBC).

The score card was also intended to be used by the energy engineers, operators and facility managers on a quarterly basis to proactively evaluate and benchmark building energy performance. The facility management group also sought to use the findings from this study as a pilot project that could be applied to other UCSF buildings.

2.2.2 Data collection method

To develop the score card, an in-person project kick off meeting was scheduled to discuss the project goals and define the project scope. To collect additional information, conference calls were scheduled as needed with the project team, building automation documents (points lists, BAS screens, and equipment data sheets), and the 2005 retro-commissioning report were reviewed.

2.2.3 Results and feedback

The end result of the case study was a report that was provided to the facility management team's building automation system technician completed in May 2009. The report included directions of how to use the score card and the data and equations and needed by the technician to program the building automation system to collect data for five energy indicators:

- Overall building energy consumption in units of BTU/SF/year (W/m2/year)

- Energy consumption per source for electricity in kW/SF (W/m2) and natural gas in BTU/SF (W/m2)

- Overall chiller load in kW/ton

- Overall ventilation load for air handlers in CFM (L/s)

- Peak electrical demand in kW

A 6 question questionnaire was sent to the facility management team at the end of the project to evaluate if the case study goals where achieved. The findings of the questionnaire were:

- The final score card exceeded expectations of 60 percent and met expectations by 40 percent of the facility management team

- The most valuable parts of the score card were:
    - Provided a tool to include energy efficiency within building operations metrics
    - A single standardized tool that can be customized
    - Graphs used to present data

- The inclusion of cost data would add value to the score card

2.2.4 Lessons learned

The following lessons were learned during the case study:

- The BAS points and type of points needed by the operators are not necessarily the same points needed to track energy performance. For example, many of the points were setup as change in value for the operation of the system. However, when tracking energy performance data, collecting data at a specified time interval allows data to be normalized more accurately.

- The primary function of BAS is to control equipment, not necessarily to track energy performance. Completely automating the score card was not possible as the electric and natural gas meters were not connected to the BAS. Additionally, customized reports needed to be developed in order for the score card to be developed.

2.3 Case study #3, Central Plant BAS Upgrade: Sutter Medical, Sacramento Sutter Medical Facility

Sutter Health owns and operates 26 affiliate hospitals in northern California. The case study was completed for the facility management group at the Sacramento Sutter Medical Center. The Sacramento facility was in the process of replacing an existing building automation system (BAS) from the mid 1980's with a new Siemens APOGEE® building automation system. The replacement of the control system is occurring in conjunction with the construction of a new Women's and Children's Hospital and a mixed use diagnostic and clinical building for the Sutter Medical Foundation.

Figure 4: Sutter Medical Central Plant

2.3.1 Goal

The goal of the case study was to document and create a methodology to implement a building energy performance program for the new BAS. The case study report was developed to serve as a road map for Sutter to move towards a proactive building energy performance program.

2.3.2 Data collection method

A project kick-off meeting was held with the project team. Following the project kick-off, phone and e-mail correspondence occurred to narrow the pilot study scope and collect necessary information. Project documents, including basis of design narratives and building control system product data sheets were reviewed.

2.3.3 Results and feedback

To create the road map, 3 one-page summary sheets were developed to summarize the 3 most needed energy performance program needs within the case study report completed in July 2009. The summary sheets included:

- An energy program planning pyramid

- A sensor de-calibration detection guide

- A critical equipment selector

The energy program planning pyramid is a set of bounded steps to help the facility management team to plan, implement and refine an energy management program. Each bounded step is represented by a box within the pyramid. Using the bounded step approach, facility managers will be able to incrementally develop an energy management program, while also completing other daily responsibilities.

The critical equipment selector is tool to help the facility management team quantitatively determine the tradeoffs between energy efficiency and equipment criticality. Determining the criticality of equipment is especially important in a hospital as hospitals often operate 24-hours per day, have stringent air quality and ventilation requirements and have significant potential for energy and cost savings. However, mission critical needs of a hospital must not be sacrificed to reduce energy consumption or utility bills.

The sensor de-calibration detection guide provides facility managers with guidance to develop a sensor calibration and re-calibration plan, as well as tips to consider during plan development. It is important to re-calibrate sensors because they drift outside of tolerance over time. As a result, the building control system actions may not be triggered as needed for proper system operation and/or the value of trend data for energy analysis is reduced.

A 7 question questionnaire was sent to the facility management team at the end of the project to evaluate if the case study goals where achieved. The findings of the questionnaire were:

- The results of the case study met expectations by 2 participants and exceeded expectations of 1 participant.

- The energy program pyramid was found to be of greatest value by all 3 participants. The energy program pyramid was found to be of greatest value because:

    - It is an easy map to understand and helps the user to focus on key areas

    - It is the basis for the remainder of the other 2 tools

- The sensor de-calibration guide was found to be of least value by 2 participants. One participant found the critical equipment selector to have the least value. Least value was assess by the regulatory nature of the health care industry requires a risk assessment whenever new equipment is installed and daily responsibilities of the participants.

2.3.4 Lessons learned

The following lessons were learned during the case study:

- Cost and energy savings alone are not significant enough to motivate change within a large organization. Day to day responsibilities and direction from executive decision makers are needed to encourage energy efficiency.

- Hospitals are large energy consumers; however, the criticality of operation increases the complexity of energy efficiency.

- The culture and structure of an organization and project teams greatly influences how new ideas are embraced.

3. Framework concept development

The case study findings and support from literature allowed the researcher to conclude that facility managers need tools to help plan and implement maintenance and energy management programs. To help meet this need, a building operations decision framework is being developed. The framework will provide a systematic, structured and measurable approach that can be readily applied by facility managers for making energy and maintenance management decisions.

Within the research, a framework is defined as a structure to study, discuss and develop an approach for practitioners to understand the interdependencies between energy and maintenance. The framework will be used to apply the understanding of the interdependencies through defined, actionable steps in the form of recommendations.

The framework will:

- Be a simple, robust, question-driven decision analysis tool for maintenance and building energy management planning, implementation and continuous improvement

- Help to transfer knowledge of energy and maintenance management best practices by providing guidance about how to more fully utilize smart technologies to improve building energy efficient and reduce maintenance costs

- Help facility managers to collect repeatable, verifiable maintenance management and building energy performance data for mechanical systems

- Be tested through an efficient process using test case studies

The primary users of the framework will be practicing facility managers who manage single buildings or campuses of buildings. Consultants to facility managers and building owners, such as facility management consultants, maintenance management consultant and energy engineers will also benefit from using the framework.

3.1 Framework components

As the 3 case studies were completed, 4 main thrusts emerged (Figure 5):

- Energy performance program planning
- Energy performance program implementation and refinement
- Maintenance program planning
- Maintenance program implementation and refinement

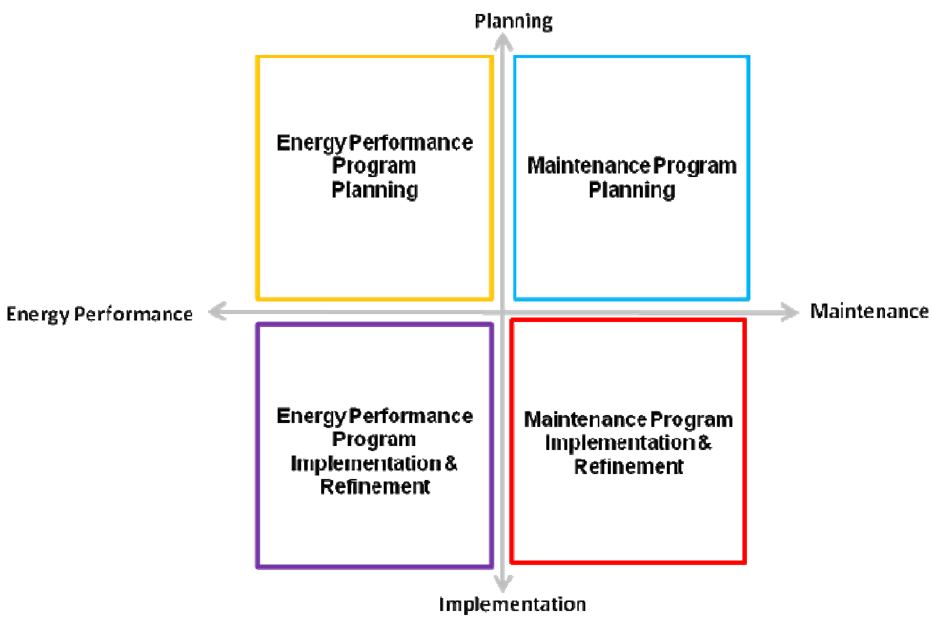

Figure 5: Framework Level 1: Four technical framework thrusts

After review of the 4 thrusts by a team of facility managers, a fifth thrust was added: the human factor. The human factor acknowledges that a planning or implementation process cannot occur without the interaction of team members and that the success of a project is limited by the abilities and motivations of the team members and their ability to interact and communicate effectively. It also acknowledges that the level of sophistication of a plan or project implementation cannot exceed the technical competence of the team who will be implementing the plan or the users of the end product.

Several tensions exist between the human factor and the 4 technical thrusts:

- Return on investment (ROI)
- Competencies and skills of the facility management team
- Strategic goals

Level 2, the *Framework Architecture*, (Figure 3) depicts the relationship between the technical thrusts and the human factor, as well as the tensions and flow between components. Planning is followed by implementation, and implementation results in a balanced operations program. A balanced program achieves equilibrium between facility goals, planning, and implementation; acknowledging limitations created by tensions.

Within this conference proceeding, the framework development is limited to Levels 1 and 2. Several other framework components have been developed or are also under development, including the *Needs Assessment*, *User Interface*, *Framework Tool Summary Sheets* and *Implementation Evaluator*. More information about the framework components not covered within this proceeding can be found at the research project website: www.improvebuildingperformance.com.

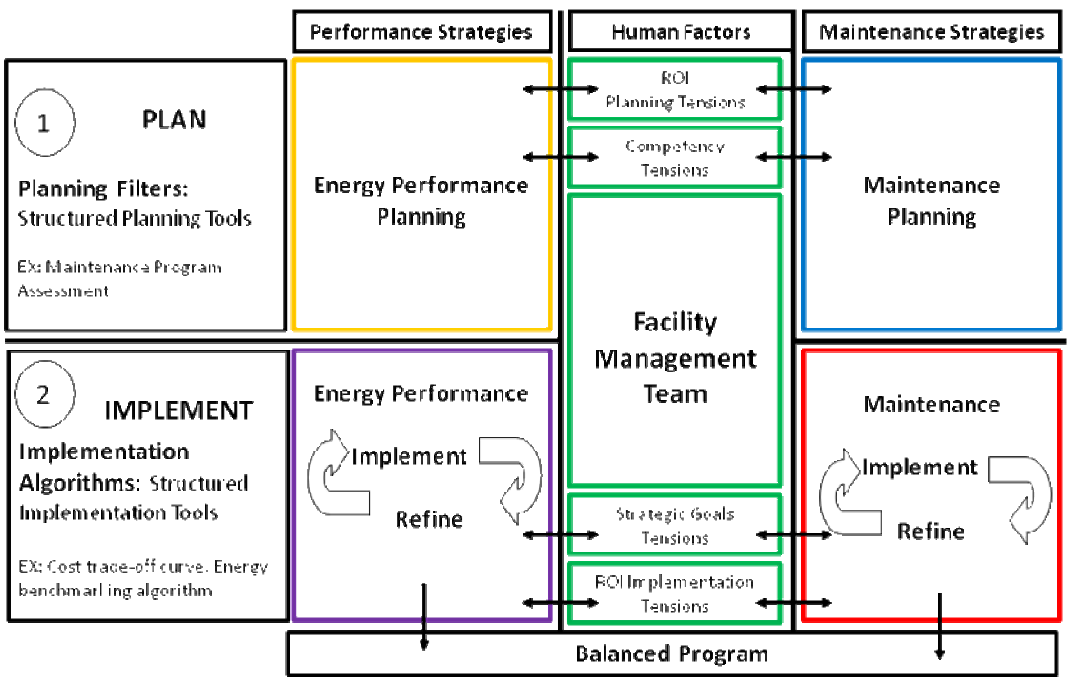

Figure 6: Framework Level 2: Framework Architecture

4. Further research

At the time this paper was submitted, the conclusions of Current Practices, Challenges and Needs of Maintenance and Energy Management Programs Survey to inform the framework development was recently completed. The next steps of the research are to test the Needs Assessment and to develop the coding structure for the User Interface. After the User Interface is developed, it will be tested by a pool of facility management, energy management and maintenance management practitioners.

5. Conclusion

Three case studies were conducted to study the interdependences between energy and maintenance management. The results of the case studies allowed the researcher to conclude that tools are needed to assist facility managers to plan and implement energy and maintenance management programs. As a result of this finding, a *Framework to Improve Building Operating Decisions* is currently in development. The goals of the framework are to help promote best practice sharing across the industry, provide a method of knowledge transfer, and promote the understanding and use of smart and intelligent building technologies. More information about the framework can be found at www.improvebuildingperformance.com.

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Smart Dwelling Environments - Be Everywhere From There

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Abstract

Last century was stage for numerous transformations within familiar structures, life expectancy, new ways of settle and new forms of survival. The majority of the population lives on Metropolitan Areas where the space is scarce and expensive; families are smaller with a significant percentage of mono-parental structures and people who live alone. European population is ageing, due to better health and economical conditions and they look forward to participate actively on society. The revolution inspired and motivated by ICT, stimulates new forms of work and living where the access of information and the possibilities of communication decrease geographical and social barriers. Crossing these two realities, the place of settlement emerges as a central point: from there it is possible to go everywhere. People can work, interact with friends and relatives, shop learn, entertain, etc...from home, since there are technology available and ability to manage ICT. Dwelling emerges as the function which needs another perception on its conception: flexibility towards user expectations and requirements. Answering to this idea, Lifetime homes appear as a good paradigm once they are conceived thinking about the human being considering his/her physical, sensorial, and behaviour abilities as daily routines. The main idea is the integration of individual and this attribute is achieved by the concerned of neighbourhoods layouts and multi-functions keeping in mind the importance of aesthetical considerations to avoid individuals social segregation. This is not just a good solution for people who have different routines, like a teleworker but also elderly. The need of different routines proposed by ICT or the requirements of elderly can be supported by technology embedded on house. Here Smart Houses is a good concept, once it expects to control and monitor the space and its occupancy. Standardisation of technology is needed to its development and affordability as well as pilot studies to experiment (special attention to the usability needed on the communication panels), test and to validate the model. New typologies, construction models, interiors layout and technology embedded can be very supportive to the challenges proposed by this turn of millennium. The appliance of Inclusive Design principles as part of natural solution and not as a trend can lead to a more humanised built and human environment.

Keywords: smart houses, lifetime homes, dwelling environment, TIC, domotics

1. Introduction

“Physical architecture is designed and built to create meaningful places in which society can inhabit and interact.” (Campbell, 1996). The main objective of this paper is to identify and characterise the new functions arising on the domestic environment, as work, business, entertainment, etc. and establish the required levels to a more qualified life, social integration and individual dignity.

New models of living raise the need to reconsider dwelling typology, construction process and the impact of new technologies in the building performance. Dwelling environment became one of the most interesting issues to explore, as through technology anything can be done from there (Caramelo Gomes, 2004) and, on the other hand and regardless of technology, human being, as a social and gregarious being, needs the fell of belonging to a place and community; once again, dwelling environment comes out as a place of excellence. In a near future, these environments will be rated and assessed by their response to user’s requirements and their flexibility to change. This is the context where the concept of Inclusive Design emerges, seeking to emphasise the importance of user participation in space conception and harmonising individual and building life cycles. This approach implies the identification, characterisation and consequent satisfaction of the user in general, and may, if a broader approach is adopted, include the identification and fulfilment of special group requirements, such as senior population or other. If this is the case, then ICT (Information and Communication Technologies) are an invaluable tool to increase the individual’s autonomy. Inclusive Design’s principles within the building (or urban areas) conception and construction (planning) appear as a critical parameter to attract investment, development and valorisation for the built environment. In recent years legislators have become increasingly aware of the need of Inclusive Design, especially in consequence of two main landmarks:

- The United Nations adopted the “Enable” program, in result of which the Convention on the Rights of Persons with Disabilities (SCRPD) was adopted on 13 December 2006 at the United Nations Headquarters in New York and entered into force on 3 May 2008, after the Convention received its 20th ratification, and the Optional Protocol 10 ratifications. To date, there were 144 signatories to the Convention, 88 signatories to the Optional Protocol, 77 ratifications of the Convention and 48 ratifications of the Optional Protocol (United Nations, 2009)
- The European Commission issued a Communication to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions about the Situation of disabled people in the European Union: the European Action Plan 2008-2009. (European Commission**,** 2007)

National legislators have followed this trend (some actually started long before – see Toegankelijkheidsbureau, 2001) and rules about the subject arose in many countries, Portugal included (Caramelo Gomes, 2007). The industry and market response to this trend points to technology and the concepts of lifetime houses and smart houses are in the order of the day.

2. Lifetime houses and smart houses

2.1 Lifetime houses

In different European countries, as United Kingdom and Portugal, the purchase of the house is a major effort to the family income. People acquire a specific house for different reasons, ranging from insufficient offer in the renting market to investment driven decisions. Usually, ordinary people purchase the house that they can buy, not the one that satisfies their needs; exceptionally, but increasingly, people sometimes enlarge mortgage duration to gain access to better, although not necessarily more suited, products. The enlargement of the period of mortgage results in the fact that people take more time paying and in extremis pass the burden to the next generation. While the acquisition is generally interpreted as a good investment it is also truth that the property emerges like an anchor, bringing some complexity in case of individual's requirements which force the exchange. In result, the permanence on it throughout lifetime is real.

According with different documents (Eurostat, 2008; Communities and Local Government, 2008) it is possible to state that European society is ageing bringing a new relationship between home, health, care and social participation within community:

"The ageing society poses one of our greatest housing challenges. By 2026 older people will account for almost half (48 per cent) of the increase in the total number of households, resulting in 2.4 million older households than there are today. By 2041 the composition of the older age group will have changed dramatically. There will be a higher proportion of the older age groups, including the over 85s, a greater number of older people from black and minority ethnic groups, and double the number of older disabled people. One in five children born today can expect to live to 100 years old." (Communities and Local Government, 2008:14)

Observing the reality, it is possible to affirm that young people reveal more community participation by their physical conditions and energy while people with more age or by temporary or permanent impairments prefers (or is forced) to stay at home. Sometimes this distinction is based on the exclusive solutions presented by the built environment, which by its design or construction methods excludes people who don't achieve the percentile 50, or in other words, the average man. Frequently, the solutions encountered reveal safe and security responsiveness; yet they need also to attend inclusive considerations. Planning in the future requires that considerations of inclusivity should be taken, conceiving solutions which allow the participation, enjoy and integration of the individual with the house and the neighbourhood environment.

"We all want to ensure that we can stay independent in our own homes as long as possible. But age brings with it a greater acknowledgement of interdependence with family, community, services, and neighbourhood." (Communities and Local Government, 2008:20)

The reality of the life expectancy and the enlargement of the mortgage duration endorse the concept of Lifetime house. "Lifetime Homes standards is a cost-effective way of providing homes that are adaptable, flexible, convenient and appropriate to changing needs. They enhance choice, enable independent living and help to create more balanced and inclusive communities.” (Greater London Authority, 2006:vi)


Figure 1 & 2: New ways of living within dwelling environment. (Greater London Authority, 2006:20)

The principles that support this concept (Lifetime Homes, 2010) defend more than accessible solutions, which mean that these environments although driven to special people requirements can be comfortable and appellative to everyone, considering the inclusive design concept and a sustainable understanding: “All the residents the researchers met appreciated the sense of extra space and convenience built into the dwellings. Not all had mobility impairments but with children and increasing numbers of people working from home, all valued the flexibility of their space.” (Greater London Authority, 2006). The main idea is to identify the major requirements presented by individuals and try to fulfil them through typological and technical suggestions/solutions. Some importance should be given to a constant requirement from lifetime homes’ inhabitants which are the need of some extra space which means more flexibility without compromising area considered to social interaction. The knowledge provided by different experiences, mainly the information gathered from inhabitants who chose to live in lifetime homes environments allows identifying the more and less positive issues towards the improvement required by new communities. It is also relevant the knowledge obtained by the questioning of this nature of population. A recent discussion with aged individuals allowed the Communities and Local Government to achieve their aspirations and concerns:

- “Housing should be well designed with growing older in mind; it should meet the needs of all age groups. We should build adaptable ‘homes for life’.
- Space is important: we often need room to accommodate visiting family or a career, and need good storage space.
- Housing design should be user-friendly, low maintenance and safe – a downstairs WC and bathroom with shower and bath are especially important. Our homes should also be affordable to heat.
- Access to green, private space, and a safe neighbourhood is important, as is housing that is accessible to good local transport, facilities and amenities.

- Access to independent information and advice about our housing options is needed.
- Support is necessary for people to stay living in their own homes. A reliable repairs and adaptations services is needed for that bit of help around the home.
- But above all, people want to be listened to, to be involved in the design of everything that will affect us, from planning and lifetime homes standards, to the creation of safer environments, to testing new equipment and IT device" (Communities and Local Government, 2008:21)

Figure 3 & 4: Area to social interaction. (Greater London Authority, 2006:21)

All over history, individual health was always directly related with dwelling conditions. Old people and people with special requirements expect almost the same from the house as young people: security, comfort and an aesthetical image. The concept of lifetime homes is based on the need of functionality of the dwelling environment to the user (not for the function or the equipment efficiency on itself). The solutions provided can be as simple as just the width of the corridor and the doors, or an accessible design to the bathroom and kitchen, yet, it is essential the integration of the individual also through the aesthetical considerations within the solution provided. Flexible solutions are needed to support new adaptations whenever required at an affordable cost.

The fulfilment of these reflections can contribute for a more sustainable and humanised built environment since urban environment should empower individuals to be active and participative in economic and social life, while promoting the security, wellbeing and inclusion of the individual despite his/her physical, sensorial or cognitive abilities and cultural behaviour. The lessons learned from this new approach to dwelling environment should be applied to every new property development and when possible on rehabilitation and requalification of existing typologies and it must not be understood as a stigmatised environment or community, driven to individuals with special requirements. Marketing is a fundamental tool to fight this preconception.

2.2 Smart houses

The last century saw the emergence of several technologies aiming the performance of the most exigent (in effort and time) activities. From the telephone and the washing machine to the computer, peripherals and mobiles achieved our attention and investment. Technology inhabits our houses and our ways of living creating the sense of assistance and dependency to accomplish the most simple or complex tasks. They appeared gradually, within particular houses and families but the standardisation of models and the intensive use of them democratised their existence within the majority of families and residences.

During the seventies, the concept of Intelligent building was launched, namely in some offices' buildings, on Japan, United Kingdom and USA. Their objective was, by electronic systems, the control of the facilities (security, alarms, energy consumption, HAVAC, etc.). The aim of this technology was the facilities management with special impact in energetic consumption and costs. On the nineties, this concept was applied to dwelling environment, raising the concept of intelligent home, based on domotics technology; the intention is the same as the one defined to public buildings. The technology that qualifies the smart houses certainly will go the same pathway. Until now, this concept is connected with domotics, and appears as a new concept mainly used on new constructions. Frequently this concept relates to the security of the house, allowing the local or remote control of intrusions. Nevertheless, smart house is a concept that goes much further than security control.

The development of ICT, with special attention to Internet and wireless technology, stimulates the connection between different equipment and the contact (driven by different causes) with and between institutions and individuals. Several authors defined with some nuances of the concept of Smart House; to avoid the preference of an author or the misconception between the diverse definitions, it was accepted the definition proposed by Smart Home Association in the Netherlands, which in 2007 defined smart homes technology as "...the integration of technology and services through home networking for a higher quality of living at home." (Tiresias, 2009a)

"The principal idea behind the smart home concept is to use networking technology to integrate appliances, devices, and services within the home in an effort to control and monitor the entire living space." (Sandström, 2009:13)

Different approaches to this concept have been applied to recent buildings; they depend on the users' demands and objectives to which the edifice is build. A more representative form of technology in our houses will be slowly introduced due to different reasons from which the need of a new mentality will be elected. According to Pragnell opinion, the identified reasons to this apprehensive increase are due to economical limitations, location and technology available, prices of the solutions, availability on the market and technical assistance of equipments, patterns of work/living and users' mentality, this idea is also defended by other authors (Pragnell, 2008).

"Smart Homes are about something much more exciting. They are about using the latest information and communications technology to link all the mechanical and digital devices available today – and so create a truly interactive house. They started by designers examining the way people live now, and then exploring how society might look in the future. This generated a number of new ideas that could improve people's lives and help them stay independent for longer." (Pragnell, 2008: IX)

The introduction of different technology inside the dwelling environment is a slow process which starts by the fulfilment of an activity requirement, rising on the residences which materialise a better economical situation and a location within a metropolitan area. At the beginning the related costs are elevated and it needs the standardisation to guarantee its access by the majority of individuals. More than including plenty gadgets and technology into a home, it is important to define what is really important towards health, safety and comfort of users. This sense of comfort is provided not only because the user can be informed about possible intrusions inside the house (which can be more a sense of constant concern than a sense of well being) but also by the communication between different technologies to recognise and react to occupants' routines. On this matter different research projects exists, however it is important to mention two of them: *AMIGO* because of its involvement with industry and the *Making Smart Homes Smarter* because it is an academic research project with a curious interpretation of Smart Homes concept; both can illustrate how academia and industry have the same research interests, and how users can gain from a closed collaboration.

AMIGO was funded by the European Commission which aims to "develop open, standardized, interoperable middleware and attractive user services, thus improving end-user usability and attractiveness". The concept of networked home or connected home permit that home appliances, such as heating or lighting systems and personal devices, such as mobile phones are linked into the home network in an interoperable way. The big issue is the effort made to focus the project on users, questioning, answering and validating the data throughout a user-centre design process. (AMIGO, 2008)

Making Smart Homes Smarter, is a research project developed at Ulster University, conducted by Dr Juan Carlos Augusto which aims to develop technology to improve the assortment and the quality of services that buildings can offer for their occupants. "The architecture of a house can be enriched with different sensors to detect movement and identify the cause of the movement. The technology can also be used to gather medical information which could be vital for people who live alone...One example would be to help older people by spotting when they get into difficulties. It could also improve security around buildings detecting unexplained movements or to help diagnose health problems before they become serious". (PressOffice, 2005)

From these two projects it is easy to understand and envisage the interesting and useful direction that this area of knowledge is pursuing. In fact, home should not be a project made by investors and architects (and another technicians from construction cluster) where their concepts or preferences overcome users' requirements; nor a technologic experimental depot, where the continue experience can lead to technological evolution yet forgetting the user that perceives dwelling environment with his/her senses, mobility capacity and daily life routines.

"In this technological vision of the future, our homes would need to provide spaces that can be programmed for work, education, and entertainment. New forms of interactive space will be needed rather than the traditional rooms in which activities are dictated by the needs of various biological functions. Rooms could provide sites where:

… bits meet the body – where digital information is translated into visual, auditory, tactile, or otherwise perceptible forms, and conversely, where bodily actions are sensed and converted into digital information" (Mitchell, 1995: 105).

An issue to consider is that Ambient Intelligence does not need nor use intrusive technology yet it can be tailored to the human being. The crucial issue is to engage users within the design process. Quoting Bierhoff and Panis, "Involving users in this case means not only consulting them when the product is finished, but giving them an active role in the design process and the actual shaping of Ambient Intelligence." Inclusive prototypes and tests to experiment and to validate results will be also an important contribution to a more qualified solution. The inclusive design concept comprises the use of the equipment as well as the usability provided by the communication panels conceived to interact with individuals.

According with the statement of Dr Juan Carlos Augusto, there is like a trend allowing different houses to be called "smart houses"; however it will become "hard to say how many actually deserve the label - as this depends on where the line is drawn between something behaving intelligently or not." (PressOffice, 2005). An interesting example can be given by a house built on Ericeira (Domática, 2009), a village located within Lisbon Metropolitan Area, near the sea and around 40 miles from the city centre. This is a luxury house, where the concept of Smart (dumb?) House is (theoretically) applied. In its interior it is possible to identify the security system, the computer which controls different equipments and allows the connection between the freezer and the supermarket, the home cinema equipment. But, looking at the pictures (see below), although fashionable and appealing, it appears everything but inclusive.

Figure 5,6,7,8 & 9: House of the future, Ericeira, Portugal (Domática, 2009)

All, or most, of the solutions can be (today) qualified as superfluous or luxurious but, based on the experience of the last century will be normal requirements within a very brief period of time. Nevertheless, a serious study should be taken, including professionals and users, to identify their requirements and aspirations: answering to human needs can be the driven force to their acceptance and general use.

3. Inclusive design – the user as the main issue

The cities' growth during the last century followed an unsustainable model, both to their identity and the quality of life provided to their inhabitants. The use of the car in daily life expanded the distances between residence and workplace, families and individuals, like no other mean of transportation.

Inclusive design, a conscious and human centred way of conception, (products, environments or communication systems) envisages the right of equal opportunity for individuals with different (physical, sensorial or cognitive) characteristics. The last decades provided the eco for the equality between individuals. Despite racial reasons, sex, religious or political options, several institutions reclaimed the opportunity to participate in public and private lives, in equal conditions. Remarkably, people with special requirements and senior citizens are still living of governmental or familiar help, locked at home, as they cannot find in the community environmental conditions or equipments for their requirements. If human engagement is not a strong argument anymore, or just because models which defend the rejection of individuals who do not fit the "average" are still up to date, the economical argument is increasing in importance as in reality.

European population is aging, and this population should be active and participative. In practice, the big majority lives by retirement, unemployment or impairments aids, contributing to the deficit of social security. Individuals with special requirements, specially the sensorial ones, depend on parents and relatives support and sometimes from neighbourhood charity. To get support of official institutions requires plenty of bureaucracy and years of expectancy and wait. The traditional European age pyramid is changing dramatically, demonstrating that the number of individuals with more than 65 years old is more or less in the same proportion as young people (Eurostat, 2008). Although a considerable number of individuals present some deficiencies and impairments, the most significant are the "deficiencies" provided by contemporaneous life style. Loneliness and isolation are the consequence and this is the model since Antiquity, defended by different philosophers and religions alike. (Simões & Bispo, 2003).

Nowadays, residential typologies perform a conceptual model which presents aesthetical considerations with remarkable quality, yet absolutely failing to fulfil the requirements of real life (Gomes & Aouad, 2001). Considerations should be made to impairments during life, but mainly new types of life style such as telework, mono-parental families, elderly / child care which need functionality, security and a comfortable and healthy environment. The way to balance both life cycles requires flexible environments conceived to a contemporaneous personality.

In view of the character of contemporaneous life, it is important to define the population, its anthropometrics and ergonomics and its life style. If the percentage of people with physical or sensorial diseases / impairments is not considered significant (once compared with all population), the proportion of elderly is significant. From the user perspective it is important to mention that everyone wish to delay the day that, by behavioural dependency, needs to exchange home and memories by an assistive facility called in jargon and hopelessness language as the parking place for the next travel. The move to an assisted housing is so humanly painful as expensive for individual and direct relatives. Here, the promotion of humanised dwelling, flexible enough to support (or to be adapted) the natural pathway of live is more than desirable is fundamental. Technology on its different forms and objectives can be a helpful meaning to arouse this objective. However, pilot studies will be needed to accomplish a positive result. Technology is frequently identified with extra expenses and complexity, motivating the sense of fear of the unfamiliar, intrusion and lost of control. Another critical concern is the common idea that the use of technology reduces the need of movement or interaction; in result technology should be implemented in response to human needs, if the individual presents mobile difficulties, technology should help him/her towards the right of participation; if this is not the case, technology implemented should be able to promote also the activity and interaction which are fundamental for avoid social participation and segregation. The objective of inclusive design, is not to promote special environments to special people but to conceive ambiences which by good design solutions motivate (as equal as possible) the opportunity to everyone deal with its rational, social and emotional needs (Tiresias, 2009).

4. Conclusions and further work

Contemporaneous society presents a new paradigm, with an aged but healthy and active population, who aims and needs more inclusive environments. The planning of the cities in general and the planning of habitats in particular shows a lack of human concerns within their conceptual process. Economic profits, doubtful management and political decisions reveal their influence on the built environment.

The majority of individuals in the United Kingdom as in Portugal own their homes, an evidence resulting from deficient alternatives from renting property market or the will to invest in a trustable asset. The exclusivity presented by certain urban and dwelling environments, associates, frequently, this ownership with the difficulty to move into another habitat in response to the user requirements. In consequence there is a need to endorse communities and habitats which promote independency, security, health, and wellbeing to people that can live their lives as long as possible with their relatives, friends and memories around them.

Growing older motivates a need to be at home, by individuals' mobile or sensorial limitations, or just by individuals' choice. Despite this fact, even in Metropolitan Areas, there are plenty of old individuals who live in precarious, non-decent, inhumane or even hazard conditions. These characteristics, according with the available data, have a significant impact in elderly safety, contributing significantly to the social costs (hospital and convalescence internment or institutional supports). Older people prefer to stay at home rather than moving to another solution; still, as mobility or any health configuration declines they will need some help to enable the permanence with the safety and comfort guaranty. Flexibility is the main idea behind the conception of new dwellings or the renovation of the ancient ones; solutions must be encountered to promote the balance between the building and human life cycles. The announced flexibility can be achieved by the adoption of Lifetime Homes concept, which aims to promote an inclusive environment, through layout configuration, construction process and interior finishing, integrating any personality, and being flexible enough to allow, if necessary, any upgrade to match the users' requirements. A better solution can only be achieved by a close collaboration between planners, architects, engineers, promoters and users.

Public spaces and dwelling design must contribute to inclusion within built environment; a responsive approach to this question can lead to qualitative solutions, through security, safety, well-being as well as social participation and the sense of community. To achieve this goal ICT can be a precious help.

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Technology and Governance: Enhancing Participation Using Geographical Information Tools (GIS) in Low Income Settlements

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Abstract

This paper explores how the integration of technology based tools (Geographic Information Systems and Remote Sensing) in settlement mapping and subsequent upgrading using has impacted on planning processes particularly with regards to community participation in Kenyan context. Upgrading programmes are designed to address the existing poor infrastructure conditions or lack of secure tenure usually associated with informal settlements. Planning processes have adopted inclusive approaches which are geared towards getting all actors including the resident communities, involved in decision making and planning for interventions. GIS tools offer a platform for integration of spatial and non spatial data as well as visualisation of the settlements. The capabilities offered by these tools have enabled communities to participate especially in the planning and management of new infrastructure as well as settlement upgrading. As development-related decision-making invariably has an explicit spatial context or component, a part of the information processing and exchange will be spatial or geographic information. Participation in development issues therefore involves at least a component of spatial information. The paper examines the context and implication of technology adoption within planning at settlement level within low income settlements of Kenya.

Keywords: GIS, informal settlements, participation

1. Introduction

Information regarding attributes of human settlement is important for decision makers at all levels of planning, as they have to grapple with dynamic environments often associated with settlements. At the local level, it is particularly important for both communities and urban managers to have accurate and reliable information regarding all planning attributes. The use of GIS tools in settlement mapping and upgrading provides a platform for integration of spatial and non spatial data necessary for planning and decision making. The capabilities offered by these tools such as visualisation have enabled communities to participate in settlement planning and upgrading including the management of new infrastructure.

Information and communication technologies (ICTs) including GIS and remote sensing, are regarded as one way to support integration of local knowledge and scientific information and to support spatial planning (Freitas and Tagliani, 2009; Kyem, 2004). GIS has the capabilities to manage large spatial datasets, while the integrated spatial analysis tools allow decision makers to make more informed decisions with the development of multiple scenarios (Isaak and Hurbert, 1997).

Settlement upgrading work carried out in New Rest settlement, Cape Town, South Africa demonstrated how spatial information and GIS was valuable and could be applied in settlement upgrading. In this case spatial data related to the shacks (structures), their occupants and physical conditions was analysed within a GIS environment. A settlement database linking structures, infrastructure and demographic characteristics was developed and used to generate spatial models of the settlement. Aerial photos in this case were used to provide spatial data regarding the settlement. Community surveys and observation methods were used to obtain demographic data and infrastructure data respectively (Abbott, 2002). Abbott maintains that GIS facilitates a visual representation of spatial and attribute data which provides the underpinning technology for informal settlement upgrading, while geospatial information management provides the framework for the wider upgrading to support their negotiations with the local authority. In similar settlement upgrading programmes in Philippines, communities used aerial photos and satellite imagery for data acquisition. Analysis of these images was carried out using a process termed "participatory image interpretation"(Gonzalez, 2000). Images and aerial photographs on settlements are an important instrument in mobilizing residents since they provide an overview of their areas for identifying problem areas and exploring possible solutions together with planners (Nostrand, 1986).

In an upgrading project in Kosovo, data obtained by way of community survey and aerial photos was entered into a database and GIS respectively. Working in a GIS environment allowed for data to be mapped and spatially represented.. . A unique approach was adopted in this project where data compiled was handed over to the community for authentication and reference. This approach showed a move in the direction of 'action oriented' urban planning theory because the data did not remain in the hands of the municipal office, but was given back to the community it represented allowing them to use it for their own as well as other purposes. The case presented here depicts a good example of the collaboration between local community and local organisations and the city / municipal authority and use of GIS tools for informal settlement planning (Garstka, 2009).

It is important to take note of critics concerning use of GIS tools within planning processes and participation. GIS and related tools have the potential to alienate and exclude non geo-information and technology experts. The use of such technology carries the risk of undermining participation rather than promoting it (Craig and Harris, 2002). This may be the case in developing countries and particularly informal settlements where communities have limited access to basic services including information and communication technologies.

This paper illustrate how the application of technology based GIS tools has enhanced community participation within informal settlement upgrading programmes in Kenya. This is done by presenting a case study where GIS tools were used within Mukuru Informal settlement located in Nairobi city, Kenya. This is one of the largest informal settlements in Nairobi and home to over 100,000 people. The living conditions within the settlement are poor. Majority of the households have no access to clean water, sanitation and live within crowded environments. This is typical of many informal settlements within urban areas in Kenya.

1.1 The actors, participation, decision making and GIS tools

Four main actors or stakeholders play a crucial role in the urban upgrading process. These include; the community, local authority, non-governmental and community based organisations, and the international donor community.

The International Association for Public Participation - (IAFPA) 2006 articulated five levels of public participation – inform, consult, involve, collaborate, empower. Each level enabled a participant with increasing and meaningful impact on the overall process. The use of information tools such as maps, aerial photographs and interactive Web sites for public comments was common within the lower levels of participation (inform, consult), The higher levels of participation (involve, collaborate, empower) required analytical tools for "what-if" simulations of decision impacts in addition to utilizing informational and communication tools.

McCall (2003) presents a perspective regarding effective participation. He sees facilitation at one end, empowerment on the other, and mediation and collaboration somewhere in the middle. Different groups of public intersected with different types of participatory processes pose different requirements for technological support including GIS. Understanding the domain in which the participation takes place is essential to the credibility, efficacy, and theoretical foundation of such participation. Internet GIS for example, is suited to internet-savvy public, but disadvantageous to those who did not have access to the use of the tool (Schlossberg and Shuford, 2005).

> *"Large-scale, replicable upgrading of informal settlements is only possible through the use of spatial information technologies. The primary objective of upgrading has to be the social and economic development of the community. For GIS is to be used effectively, it has to support this process. It is not simply a technical tool to underpin physical development...it should be seen as a tool that liberates local authorities, communities and professionals...and allows for the interaction between the spatial and physical elements on the one hand, and the social and*

economic opportunities on the other, in a three-dimensional virtual environment" (Abbott, 2003)

The use of Geo-information technologies for informal settlement upgrading and related urban planning activities is widely recognised (Hasan, 2006; Aksoylu, 2005; Barry, 2005; Glöckner, 2004; Sliuzas, 2004; Ceccato, 2000). The starting point is the recognition that large-scale, replicable upgrading of informal settlements is only possible through the use of spatial information technologies (Abbott, 2003). The successful implementation of GIS tools for slum upgrading depends on the tool supporting improvement of social, economic and environmental conditions within the settlements concerned. GIS tools are seen as tools that liberate local authorities, communities and professionals from the constraints of paper-based space, and allows for the interaction between the spatial and physical elements on the one hand, and the social and economic opportunities on the other, in a three-dimensional virtual environment. This then allows all parties to work in a much more interactive way to address the multi-faceted nature of informal settlements (Abbott, 2003).

1.2 Technology integration and upgrading process

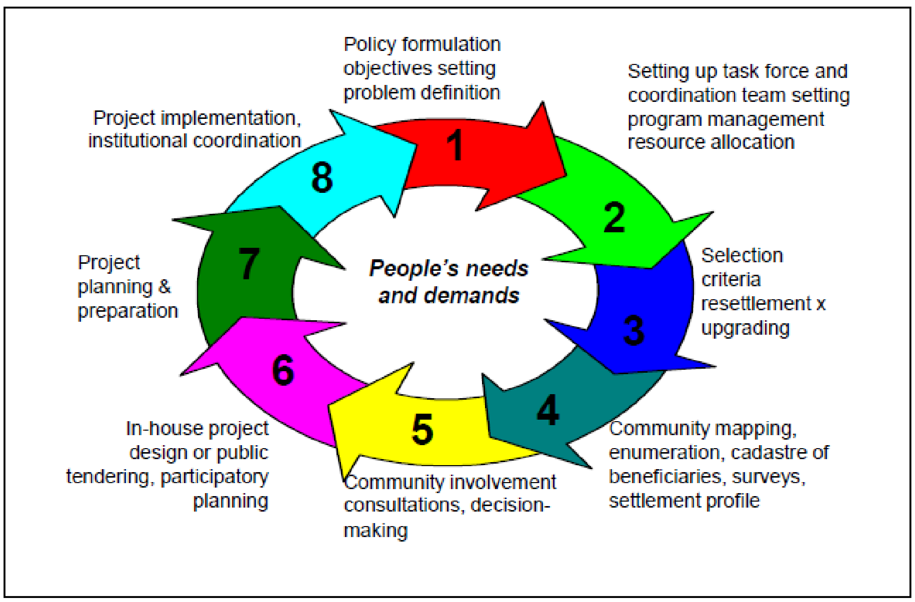


Figure 1: Informal Settlement Upgrading Cycle (Source: Acioly, 2009)

In the upgrading process model by Acioli, the potential of GIS tools integration is clear within the community mapping and enumeration stage. Community mapping , enumeration and survey may use GIS tools. Spatial data regarding settlement layout may be obtained from remote sensing images whereas GIS tools provide a platform for analysis and visualisation of settlement data captured during survey or enumeration carried out with the assistance of resident community members. Data collection using community surveys or enumeration, aerial photography or satellite imagery, yield raw data defining settlement characteristics. Enumeration using questionnaires and checklists for example provides data that is not collectable using remote sensing sources (imagery and aerial photos).This data (non spatial) may include access to basic services and population characteristics. A GIS platform is able to analyse spatial and non spatial data sets and provide information and visual models regarding the existing situation. The models obtained after GIS analysis provide useful information in the form of indicators about the situation or challenges existing. These indicators provide planners and decision makers with information for decision making towards addressing issues to improve the living conditions or infrastructure status within a settlement. Data to be collected and analysed is determined by the objective of the project or intervention strategy. This process may be driven by development partners or communities themselves in-order to gain a better understanding of their environment. The information generated may also be used as a tool for bargaining with local authorities, thereby empowering communities.

2. Methodology

2.1 Study context

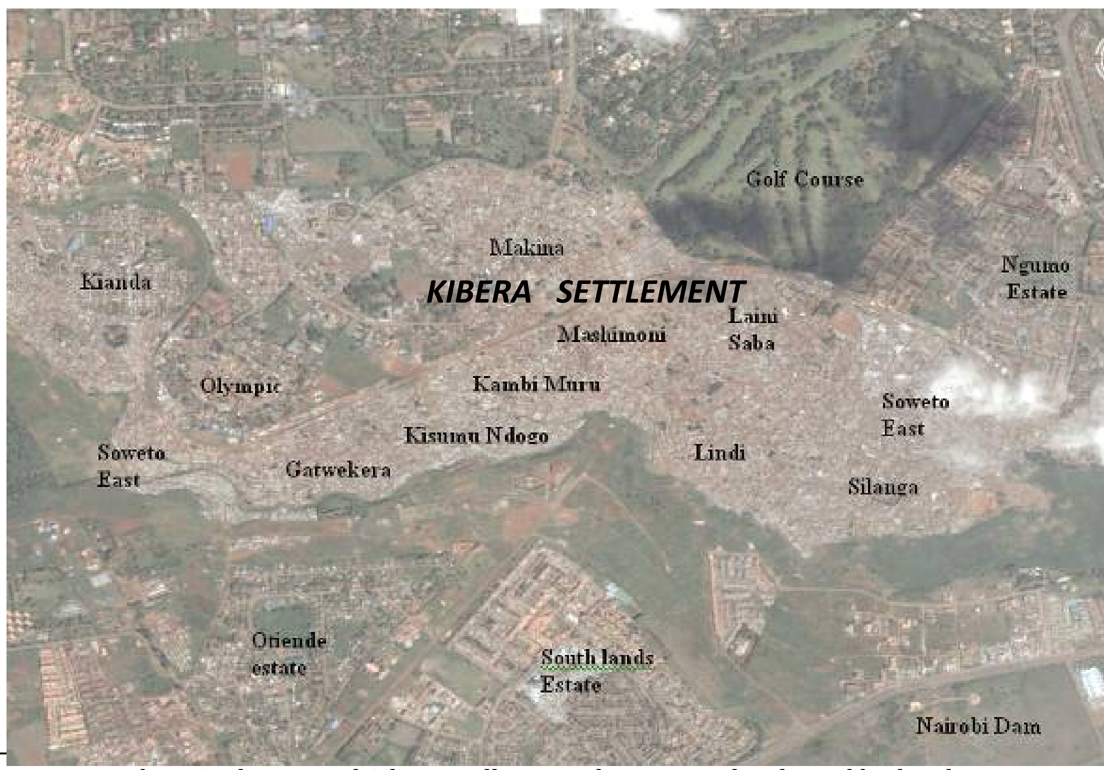


Figure 2: Kibera Settlement and Silanga Village: Study area Local and Neighborhood context

Silanga village is located within Kibera informal settlement in Nairobi City. Nairobi city started as the capital of the British East Africa Protectorate during the construction of the railway line to Uganda in the 19th century. The city like many others within sub-Sahara and developing countries is characterised by formal and informal setting with regards to human settlements. Informal settlements have grown over time to house the increasing urban population largely due to rural urban migration and natural growth causes. Informal settlements are growing at a rate of about 5 percent per year and accommodate a total population estimated at over 1.5 million (representing approximately 60 percent of the population of Nairobi Informal settlements, occupying approximately 5 percent of the total residential land area (Syagga, Mitulla and Gitau, 2002; World Bank, 2006). Most significantly two-thirds of slum populations survive on less than one dollar per day (APHRC, 2002).

There are six main informal settlements that trace the evolution of slum informal settlements in the city of Nairobi. These are: Kibera, Mathare Valley, Mukuru, Dagoretti, Kawangware and Korogocho. However, the provision of basic urban services within these settlements has not kept pace with their rapid growth. In 1993, just 45 percent of the city's residents had access to potable water, and only 63 percent had access to regular waste collection (World Bank, 1999).

3.2 Study objective

The main objective of the study was to develop a settlement information model or system based on geographical information system (GIS). The expected outcome would be used a base for future monitoring efforts and also one that is operated by the community itself. Other objectives included;

- Determining the current levels of infrastructure within the settlement including water supply points, toilets, and roads of access,

- Mapping relevant attribute data such as population, ownership characteristics, housing and land use patterns,

- Provide outputs and information that may be used by community and development partners for decision making,

- Develop a model that may be implemented and improved upon for monitoring slums within the city of Nairobi and country as a whole.

To develop a settlement information system, Geographic Information Systems (GIS) and Remote Sensing tools were used. A settlement image was obtained from a high resolution satellite image (1 meter resolution). From this image spatial objects / features were delineated. Other information obtained from the image included structures / buildings, roads, vegetation, rivers and streams, and other infrastructure like power lines.

Figure 3: Part of Silanga settlement with high density development of structures

The model above presents a section of the village that also depicts the character within similar settlements. Using feature identification tools, the individual structures were isolated and given unique IDs. For each structure, data was collected and analyzed within a GIS environment. Models showing spatial characteristics of attributes were developed and used for decision making.

3.3 Data collection

Data was collected by use of a checklist and as well as observation methods. The data collectors were drawn from the settlement and comprised social workers and youth group members. This was done in conjunction with staff members of a Practical Action (Non Governmental Organisation) in order to develop capacity within the residents of the settlement. The residents who were trained on enumeration skills were expected to collect data on a continuous basis to support future monitoring activities.

Attribute data was collected on the following aspects;

- water supply,
- lighting and cooking energy sources,
- solid and human waste disposal methods,
- accessibility,

- population and structure ownership,
- housing conditions, and
- economic / small scale economic activities.

This data was inputted into a Geographic Information system (GIS) for analysis and generation of outputs.

3.3.1 Role of the community

This was done with the help of community members from the settlement. The direct involvement of the community was justified given that they had first knowledge regarding the settlement and related developments. The process of integrating community members started with sensitization and information dissemination. It was necessary to inform the wider community on the purpose and objective of the exercise. This initial phase prepared residents to expect enumerators and data collectors in their homes. Training on structure identification using the settlement image was provided by members of Practical Action and the consultant / researcher. Having lived in the settlement for considerable periods, the residents were able to orient easily and identify key landmarks. During this phase, each structure on the ground was given a unique identification number which corresponded with the number in the GIS statistical database.

3.3.2 Tools: visual interpretation, observation and questionnaires and checklists

Visual interpretation was used to identify structures on the image and locate them on the ground. With local knowledge, the trained enumerators were able to locate structures on the image and locate their precise location using land marks like roads and open spaces. Attribute data pertaining to the structure was obtained by posing questions to the structure owners and tenants alike. Observation methods were used to collect data relating to the structures. Data regarding building materials used, availability of water and sanitation facilities was gathered by way of observation. To determine population numbers per structure, a physical count was conducted. Where residents were absent, neighbours would be used to collaborate and verify numbers of persons residing within a particular structure. Questionnaires were used to gather information on structure ownership, rent, and other infrastructure availability and use.

3.3.3 Data integration and analysis

This was done within a GIS environment where attribute and spatial data was combined to give more information about the settlement. A database of all the attributes was developed and using Statistical Package for Social Scientists (SPSS) frequencies and descriptive statistics were generated. Below is a graphic presentation showing data integration model.

Spatial Information

Structure size, location, type, services, and number details provided.

Structure Attribute Information

Population, Infrastructure availability, Building material, Ownership details

Spatial and Attribute Data

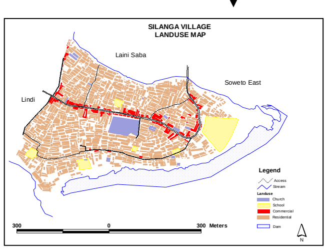
Integration

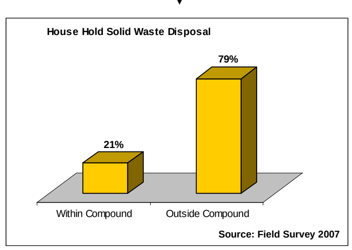
GIS

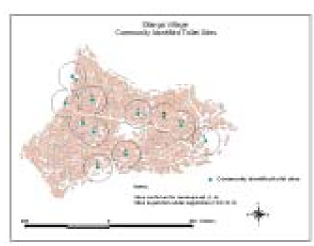
Database development

Structure Number	Water source	Number of Rooms	Roofing Material	Ownership Status
1478	Stand pipe	5	GCI	Male
1290	Stand pipe	8	GCI	Female

Spatial models and statistical outputs







3.3.4 Discussion of Results

Documenting and mapping informal settlements and their attributes has important repercussions for urban policy, planning and infrastructure investment, and provides a platform for people's involvement in development. The analysis of various indicators provided a detailed picture of the situation within Silanga settlement. For each variable, a spatial model was generated showing which areas and structures within the settlement had access to a particular infrastructure like water and sanitation. This information enabled decision makers and interventionists, including NGOs to determine which locations deserved attention / infrastructure supply. The overall objective was to improve livelihoods locally and achieving the Millennium Development Goals locally and nationally.

3. Sector based analysis

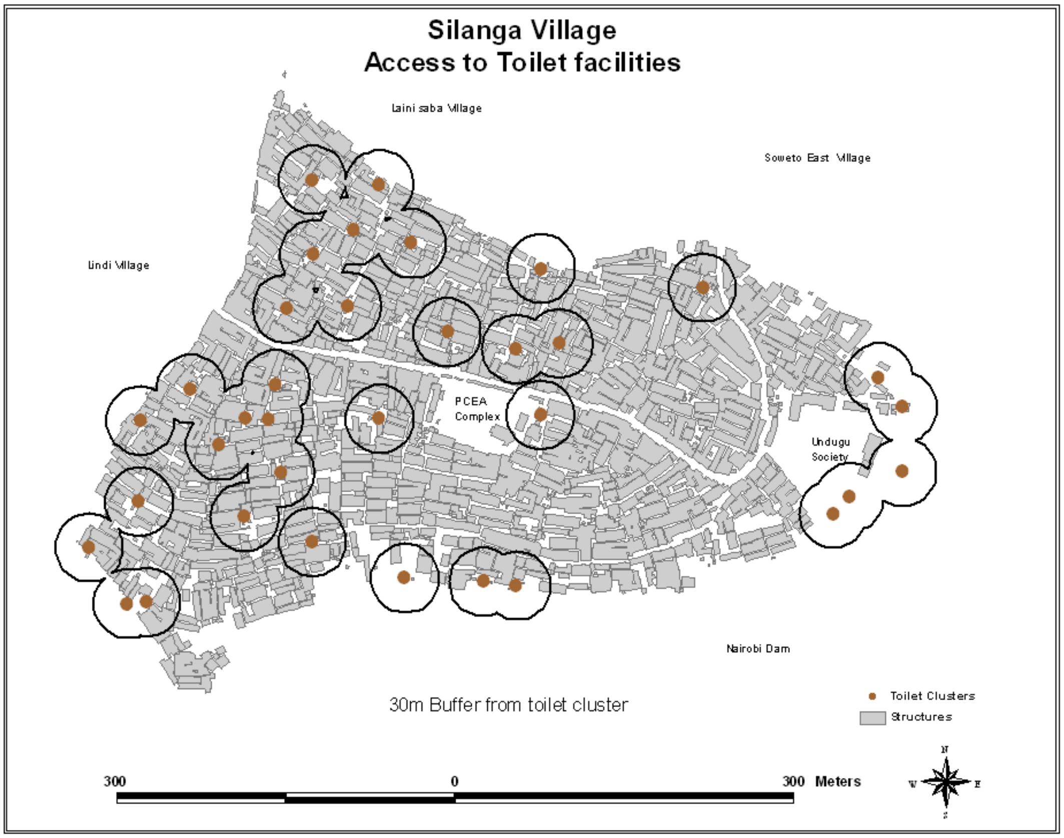
Spatial analysis and models were produced for each of the attributes were data was collected. Settlement models based on data pertaining to infrastructure availability, land use and population were developed.

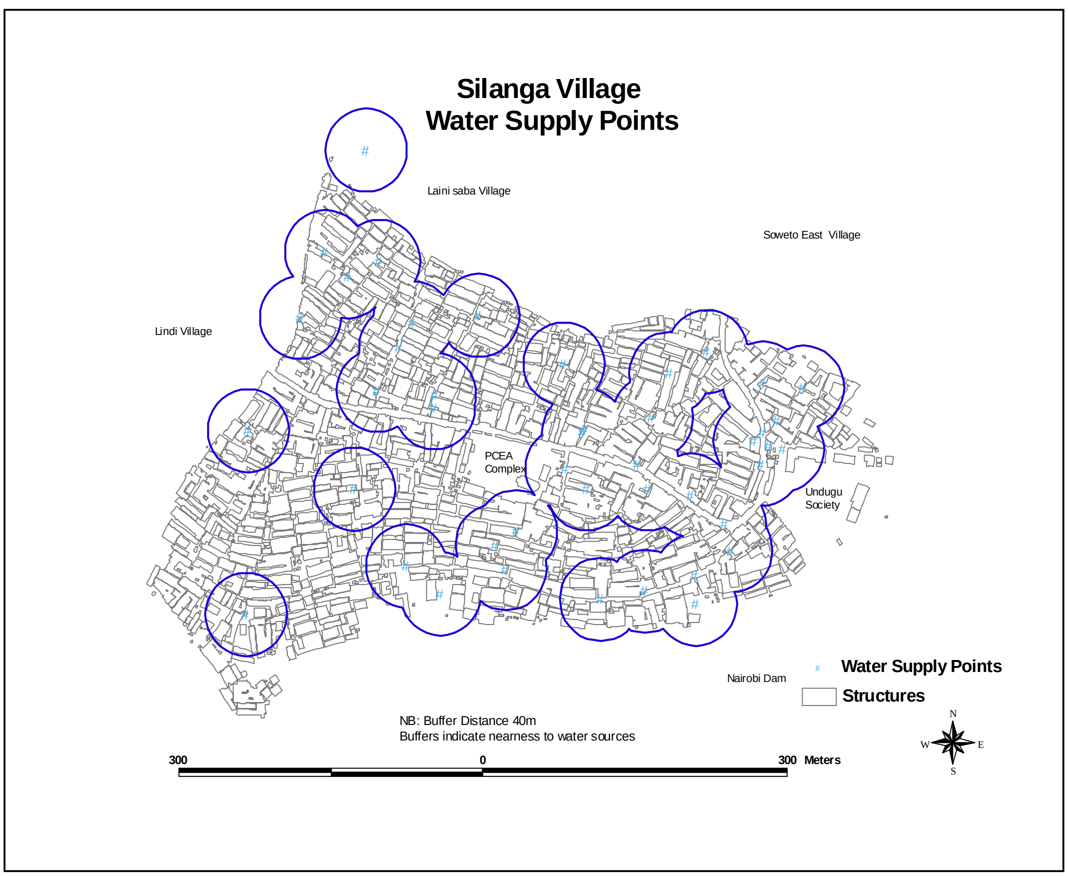
Upon spatial analysis and modelling, pockets of residents without access to water and sanitation were identified. Water and sanitation are regarded as central components of many slum upgrading programmes.

The lack of adequate sanitation and clean water was seen as a major source of public health problems within Silanga settlement. Diseases like diahorrea and dysentery are easily spread in environments with poor drainage and sanitation facilities. Poor excreta disposal will lead to the contamination of water sources as well as the general environment.

Within Silanga, only 16% of the structures had on site pit latrines while 84% did not have the facility within the compound. Residents relied on facilities located far from household. The available toilets within the settlement were shared and at times residents would pay for the use of the latrines.

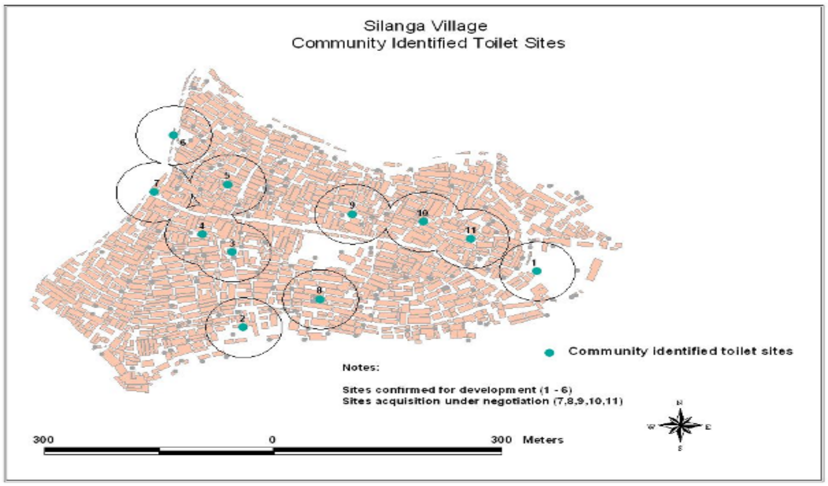
Figure 4: Toilet facilities within Silanga


Silanga Village
Access to Toilet facilities
Laini saba Village
Soweto East Village
Lindi Village
PCEA
Complex
Undugu
Society
Nairobi Dam
30m Buffer from toilet cluster
Toilet Clusters
Structures
300
0
300 Meters


Silanga Village
Water Supply Points
Laini saba Village
Soweto East Village
Lindi Village
PCEA
Complex
Undugu
Society
Nairobi Dam
Water Supply Points
Structures
NB: Buffer Distance 40m
Buffers indicate nearness to water sources
300
0
300 Meters

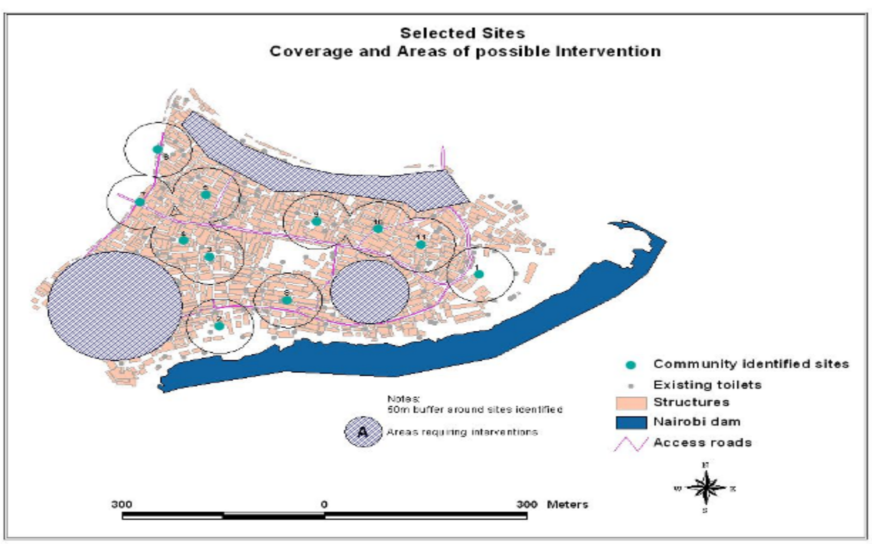
4.1 Using the results for decision making

Based on the results of the spatial mapping of attributes, residents were asked to identify suitable areas for construction of new toilet blocks to provide better access. In this case, GIS supported tools and outcomes facilitated communities to participate in decision making. The results of their selected



areas was influenced and supported by the settlement spatial models.

As part of the intervention strategy, residents were asked to identify suitable sites for new toilet blocks. The selected sites were superimposed on the settlement spatial model to determine their suitability. After analysis of the sites, areas deemed to be well served were identified. A buffer or access distance of 50 meters was used to determine areas to be served by the new toilet blocks. With the spatial model showing new and existing sites, areas that required intervention were identified. This helped programme officers and residents in determining areas to address and invest in new toilet infrastructure, to ensure all residents had access to services.



Site 10

Site 6

Site 1

Site 7

Site 2

Community identified toilet sites

4.2 Enhancing participation using GIS in low income settlements

If technology based tools including GIS and Remote Sensing are to have in impact within informal settlements and enhance participation, the following issues need to be addressed. There is need to ensure the settlement database is regularly updated to reflect the dynamic situation within settlements. Informal settlements owing to continuous population growth are bound to grow vertically or horizontally where space permits. This is bound to increase demand on existing infrastructure. Stakeholders need to consider access to information. Specifically, communities should be able to access databases, information and spatial models (whose construction has community input) for various use including advocacy and future planning. To ensure sustainability of settlement information systems, the stakeholders must make sure these models address community needs such as planning data. The primary goal of any urban upgrading project is to meet the needs and vision of the local residents. Therefore, a settlement information system based on GIS should provide information to land owners and tenants within the settlements for planning.

A settlement information system model is presented below, which outlines the key stages to be followed with regards to integrating GIS tools within upgrading informal settlements. The model is divided into two phases, the primary and secondary phases, where the former is entails legal procedures of notification, base map development and sensitization of landlords and tenants. The secondary phase entails data (spatial and attribute) management, data analysis and output generation, and communication, feedback and planning aspects. In all these phases the community is well integrated and involved. This ensures the process is inclusive and provides an opportunity for communities to participate in the decision making.

Examples of GIS tools facilitating and enhancing participation by communities have been documented. In the Pune (India) and Karachi (Pakistan) slum mapping, marginalised men, women and youth from these settlements participated in data collection and other mapping processes which illustrate the importance of communities in the development process (Hasan, 2006; Joshi, 2002). The participation by community members helped to increase the legitimacy of the data collected and mapping process adopted. Communities through elected committees are able to voice their concerns to higher levels of decision making organs as well as lobbying for resources for development. In South Africa, development partners, local authorities in partnership with the communities developed a GIS based approach to informal settlement upgrading which aimed at empowering the community, both through the provision of detailed information on the community and then by the use of that information to support their negotiations with the local authority (Abbott, 2003).

4.2.1 Model for settlement information system development

Primary stage

(Introduction, notification and justification, planning of approach consensus building, data collection, training of data collection teams)

Notification and information to the settlement committee

- *Introduce purpose and objective of scheme*
- *Actors Settlement Committee, provincial administration and interested NGOs*

Establishment of a sub committee to implement the proposed scheme

- *Consensus building*
- *Nomination of members from each zone into sub-committee*
- *Development of a structure numbering system or adopt existing one*
- *Actors Community and settlement committee*

Develop a base map

- *Definition of settlement boundaries*
- *Spatial data acquisition*
- *Actors NGO representatives and settlement committee*

Sensitization of structure owners and occupants

- *Expound on the purpose of the scheme*
- *Address benefits of the scheme to all*
- *Identification of actor roles*
- *Actors Structure owners, tenants, and committee*
- *Nomination of youth or settlement members preferably 2-4 from each zone for data collection*
- *Introduction to data collection tools (Checklist/ questionnaire*
- *Training on spatial data interpretation*
- *Training on attribute data collection*
- *Actors Community, settlement committee, and NGO's*

Data collection

(Preliminaries)

Secondary stage

(Data analysis, output generation, feedback session, problem identification, planning, and sustainability issues)

Data management

- *Open a register for all structures*
- *Data entry*
- *Identification of information gaps*
- *Data collection to fill in identified gaps if any*
- *Actors Sub Committee, select group of data collectors, NGO's*

Data analysis and output generation

- *Data analysis*
- *Mapping of attributes using GIS tools*
- *Output generation*
- *Actors Select group, sub-committee, NGO's*

Communication and feedback sessions

- *Demonstration of generated outputs and feedback sessions*
- *Problem identification (magnitude)*
- *Preliminary identification of intervention scenarios*
- *Actors Entire community, and NGO's*

Planning sessions

- *Problem identification based on data collected and outputs generated*
- *Propose suitable interventions*
- *Consensus building*
- *Implementation strategies*
- *Way forward*
- *Actors Tenants, structure owners, groups(women, youth, environmental), NGO's, Administration*

4. Conclusion

The potential uses of GIS tools to enhance participation by communities within informal settlements in planning and decision making processes are significant. Information poor environments hinder actors including communities to participate in decision making processes. The setting within informal settlements where marginalised communities cannot access information and basic services results in exclusive practices and more marginalisation. The integration of GIS tools in planning and decision making processes enables "all" actors have equal access to information regarding their environments. In particular, the participation of women and youth in mapping and data collection exercises provides an avenue for them to better understand their world. Participatory GIS practices within informal settlements provide avenues for communities to communicate horizontally and vertically with peers and policy makers in an effort to address challenges within the settlements.

The risk of exclusion with the introduction of GIS tools is a possibility where communities are not information or technology driven. To avoid this sensitization and communication strategies should be tailored to offer soft landing for all actors. The communities within informal settlements have the advantage of local knowledge and experiences which may be tapped into to support settlement mapping processes. The decision making process is bound to benefit from local knowledge if again communities are involved in making decisions based on outcomes they have contributed towards. The use of spatial models developed by data generated by community led enumerations for decision making validates the planning process. Project support and sustainability is likely to be achieved under these conditions.

Much as the integration of GIS tools within slum upgrading has the potential of providing communities and development partners with better information and visualisation capabilities, there is need to consider continuous data updating. This is necessitated by the dynamic settlement environment where vertical and horizontal developments as well as population increase due to in-migration occur by the day. Communities should be encouraged to take up settlement monitoring and use the outcomes to plan for interventions and address new challenges that may arise. This however calls for the support of all partners especially the local government whose mandate includes providing basic services to residents.

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Sustainable Eco-Resorts

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Abstract

Figure 1: Camping Lounge

This research paper intends to show the emerging concepts in sustainable eco-resorts. The purpose of the study takes in consideration a case study in order to define basic principles in eco-architecture and eco-urbanism to develop rural areas. The research methodology is based on a single-case study. The results achieved, points to the emerging of a new paradigm in architecture, urban planning and tourism, and particularly to new formal solutions and specifications in technologies and materials and the authors used the case of the most popular area at international level, in Portugal, to illustrate the concepts achieved. The results show that low-technology is possible to increase good architecture and design. This evidences and conclusions allow the emerging concepts to be used in Mediterranean geographical areas.

Keywords: eco-architecture, bioclimatic, eco-urbanism, eco-resorts, sustainability

1. Introduction

The purpose of this study takes in consideration a single-case study in order to define basic principles in eco-architecture and eco-urbanism to develop rural areas, taking in consideration the most relevant research and theories based on the real world of camping and holiday parks in Europe. In the real world of camping and parks, the main idea of architects, town planners, surveyors and managers is based on proposals to contribute and resolve the economic and financial crisis with solutions supported by solar and aeolian energy, sustainable vision on architecture and urbanism, water supplies and eco-maintenance of buildings and materials and low-technology.

The study case research uses experiences in France (Montpellier and La Rochelle), Spain (Tarragona) and Netherlands, to support new directions in resort planning and design, according to recent theories in architecture and urbanism, such as, the principles supported by European Directives, Charts, Conventions and Recommendations, that refer the emerging concepts based on eco-architecture and eco-urbanism.The research uses a holistic vision and takes in consideration the antecedents that had led to modify the change of the paradigms from an industrial consuming society for a model that points in the direction of urban ecological sustainability. The objective of the research is to systemize a set of emergent concepts in the areas of the architecture, urban and tourism, in the way to establish an innovative program and, consequently, an urban and architectural proposal for a real context in the south of Portugal, more properly in Zambujeira do Mar, (Odemira, Alentejo).

2. Literature review (the emerging concepts in eco-architecture and eco-urbanism)

Until the decade of 80, of XX century, the related global problems with the ozone depletion and with the climate change are apriority for a minority of scientists who did not hear its voice in the medias. The few that had attended the oil crisis of years 70 forgotten the problem that the “energy crisis” raised and, each time, raise more. Why the smashing majority of the experiences in architecture and urbanism consumes so much energy and produce a great impact in the environment?

Based on the consideration that we do not learn the sufficient with the good practical examples or we do not systemize the technical standards which answer with severity to the sustainable principles of human being survival according to actual standards of life. (Emmanuel, 2005).

According to Emmanuel (2005) the questions related with the global heating, the exhaustion of the energy resources and the bankruptcy of the speculative capitalist model meet in an impasse. Today we reach the border between the concerns of sustainable comfort and the projection of conducive secular shares to the survival of the species (Geyer-Allely, 2002).

Our generation, probably, is conditioned to prevent future cataclysms provoked for a set of factors that, cumulatively, has come to play a basic role in the constant degradation of the ecosystem conditions of the planet. Almost two decades that we are going to create knowledge capable “to support” the development model, guaranteeing the occidental way of life to emergent countries that intend for in practical. According to possible scenes such as the considerable increase of the average level of waters of the oceans for saw of the global heating or the announced end of the fossil fuels, the world that we know would be obliged to move drastically (Stern, 2007). In such a way, we can consider that the climate changes, each time more visible, allied to the social changes and politics in the world provoked by the energy crisis need being equated according to a new “paradigm”. In this picture, it will be necessary to review the models currently acceptances for the organization of the built environment, in general, and of the architecture and urbanism in particular.

The “eco-resort” means a friendly environment development of the area and has assumed the figure of a concept of resorts whose localizations and destinations offer a set of products, services and animation related to the environmental questions. Referred by Baud-Bovy (1998) a resort is essentially a place developed for the sojourn of tourists, providing multiple facilities for their accommodation, recreation, entertainment, rest and other needs. Through the concentration of facilities the resort acquires an identity and character: it becomes a specific place to go to and to enjoy in its own right, in addition to serving as a gateway to other resources in the area. Tourist resorts enable the best use to be made of infrastructure and land and operational services.

In a next future the “eco” will have to be transversal to all this developments. A layer is not treated more than, a concept but yes of an imposition of market to the developments. This attitude came to be whichever the concept of the resort, the type of exploration or the classification for the development.

Based on this vision it is necessary to understand the emerging concepts in eco-architecture and eco-urbanism. Schwanke and al (1997) stressed that one of the primary objectives of resort planning and design is to create a sense of place and the effort begins with the setting. Planning and design are essential on shaping the setting, visitors’ or residents’ perception of it, and, ultimately, the sense of place conveyed by the resort in the context of its natural surroundings. Sustainability has become a widely applied concept – so much, that the meaning lost precision and definition; today, it probably acts more like a symbol of a necessary civilizational change, i.e. a different perception of human activities and values, in relation with an environment conscious attitude and accounting. According to Camagni (1996) and others (Marret, 1995; Fusco and Nijkamp, 1997; Lombardi and Basden, 1997), it is the following: "A process of balancing and integration (or co-evolution) between sub-systems, i.e. social, economic, physical (including the built heritage) and environmental". This process should be able to guarantee both: "a non-decreasing level of well-being to local community in long term (quality of life) and the reduction of negative effect in the biosphere (environmental quality)."

The word sustainable suggests the idea of constant, permanent or continuous and it is translated to some language as durable (e.g. Dutch, Finnish and French) but this may change the meaning of the concept. In this study, it refers to the “opening process” of all the fifteen “aspects” in a built environment and its community. A specific definition has been provided by Lombardi and Basden (1997), saying that: "Sustainability in the built environment is a result of the subjects related to the built environment acting in line with the laws of all aspects in an integrated and balanced manner over the long term, and threats to sustainability come from going against or ignoring the laws of one or more aspects". The concept of environment was also evolving, at the same time - from an almost identity with nature and the physical quality of its components affecting mankind, to the perception and evaluation of the surrounding universe, through social, economical, philosophical and cultural criteria, focused on the more subjective goals of "quality of life" and "sustainable development".

In the field of architecture, sustainability is now also becoming mainstream; but the seeds were already there for the last decades - mainly after the oil crisis of the 70s: - passive solar, bioclimatic, green and eco-architecture had often claimed for the need of a better relation with site, physical environment, resources, human scale and cultural diversity, pointing out the importance of local input and scale, towards a more humane architecture. Governments, specially of the industrialized northern countries, have supported the climate conscious approach that some of these trends proclaimed, on a saving energy policy basis; but up till now, failed to influence the majority of architects and public opinion - besides the first buildings formal inconsequence and certain lack of quality, the consumerist way of life that the industrialized world also sustained and publicized, and the civilizational blind faith on techno scientific solutions to dominate nature and mechanically solve problems, prevented a wide acceptance of an environmental attitude in the architectural process. A very representative number of architects and theorics choose the ecological principles as the reference to follow, in order to achieve the desired sustainability in architecture- even here with a wide range of attitudes. If one follows the original concept applied in the Bruntdland Report, and besides the optimal resolution of the binomial relation between resources, management and quality of life, sustainability requires also other fundamental aspects: - continuity, which translates better in the dynamic adaptation of a building (or urban fabric) to the continuous changing ways of life and specially, ethical responsibility towards next generations, to incorporate local and civilization information, seen as the essential resource to understand the past and to provide alternative paths to build the future.

Some authors consider sustainable architecture impossible, if a strict meaning is applied to the concept; in the context the definition was presented above, but it can be considered a redundancy, because a responsible architecture should always incorporate those fundamental aspects referred, regardless of programmatically, economical, formal or other conditioning aspects in the process of architecture design and implementation. However that is still not yet the case for the majority of the architectural approaches all over the world, and so, rather than another trend or formal style, sustainable architecture should stand for a basic integrative attitude to introduce in all levels of the architectural process. The bioclimatic architecture consists of the conception of buildings having in consideration the local climate, using to advantage the available natural resources (sun, wind, vegetation) with the purpose to get through the drawing and with low energy consumption a degree of comfort raised in the use of the building. The bioclimatic architecture integrates some climatic, ambient, cultural knowledge and partner - economic finding only solutions for each design. The application of bioclimatic strategies in the buildings is essential to reduce energy consumption and carbon emission. A bioclimatic architecture is that one that takes care of all climatic conditions in the conception of project, using passive solar systems of form to increase and energy efficiency. Not to confuse with the active solar architecture that is associated with the use of mechanic instruments, for example, solar and photo voltaic panels, hybrid systems of cooling for evaporation, etc.. These active concepts are out of the bioclimatic definition but they find in sustainability vision the justification. Based on the roots of empiricism, the bioclimatic architecture is unproved of the one of technologies to acclimatize or to illuminate. Such constraints compelled to an efficient and inserted construction in the surrounding climate, using the local materials mainly. The sustainable construction is defined as a constructive system that promotes interventions on the environment, adapting it to the use necessities, production and human consumption, without depleting in this intervention the natural resources. Thus the systems of exploitation of pluvial waters, passive heating and cooling, quality of air and the water, maximization of the natural illumination as well as the use of renewed energies and impact of the used materials, are in pair and integrated in its global with the programmatically and aesthetic questions in the conception of the buildings. As result of sustainable construction we have a building that generates the resources rationally such as the energy, the water and the impact of the materials used in construction, taking care as a building to all estimated calculus of resistance of time, to allow the continuity of its function of shelter for a definitive use based on the waited indices of comfort. To relate that the sustainable construction is transversal to all the concepts, styles and stylistics languages adopted and employed in the buildings. The used passive measures can modify the form but never the language of the building. As action base we have to find a good relationship of the building with the local climate searching in its selective permeability the capacity to accumulate and to absorb heat or cold, to renew air and to control illumination.

3. The research methodology

The methodology adopted was based on "case study" in accordance with Robert Yin (1994), one of the most appraised authors in the use of this methodology. According with Alho (2000) the research identifies a contemporary problem which intends to study emerging concepts to the architecture and urbanism level specifically in rural areas. Based on Yin (1994), the researcher does not have control on the data, going to use only one case study or multiple cases as form to prove and to generate knowledge for new research. Single cases may be used to confirm or challenge a theory, or to represent a unique or extreme case (Yin, 1994). Single-case studies are also ideal for revelatory cases where an observer may have access to a phenomenon that was previously inaccessible. These studies can be holistic or embedded, the latter occurring when the same case study involves more than one unit of analysis. This technique, being sufficiently including, must be flexible and to use, at the same time, others techniques of research associated in order to produce final results which can be confirmed by another researcher that, following the same methodology, would arrive to identical conclusions (Hinks, 1996). According to Denscombe (1998) case studies characteristics are:

- spot light on instance,
- in-depth study,
- focus on relationship and processes,
- tend to be holistic and,
- the case study is a naturally occurring phenomenon. (Yin, 1994)

The authors take in consideration in special case study advantages (Denscombe, 1998):

- deal with the subtleties and intricacies of complex social situations,

- the use of multiple methods and multiple sources of data in order to capture the rarity,
- no pressure on the researcher to impose controls or to change circumstances,
- concentring effort on one research site,
- theory testing and building.

Finally take care with the disadvantages of case study approach (Denscombe, 1998):

- credibility of generalizations made from its findings,
- perceived as producing “soft” data,
- boundaries are difficult to define and poses difficulties in deciding sources of data,
- negotiating access to people and documents can generate ethical problems,
- the presence of the researcher can lead to the observer effect,

4. Findings and discussion of case study proposal

To create a playful park with two different sources of clients, first destined to a floating public who will go there only to spend the day and usufruct the varied equipment which will offer, second destination to the public that will lodge and privilege comfort and the benefits of nature in bungalows or mobile homes. The eco-resort will function as a self-sufficient island, where the guests will find satisfaction for one varied gamma of interests and leisure, like sports, environmental and regional culture in a combination that attends de demands of different age levels.

This design project differs from its similar in camping, for the raised standard of quality that it reflects in the following areas:

Functionality

While unitary, this eco-resort intends to take care of two types of different visitors and the functionality was divided in four functional sectors, as it can be observed in the master plan (figure 2).

Figure 2: Eco-Camping-Resort Master Plan

1º Sector 0 - Lodging

The lodging area, foresees beyond a dimensioned parking, a generous reception, and a cycle-center (to rent bicycles), which precede a central square, where the first contact with the resort will arrive, with a set of services and activities, and leisure, such as restoration area, commerce and entertainment complemented for units of entertainment like amphitheatre, mini-golf, toys, sports and so on.

This central square will function as a distribution zone linked with the remaining areas. Its localization is central and privileged in relation to the entrance in the complex and relation to the elements of bigger landscape attraction and offers several activities.

2º. Sector A - Shelter

This camping leisure will be the nuclear area of the complex, and will agglutinate the biggest number of users and will offer a different concept of lodging linking with the nature. It corresponds to the camping zone, with diverse sources lodging like: tents, caravans, motorized caravans, until the most definitive solutions, such as bungalows (figure 3) and mobile homes (figure 4), and it will enjoy a great autonomy of functioning and management of resources, and it is the sector that will make the project economically viable.

This sector, on which was based this case study, is the most structural base of the complex and will be supported by a diversity of activities and services that complement a panoply of existing activities in the other sectors and it is also responsible for the landscape and environmental development of the complex, with the creation of a biological swimming pool as well as a big tent (the camping lounge or ZEN tent) that provides this area of a social meeting point (figure 1).

3º Sector B – Aquatic leisure

This sector corresponds to the main zone of the aquatic entertainment, where more traditional equipments are proposed, presenting more options on the sport offer. Complementing the wealth of the beautiful beaches in the proximity, this sector endows this complex with an attractive of great importance for the resort.

This sector counts on swimming pools of diverse activities (swimming pool/beach with waves, *Jacuzzis*, lakes, islands, rivers, cascades, aquatic animation and nautical, health club and winter swimming pool, etc.), persecuting the main objective of working all the year.

4º Sector C – Environmental animation

This sector beyond usufruct of the natural resources will improve and rent areas of the park, with activities of preservation and environmental animation, such as sport of the nature, programs of sensibilization and environmental interpretation, agricultural activities, fifth of animals, environmental and cultural animation.

Figure 3: Cluster of Bungalows

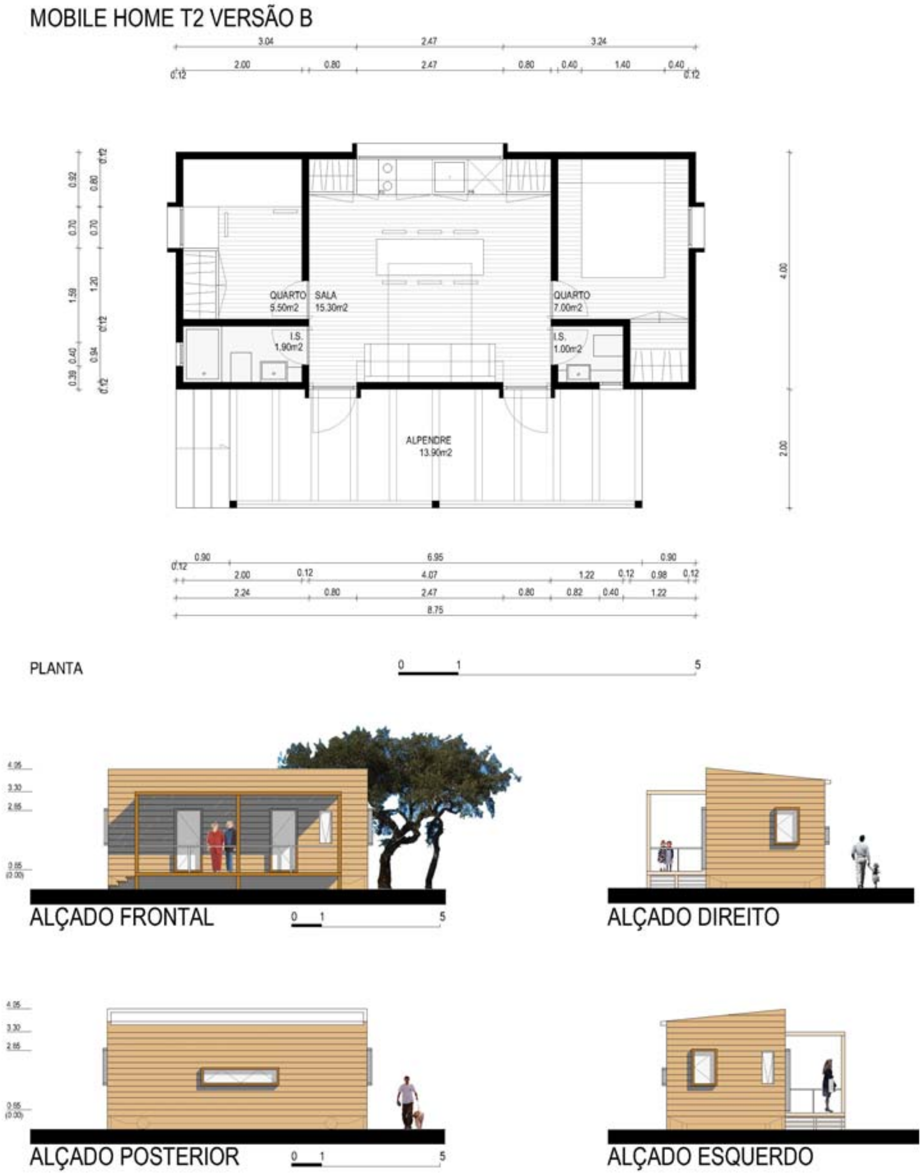

Figure 4: Mobile home, tipology T2 version B

5. Conclusions and recommendations

Eco-camping resort gains a new importance in front of the new paradigm and it seems to appear in the camping leisure, two different and opposite forms in evolution.

In an upward direction, where this proposed project is integrated, expresses sophistication and the constant institutionalization, earning new contours pointing until the new classifications of "Luxury". In descending direction, the provisory lodging becomes in a form of permanent residence for a considerable part of population with modest incomes.

Thus, made these considerations of this case study, it seems us pertinent to take off the following conclusions:

- Tourism is to move, answering the new ecological and environmental concerns and also to a dramatic problem created by the development of masse tourism, that aggravate from Second World War until present, leaving entire cities structures that are not used during half of the year, what configures a clear problem of sustainability.

- That, will make the industry of tourism, on the XXI century, go thought substantially structuralized changes, and surely, make it more responsible, environmental and socially speaking.

- The proposal of echo-camping resort that configured the presented case study is surely a new reply to a new program of tourism, looking for creative standards of quality and to propitiate a bigger contact of the customers with nature, as well as minimizing the negative impact of tourism.

- Thus, it makes sensible to conclude that the lodging in tourism of nature, in the case of eco-camping, is probably the evolution on the direction of sophistication and comfort, in the physical and architectural type of lodging, as well as in the number and quality of the leisure equipment.

- The notion of “luxury” is changing, and the close link to nature, related to unpolluted areas and harmonious natural environment is one of the great luxuries today.

- Solar and aeolian alternative energies had come to be and are in a primitive period of training development and will go to prosper and reach efficiency standards that at this moment still are considered utopian.

- As well, architecture and urbanism will go to follow development standards supported on “low” and “high” technology concepts. In the first case, simple and economic traditional constructive processes will be retaken and improved. In the second case, new, lighter and sophisticated materials will be developed, as well as, new equipments in order to achieve and improve technology.

- The “economic” and “efficacy” notions will walk along with energy efficiency, comfort and human well-being and in harmony with nature preservation.

- Eco-camping-resort appears as a valid option to the construction of a new conventional tourist enterprise, and search to create permanent employment.

- In conclusion, changes in society creates new human and physical conditions on the built environment witch defines emerging concepts for eco sustainable resorts in rural areas of Europe.

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A Life-Cycle Approach to Reducing Residential Construction and Demolition Waste

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Abstract

Approximately 164 million tons (149 million metric tons) of waste are generated annually in the United States by building-related construction, remodelling, and demolition activities, as estimated by the United States Environmental Protection Agency (U.S. EPA 2009a). The residential sector accounts for 64 million tons (58 million metric tons), or 39% of this waste stream. Architectural, engineering, and construction professionals are adopting sustainability practices. Reducing construction and demolition (C&D) materials generation is one attribute of sustainability performance. However, the benefits of recycling, reusing, or recovering C&D materials for energy as alternatives to landfill disposal are not well understood. The 2009 Version 3 of the U.S. Green Building Council's Leadership in Energy and Environmental Design rating system (USGBC 2009) awards credits for reducing C&D waste, but the actual environmental effects are under-represented. Current building removal practice in the U.S. is still governed by the lowest cost of services to the owner rather than the environmental consequences. Other environmental impacts and external costs are incurred by landfill disposal, but are rarely acknowledged in decision making processes. This paper describes a life-cycle assessment (LCA) approach to identifying environmental impacts of recovering residential C&D materials for reuse versus landfill disposal. It quantifies the energy, raw materials, air and water emissions, and land consumption incurred by wasting materials, unnecessarily extracting virgin resources, and manufacturing and transporting new materials and products. It is concluded that the majority of environmental stressors occur during building materials' extraction, harvesting, and manufacturing processes. These stressors can be avoided by recovering and reusing building materials. The Athena Institute's Impact Estimator for Buildings software (Athena 2009), is used to assess the life-cycle impacts. External and social benefits associated with reducing the landfill disposal of C&D debris are being addressed.

Keywords: C&D waste reduction, recycling, deconstruction, reuse, demolition

1. Background

The environmental burdens created by buildings are significant. In the United States, buildings accounted for 39% of the total energy consumption and 67% of electrical consumption. They also contributed 38% of the total carbon dioxide emissions and consumed 12% of the total water used (U.S. EPA 2004). Wagner (2001) determined that roughly two -thirds of the raw materials consumed in the U.S. are used by the construction industry.

Waste is the antithesis of sustainability. Industry and environmental experts such as Paul Hawken (1994, 1999), William McDonough (2002), Brian Nattrass (2002), and Ray C. Anderson (1998) leave little doubt that wasting resources is an extremely undesirable behavior from environmental, economical and moral perspectives.

In a facility planning, design, and construction context, the environmental problems relate to the landfill disposal of waste materials from construction sites and debris from building renovation and demolition. The amount of construction and demolition (C&D) debris generated in the U.S. was estimated to be 164 million tons (149 million metric tons) in 2003, an increase of 25% over the preceding five years (U.S. EPA 2009a). This quantity of waste would cover a mile–square (1.61 kilometre-square) area 20 feet (6.1 meters) deep every year. C&D debris constitutes roughly 40% of the non-hazardous, non-industrial solid waste burden in the U.S. (U.S. EPA 2009c).

The most obvious impacts of generating C&D debris are seen in terms of land use and landfill consumption. The number of landfills in the U.S. has decreased from 1,889 in 1994 (U.S. EPA 1998) to 1,367 in 2009 (Waste Management Journal 2009), or 28% in 15 years. Other environmental stressors include toxic discharges such as heavy metals into groundwater, hydrogen sulfide gas emissions, greenhouse gas emissions, and negative impacts on humans such as noise, dust, and unpleasant odours.

Less obvious are the negative environmental impacts of wasting and replacing building materials. Production of new materials involves the further depletion of resources, the impacts of manufacturing processes (energy use, water and air emissions and waste), and the impacts of product transportation (fuel consumption and vehicle emissions). Jackson (2009) calculates that demolishing a typical commercial building and replacing it with a contemporary “energy efficient” building actually wastes energy – the embodied energy invested in the original building. It could take 35-76 years of operating energy savings to recover the waste of embodied energy in discarded existing building materials. Yet this energy waste is not considered when budgeting, planning, or designing new buildings because costs have traditionally not been externalized to the environment and human quality of life.

Our “green building” sensibilities tell us that eliminating C&D waste is necessary. McDonough and Braungart (1992) developed the Hannover Principles, for the City of Hannover Germany’s Expo 2000, which include the following:

> "4. Accept the responsibility for the consequences of design decisions upon human well-being, the viability of natural systems and their right to co-exist," and.
>
> 6. Eliminate the concept of waste. Evaluate and optimize the full life-cycle of products and processes to approach the state of natural systems, in which there is no waste."

Unfortunately, current planning, architectural, engineering, construction, and facility management practices do not always address the fact that C&D waste reduction is an important part of sustainability. High-profile examples of green building, such as wind or solar energy, bio-remediation fields, green roofs, or geo-thermal heating and cooling, attract greater attention. Landfill disposal of C&D materials is still the most common practice because it is the path of least resistance. Landfilling is not illegal, nor is it improper if performed within prevailing waste disposal regulations. Landfill disposal is also still relatively inexpensive in most regions of the U.S., which is attractive to a construction industry whose business model almost always favours the lowest first cost.

2. Problem

Decision makers do not have sufficient information to assess the true environmental impacts of wasting building materials or the benefit of reusing or recycling them. In addition to direct project costs such as demolitions services, landfill tipping fees, and recycling costs and revenues, a methodology and metrics representing long-term environmental behaviors and costs relevant to the building industry is necessary.

3. Objectives

The objectives of this paper are to: reveal the adverse environmental impacts associated with wrecking and landfill disposal of residential buildings; describe the benefits (in terms of reduced adverse impacts) of recovering and reusing or recycling building materials on a project and national (U.S.) basis; and begin to associate cost benefits with reducing environmental impacts created by C&D waste.

4. A Life-Cycle Approach

While a comprehensive description of life-cycle assessment (LCA) is not given in this paper, it is important to understand the LCA fundamentals, especially in the context of buildings' environmental performance and the impacts associated with materials use and waste.

The Society for Environmental Toxicology and Chemistry (1991) published <u>A Technical Framework for Life-Cycle Assessment</u>, which established a uniform, consensus-based LCA and information exchange process. LCA is a process used to evaluate, holistically and objectively, the environmental effects of a material, product, or process occurring through its life. All phases of a process or product life are addressed in LCA, from the extraction of materials to the disposal of the product. Life-cycle phases are commonly described as material acquisition; manufacturing or processing; distribution and transportation; use and maintenance; and disposal or waste management. A recycling phase will sometimes be included between the use and disposal phases.

The LCA process comprises of three general components. The first is the inventory, in which all energy use, material inputs and outputs, and waste products involved in producing the product are identified. The second is the impact assessment, in which impacts of resource use, emissions and discharges, and energy use are evaluated. The third is the improvement analysis, in which opportunities for reducing adverse impacts are identified and incorporated into the process or product. The International Standards Organization (2006) has further codified the LCA process in ISO Standards 14040 and 14044, which define four components: goal definition and scope, inventory, impact analysis, and interpretation.

LCA is a data-intensive and relatively complex process. Therefore, LCA studies typically have been applied to situations where results could be applied repetitively over a long duration, such as a production environment. As buildings and structures are essentially unique, custom-crafted products consisting of thousands of components and tasks, applying a thorough LCA process has been considered impractical.

More recently, LCA software tools for buildings have been developed, made possible by the compilation of life-cycle databases and advanced desktop computing capabilities. SimaPro by PRe' Consultants, the Impact Estimator for Buildings by the Athena Institute for Sustainable Materials, and Building for Environmental and Economic Sustainability (BEES) by the U.S. National Institute for Standards and Technology (NIST) are prominent examples of systems developed for buildings in North America.

5. Comparing residential demolition and new construction

While not a universal practice, recovering building materials through deconstruction, salvage, recycling, and reuse is not uncommon. Falk and Guy (2004) developed a directory of over 1,500 businesses across the U.S. that deconstruct buildings, salvage building materials, and/or sell used materials through retail outlets. The Building Materials Reuse Association and Construction Material Recycling Association both promote the recovery of building materials for beneficial use.

A study by Napier (2007) and others suggested environmental burdens can be reduced significantly by using recovered building materials, that is, materials salvaged or recycled for reuse. Life-cycle assessments were performed using the Athena Impact Estimator for Buildings for reusing dimensional lumber and structural steel, and recycling asphalt shingles and cast-in-place concrete. Both the reuse and recycling scenarios indicated that a reduction of adverse environmental impacts by over 90% compared with landfill disposal was achievable.

The following analysis describes the environmental burdens associated with constructing, occupying, and removing residential buildings. Rather than isolate selected reusable and recyclable materials, as in the study cited above, a whole-building scenario is more representative of mainstream construction practices and impacts.

A single-family residential building was selected for this example because it is easily visualized by a wide range of readers and audiences. However, the same principles apply to commercial and institutional buildings. Furthermore, the analysis of one residential building can be extrapolated to represent both the total annual residential debris burden in the U.S. and the potential benefits of recovering materials for reuse. The LCA were performed using the Athena Impact Estimator for Buildings. This software enables designers to develop and compare alternative designs..

Athena's inventory analysis identifies the energy use, inputs, emissions, and waste involved with each material, over each life-cycle phase. Inventories are described as energy inputs; air emissions; water emissions; solid waste; and resource use. Inventory values are expressed in the total quantities of each constituent element or compound present in the building.

Impact summaries represent the combined effects of the inventory, over all life-cycle phases. Impact categories are described as: energy consumption; resource use; global warming potential; acidification potential; eutrophication potential; ozone depletion potential; and smog potential.

5.1 Building models

In order to assess the impacts of using recovered building materials, instead of new materials, a simple house design was developed. From this design, two models were developed for the Impact Estimator. The first was a 2,800 square foot (260 square meter) two-story house of conventional wood framed construction and brick veneer, constructed with all new materials. The second was an identical 2,800 square foot (260 square meter) house of identical wood frame and brick veneer construction constructed using recovered materials for the following: 75% of the framing lumber; 50% of the veneer bricks; 100% of the windows and doors; 75% of the finished flooring; 100% of the kitchen and bathroom cabinets; and miscellaneous equipment. The quantities of recovered materials used are optimistic but entirely reasonable. It is reasonable to assume that recovered materials would be of equivalent performance to new materials. A 40-year life expectancy was designated for both models.

Based on user inputs for design configuration, dimensions, materials, and assemblies, the software develops models of the design or alternates, identifies material types, and calculates quantities. The software then applies its database to develop life-cycle impact analyses.

The Impact Estimator software was not designed specifically to assess the relative impacts of wasted or recovered building materials. In order to represent a quantity of recovered materials, the quantity of that material generated by the Impact Estimator was manually revised. Therefore, the manufacturing inventories and impacts would represent only the new materials, and the end-of-life inventories and impacts would represent only the landfilled materials. These adjustments were performed in consultation with Athena representatives.

LCA is sensitive to location, so the Impact Estimator adjusts the inventory values and impact assessment accordingly. The Athena Institute is a Canadian-based organization, but its data are applicable throughout North America. A "U.S. Average" location was used.

Operating energy is not included in this LCA because the construction of the models was identical and the recovered materials used in the second model would have no impact on energy consumption if their performance is assumed to be equivalent to the new material.

5.2 Life cycle assessment of the two models

The results generated by the Athena Impact Estimator for the conventional construction model show that the vast majority of energy use and emissions occur during the manufacturing phase. In summary, manufacturing energy consumption amounts to 75-90% of total life-cycle energy consumption. Manufacturing emissions to air are 70-90% for the top 12 (of 106) air emissions inventoried, and emissions to water are 70-75% for the top 12 (of 98) water emissions inventoried. The LCA impact summary for conventional construction is shown in Table 1.

Table 1: LCA Impact Summary by Life-cycle Phases, Conventional Construction Model

LC IMPACT CATEGORIES	*Manuf'ing*	*Construct'n*	*Maintenance*	*End - Of – Life*	*Operating Energy*	*Total Effects*
Primary Energy Consumption MJ	*1,334,373*	*81,874*	*233,399*	*12,247*	*0*	*1,661,892*
Weighted Resource Use kg	*422,370*	*2,427*	*25,016*	*279*	*0*	*450,091*
Global Warming Potential (kg CO2 eq)	*91,985*	*1,196*	*14,844*	*40*	*0*	*108,065*
Acidification Potential (moles of H+ eq)	*37,982*	*525*	*8,857*	*8*	*0*	*47,372*
HH Respiratory Effects (kg PM2.5 eq)	*469*	*1*	*150*	*0*	*0*	*620*
Eutrophication Potential (kg N eq)	*0*	*0*	*0*	*0*	*0*	*0*
Ozone Depletion (kg CFC-11 eq)	*0*	*0*	*0*	*0*	*0*	*0*
Smog Potential (kg NOx eq)	*418*	*10*	*132*	*0*	*0*	*561*

These data indicate that materials extraction, manufacturing processes, and transportation create the greatest environmental burdens in terms of energy and resource use, air and water emissions, and waste. This finding also suggests that a significant reduction of environmental burdens can be achieved if the quantities of new building materials used in new construction can be reduced. In other words, using existing building materials instead of producing and consuming new building materials significantly reduces the environmental stressors caused by building construction.

Similar to the conventional construction model, the majority of energy use and emissions for the recovered materials model occur during the manufacturing phase. However, because less new materials are present in the reused materials model, some energy sources, emissions, and wastes are distributed at somewhat greater proportions across other life-cycle phases. The LCA impact summary for the reused materials model is shown in Table 2.

Table 2: LCA Impact Summary by Life-cycle Phases, Recovered Materials ModelLC IMPACT CATEGORIES	*Manuf'ing*	*Construct'n*	*Maintenance*	*End - Of - Life*	*Operating Energy*	*Total Effects*
Primary Energy Consumption MJ	*746,545*	*41,951*	*55,414.*	*8,592*	*0*	*852,503*
Weighted Resource Use kg	*276,024*	*1,518*	*11,702*	*195*	*0*	*289,440*
Global Warming Potential (kg CO2 eq	*56,957*	*1,138*	*11,867*	*31*	*0*	*69,995*
Acidification Potential (moles of H+ eq)	*20,0998*	*505*	*3,894*	*5*	*0*	*24,505*
HH Respiratory Effects (kg PM2.5 eq	*196*	*0.96*	*140*	*0.01*	*0*	*337*
Eutrophication Potential (kg N eq)	*0.34*	*0*	*0.01*	*0.00*	*0*	*0.35*
Ozone Depletion (kg CFC-11 eq)	*0.00*	*0*	*0*	*0.00*	*0*	*0*
Smog Potential (kg NOx eq)	*213*	*10*	*21.04*	*0.12*	*0*	*245*

The distribution of impacts across the building life-cycle is similar for both models. In comparison, however, the magnitudes of impact are dramatically lower for the reused materials model. Displacing new materials with existing materials reduces environmental burdens significantly. A comparison of the LCA impact summaries for the conventional construction model and the reused materials model is shown in Table 3 and Figure 1.

Table 3: LCA Impact Summary Comparison Table

LC IMPACT CATEGORY	*Conventional Construction*	*Recovered Mat'ls Construction*	*Impact Reduction*	*% Impact Reduction*
Primary Energy Consumption MJ	*1,661,892*	*852,503*	*809,388*	*48.70%*
Weighted Resource Use kg	*450,091*	*289,440*	*160,651*	*35.69%*
Global Warming Potential,kg CO2 eq	*108,065*	*69,995*	*38,0705*	*35.23%*
Acidification Potential, moles of H+ eq	*47,372*	*24,505*	*22,867*	*48.27%*
HH Respiratory Effects Potential, kg PM2.5 eq	*620*	*337*	*283*	*45.65%*
Eutrophication Potential, kg N eq	*0.399*	*0.35*	*0.048*	*11.95%*
Ozone Depletion Potential, kg CFC-11 eq	*0.001*	*0*	*0.001*	*73.97%*
Smog Potential, kg NOx eq	*561*	*245*	*316*	*56.37%*

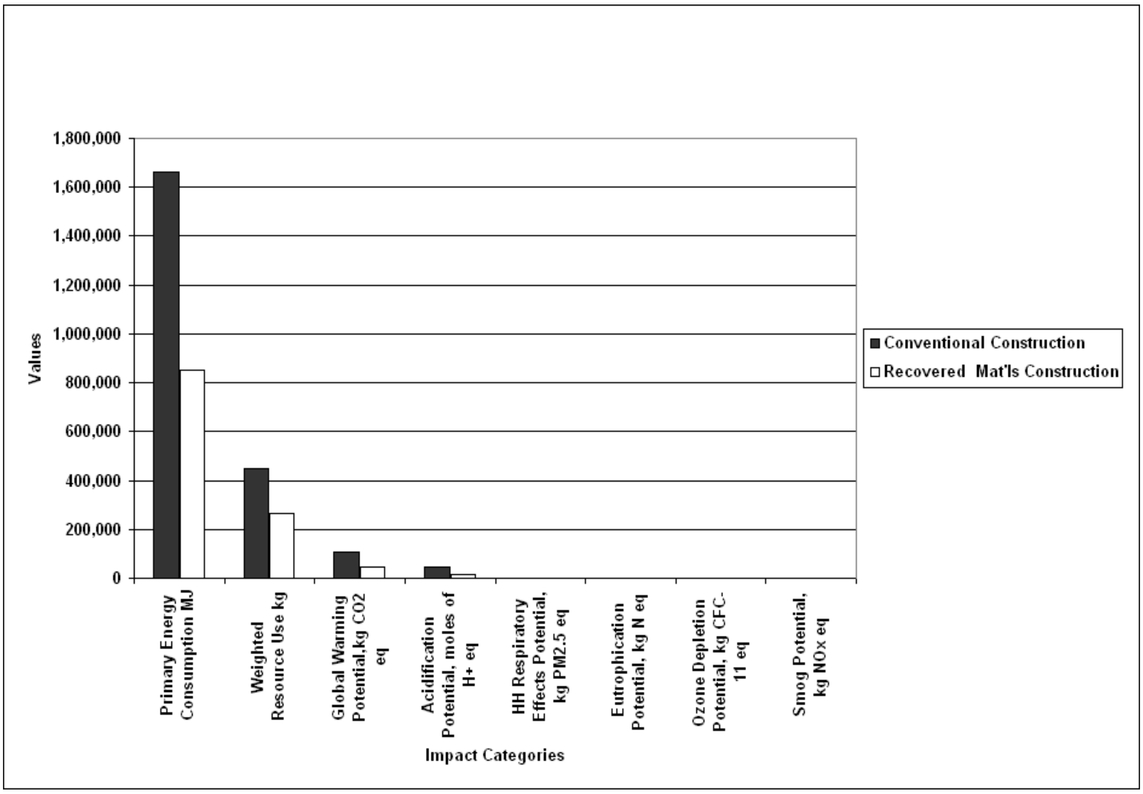

Figure1: LCA Impact Summary Comparison Chart

The potential benefit of using recovered building materials in residential construction is significant. The environmental burdens created throughout a house's life-cycle can be reduced from 40% to over

90% by using recovered materials. One exception is the eutrophication potential, which creates a negligible impact, and for which only a modest reduction is indicated.

6. A nationwide potential

Modelling one house reveals the potential to reduce environmental burdens by using recovered building materials. A total national benefit can be approximated by extrapolating these results to the residential C&D debris generated in the U.S. annually.

The U.S. EPA (2009a) estimates approximately 270,000 residential units, or approximately 576 million square feet (52.7 million square meter) of residential facilities, were demolished in 2003. This activity generated 19 million tons of debris. (17.25 million metric tons) of debris.

If 567 million square feet (52.7 million square meters) of new residential units were constructed using methods and materials similar to the recovered materials model, annual benefits across the U.S. would be:

- 163 billion megajoules of energy would not consumed.
- 33 million metric tons of natural resources would not extracted.
- 8 million metric tons of carbon dioxide equivalent would not emitted.
- 5 billion moles of H+ (positive hydrogen atoms) equivalent would not be released into water sources.
- 58,000 metric tons of particulate matter hazardous to human health would not emitted to air.
- 10 metric tons of ozone-depleting substances would not be emitted to the atmosphere.
- 64,000 metric tons of NOx equivalent (smog potential) would not emitted to the atmosphere.

One may question whether this quantity of recovered materials could be absorbed into the residential construction market. The number of residential units demolished represents roughly 30% of the new housing market. The U.S. Census Bureau (2009) recorded 905,000 housing starts in the U.S. in 2008, which represents an extremely slow period in the U.S. housing market. Roughly twice that number was recorded over the more prosperous 2003-6 period. Therefore, there should be ample opportunity to use all materials that can be recovered from obsolete housing units.

7. A monetary value of reducing environmental burdens

LCA can be applied to quantify the differences in environmental performance between alternatives, in this case using all new materials in a house's construction versus using recovered materials. Using the LCA data, a compelling argument can be made to support the potential benefits of recovering and reusing materials. The differences are significant, at least by comparison.

However, decisions in the construction industry currently are almost always based on low first cost. Life-cycle cost analysis (LCCA) addresses only out-of-pocket expenses by the facility's owner over the facility's life, not externalized or societal costs. While few would argue against reducing environmental burdens, weighing a reduction in greenhouse gas or water emissions against a contract's cost is still beyond the capabilities of building industry professionals.

To determine social benefits and costs associated with changing the material and technology constraints, economic valuation techniques must be applied to the physical outputs (i.e., the LCA analysis). Economic analysis based on LCA is a complex and expensive exercise. The U.S. EPA has developed sophisticated human health and cost models, but translations to ecological systems are not as well developed. Furthermore, the values of ecosystem goods are typically location dependent (U.S. EPA 2009b).

The facilities planning, design, construction, and management communities have not yet assigned reliable economic values to all environmental impacts associated with buildings. The application of direct costs, however, can provide some insight into the economic potential for recovering and reusing building materials. Direct costs are the prevailing costs of certain consumable resources or services performed that have been or can be paid.

Some benefits of avoiding direct costs for the annual U.S.-wide residential construction market described above can be calculated as follows:

- 163 billion megajoules of energy would not be consumed would save $4.43 billion in energy use (applying an average cost of electricity of $0.0275/MJ, per U.S. Department of Commerce Federal Register, February 27, 2006).

- 19 million tons (17.2 million metric tons) of C&D debris not wasted would save roughly $665 million in waste disposal (assuming tipping fee of $35 per ton, or $38.59 per metric ton).

It is also possible to assign an economic value to carbon emissions. A quantity of CO_2 equivalent is established through an LCA inventory, and global warming potential is established in the impact assessment. A price can be assigned from the market value of carbon traded through carbon exchanges. In the U.S., it is reasonable to assign a price of $10-28 per metric ton of CO_2 equivalent (MTCO2E), which is cited in U.S. legislation on Clean Energy and Security (U.S. Congress 2009). The 8 million MTCO2E not emitted to the atmosphere would save roughly $96 million-worth of carbon emissions, at a value of $12 per MTCO2E.

Assigning direct costs to selected environmental impact categories still does not assign economic value to all attributes of environmental performance. There is, however, one tool that may approximate a comprehensive economic evaluation of environmental impacts. The U.S. EPA has developed a Decision Support Tool (DST) to enable authorities to compare waste management scenarios for both environmental impact and cost. The DST applies full cost accounting principles to estimate the total capital cost of waste management, and also provides dollar values to represent externalized (or societal) costs and benefits. In order to avoid the complexity and expense of performing valuation studies on a case-by-case basis, the DTS developers relied on a benefits-transfer procedure. Benefits-transfer involves compiling data from existing research (Thorneloe 2004)

The Governor of Wisconsin's Task Force on Waste Materials Recovery and Disposal applied the DTS to three scenarios for the state's municipal waste management: landfill disposal, incineration for waste to energy (WTE), and recycling. The Wisconsin report cites the following as the net societal costs for managing municipal solid waste (MSW) as ($185)/ton ($168/metric ton) to recycle, $52/ton ($47/metric ton) to incinerate for WTE, and $98/ton ($89/ton) to landfill. (Wisconsin 2006).

It is tempting to apply these values to residential conventional construction and recovered materials models. However, two factors suggest this may not be completely valid. First, the Wisconsin analysis was for MSW management, as opposed to C&D materials. Second, the waste management costs used in this analysis represented local conditions and cannot simply be applied throughout the U.S. without verification. Nonetheless, if the economic benefit of recycling cited in the Wisconsin analysis is anywhere near being valid on a U.S.-wide basis, and if half of the 17.25 million metric tons of residential demolition materials generated annually in the U.S. were recovered, this suggests an overall economic benefit of roughly $1 billion annually.

8. Conclusions

Buildings have a significant impact on the environment. Within the U.S., buildings account for a large proportion of resources consumed and burdens created. Any changes that can be made in the facility design, planning, construction, and management industries to reduce environmental burdens in buildings can have a significant impact on a nation-wide scale.

By recovering existing materials for reuse in new construction, a significant reduction in life-cycle environmental impacts can be achieved. This reduction results from eliminating the end-of-life impacts of materials that are recovered for reuse, and eliminating the manufacturing impacts for the new materials displaced by recovered materials.

LCA tools applicable to buildings are available. The Impact Estimator for Buildings by the Athena Institute for Sustainable Materials is one such tool. While this software is intended to enable comparisons of design alternatives, it is also useful to identify the life-cycle performance of materials and assemblies. It was not necessarily designed to compare material recovery with landfill disposal alternatives, but with the assistance of Athena personnel, the data were available to enable this comparison.

The benefits that can be achieved by using recovered building materials instead of new materials in residential construction are significant in magnitude. The potential energy savings amounts to billions of megajoules. The potential for reducing carbon emissions amounts to millions of metric tons. These are annual figures, achievable year after year for the foreseeable future.

Placing an economic value on the reduction of environmental burdens is not yet a standard practice within the building industry. However, applying the direct costs of energy consumption and waste disposal savings indicates a potential benefit of roughly $5 billion annually. Applying a U.S. market value to carbon emissions (MTCO2E) indicates a potential benefit of roughly $96 million annually. This figure for carbon emissions may rise substantially as greater international emphasis is given to the environment and climate change.

The potential savings illustrated by this residential example represent only a portion of the total U.S. building industry -- approximately 12% of the total C&D debris stream. The potential application to the building industry as a whole is enormous.

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“Black Box Opener” Tool to Assess Material Use in the Costa Rican Construction Sector

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Abstract

The construction industry and related ones are considered the world’s largest industrial employer and natural resources consumer. 50% of all materials extracted from the earth are transformed into construction materials and products. When these materials enter the waste stream, they account for some 50% of all waste generated prior to recycling, recovery or final disposal. In developing countries construction waste is becoming a serious environmental problem, which causes significant impacts on the environment. Thus, the minimisation of construction wastes has become a pressing issue.

An assessment has been done in Costa Rica, which shows that the availability of data on material waste was scarce, the number of empirical studies is small, and mostly from developed countries, most of the studies investigated a limited number of materials in few construction sites, comparing the results is difficult, many of the studies have focussed on design of sustainable buildings and recycling of waste, scarcely information was found related to material management, and few information on waste reduction by means of material management. Besides construction materials, labour and waste production does not uniformly receive appropriate consideration and very little detailed knowledge currently exists about the origins and distributions of construction wastes.

The Industrial Metabolism has been chosen as the model that helps to understand the relationship between the system and its environment, with a focus on the extraction from and the discharge to the environment of physical flows. It is a modelling method aimed at the investigation of the industrial system, the mutual interchange of physical flows between its sub-systems, and the interchange of physical flows between the industrial system and its natural environment. The main goal of the study is to gain insights into the traditional and industrialised construction processes in order to analyse the performance of the production system and its relation with the environment. This paper presents some tools that have been prepared, in order to analyse amounts of waste, causes for its production, different factors and their significance degrees that influence the production of waste.

Keywords: construction industry, construction material management, prevention, waste, material flows

1. Introduction

The construction industry and related industries are considered the world's largest industrial employer and the biggest natural resources consumer. 50% of all materials extracted from the earth are transformed into construction materials and products. When these materials enter the waste stream, they account for some 50% of all waste generated prior to recycling, recovery or final disposal (Arpad 2004, EPA/ USA1995).

The effective management of construction materials and waste is important because of the potential raw material shortages, the impact in the environment due to the extraction or raw materials, the disposal of the construction waste and the high prices of buildings, among others.

Construction materials, labour spent on handling them to the fixing position of traditionally constructed buildings and the waste produced, constitute a major portion of the total cost in a building construction project which makes the control of this resource important. According to literature, not enough attention is given to the good practices of material management (Skoyles 1976, Cnudde 1991, Formoso et.al 2002, Navon and Berkovich, 2005).

Gavilan and Bernold already mentioned in 1994 that the reduction of waste at its source is genuinely the most logical and even most economical way to "treat" construction waste and in order to do so, practical waste reduction strategies require a detailed understanding of what causes it. Analysing waste is an effective way to assess performance of production systems, it usually allows areas of potential improvement to be pointed out and the main causes of inefficiency to be identified.

A research is being done in Costa Rica in order to analyse waste generation and its relation to construction practices. The first phase had the objective to do an assessment in order to find out the amount of waste generated in the construction sector, its causes, the drivers and constraints for the companies to be more sustainable. The main findings were that the availability of data was scarce, the few quantitative studies about waste generation are not reliable and the barriers mostly are related to awareness, legislation, and technical issues.

This paper pretends to describe some tools that have been developed in order to analyse, in more detail, the construction stage. The framework to approach the problem is based on Industrial Metabolism ideas.

2. Industrial metabolism

It is a model that helps to understand the relationship between the system and its environment, with a focus on the extraction from and the discharge to the environment of physical flows. It is a modelling method aimed at the investigation of the industrial system, the mutual interchange of physical flows between its sub-systems, and the interchange of physical flows between the industrial system and its natural environment (Lambert 2008).

2.1 The main characteristics of industrial metabolism are:

- It is an integrated view
- It is based on systems theory
- It can be applied on various levels of aggregation, varying from process-oriented to global
- It has an emphasis on physical flows, which are materials and energy flows
- It is quantitatively oriented
- It is life-cycle oriented

The purpose of industrial metabolism is to understand the relationship between the system and its environment, with a focus on the extraction from and the discharge to the environment of physical flows. Most of the current studies in the field of industrial metabolism are related to material flows models.

Different types of approaches have been developed to analyse material flows, which include: material flow analysis, physical input-output tables and lifecycle assessment. They all focus on the description of flows in an economic system.

Material flow analysis (MFA) focuses on material flows in a specific geographic area, in terms of both the economic as well as the environmental system. It is a systematic procedure that connects the sources, the pathways and the intermediate and final sinks of materials (Brunner, 2004). A MFA delivers a complete and consistent set of information about all flows and stocks of a particular material within a system. Through balancing inputs and outputs, the flows of wastes and environmental loadings become visible, and their sources can be identified. (Hendriks et. al 2000; Brunner and Rechberger 2004). But measuring just flows is insufficient to understand the processes that take place in a production system. Therefore, the description of the flows is important as well as the comprehension of the processes behind those flows.

The construction process can be described as a system that contains a set of objects with mutual relationships, which are the physical flows and their transformation This system can be considered as a **“black box”** that when opened it contains subsystems that are part of the original system.

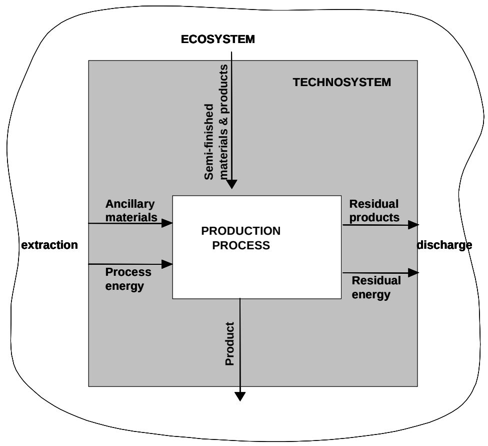

Figure 1: Simple linear technosystem. (Based on Lambert, 2008)

Figure 1 could represent the production process under study, in which semi-finished materials and products are transformed into products (edifices). Every production process needs ancillaries such as energy carriers and materials. This production process not only creates products, but also unintended residuals, such as by-products; and waste.

3. Research methodology

In order to describe the internal transformations of materials and energy to assess the efficiency (and sustainability) of the technosystem during the production of a building process, a survey and explanatory multi-method case studies have been developed with the purpose to apply the prepared tools in a real life context. The projects studied are situated in Costa Rica and they have the peculiarity of being traditional and industrialized (up to some pre-fab extend) construction systems, middle size residential projects all located in the Great Metropolitan Area.

The tools developed are based on an extensive literature research in which various authors pointed out that design factors and management are the main sources of misuse of resources and production of waste. Five research propositions are proposed in order to analyse the sub-processes as well as a quantitative method to examine the amount of waste produced during the procurement of buildings.

3.1 Cause 1: design factors

The literature review demonstrates that the lack of quality in construction activities and the waste generated on site can be attributed to: the imperfections on the design and specifications (Cnudde 1991), to structural design being poor in terms of standardization and detailing, the need to cut blocks or other materials due to the lack of modular coordination in design, poor integration of building subsystems during the design stage, poor detailing of design, lack of optimisation during design in the use of resources, imprecise specification of components and lack of site layout planning. (Bossink and Brouwers 1996, Faniran and Caban 1998, Forsythe and Marsden 1999, McGrath 2001, Formoso et al. 2002, Chi et al. 2004, Shen et al. 2004, Begum et al. 2006, Poon 2007)

A bad design may lead to two causes of waste generation: design and detailing mistakes; and change in orders (Gavilan and Bernold 1994).

Research Proposition 1: The use of design measures and concepts can reduce construction waste. (Modular coordination and standardisation, minimizing the use of temporary works, avoiding late design modifications, providing more detailed design, introduction of improved design, dimensions to match with the material size standards).

The aim of this sub-study is to examine the aspects presented in the research proposition 1, which according to some authors influence and motivate the design of the projects and the importance given by the designers of projects to environmental issues.

The information will be collected using a questionnaire, which will be applied to architects, designers, civil engineers or professionals in charge of the design of the buildings on the companies where the case studies will take place.

3.2 Management factors

One of the first studies found in literature related to materials wastage dates from 1976 in which Skoyles started to analyse the misuse of materials by the construction sector. His conclusion was that materials and labour spent on handling them to the fixing position, account for nearly half the cost of traditionally constructed building and the waste occurring in practice is on average about double the losses generally assumed or allowed for in estimating.

Since then, the importance of materials management and control has been established. Wyatt (1978) suggested that wastage of materials arise from inadequate monitoring or administration, or poor housekeeping. Navon (2005) mentioned, based on Chai and Yitzchakov (1995), the importance of monitoring the flow of materials and the data associated with them, such as their quantities and inventory levels, they asserted that the main problem is the lack of up to date relevant information.

Material management and labour productivity has also been studied and it has been estimated the work-hour losses resulting from ineffective practices. The authors argued that formal material management programmes have the potential to yield significant construction cost savings due to the fact that material resources constitute a large portion of a project’s total costs. (Thomas et. al 1989, Choo et. al 1998, Thomas and Sanvido, 2000, Formoso et. al 2002, Poon et. al 2004, Navon and Berkovich 2005 and Thomas et. al 2005). Some authors have explained the benefits of the application of materials management and control systems in order to: increase productivity and avoid delays due to the availability of the right materials prior to work commencement and the ability to plan the work activities according to the availability of materials. (Bell and Stukhart 1987 and Akintoye 1995)

Gavilan and Bernold (1994) emphasized that waste reduction is the best and generally most economical way to improve the use of materials. They concluded that more detailed planning of materials and process requirements and better material handling are needed in order to reduce construction waste. Bossink and Brouwers (1996) came to the same conclusion in which they analysed different causes for the production of waste and the most significant ones are related to management, being the most important material handling and operational issues.

Research Proposition 2. Materials' control and management do not have enough attention at the company level.

The aim of this sub-study is to analyse the material management system present at the company level with the participation of professionals from the head office, personnel on site, manufacturers and suppliers.

A checklist has been prepared that will be used as a guide to check on site material management practices, as well as a guiding tool to ask questions about management practices to managers at the head office, on site, manufacturers and suppliers.

Research Proposition 3. Various sources have a different yet significant effect on construction site waste generation.

The aim of this sub-study is to determine main sources of construction waste and to ascertain the levels of importance of those waste sources.

The information will be collected by a survey applied to senior workers from construction companies' engineers, academics and practitioners at construction sites. They will be asked to rate pre-determined attributes according to their potential contribution to the generation of waste on site, from the experience of their companies. The respondents will be invited to add new attributes if necessary.

A pilot group will be chosen from the Federation of Architects and Civil Engineers to respond the questionnaire in order check the clarity of the questions, and to adjust the instrument based on the recommendations.

3.3 Material flow analysis

Materials pass through a number of handling processes from their use to their final disposal. These processes can induce various factors affecting materials management effectiveness, thus the proper flow of these processes is important.

Shen et al (2004) developed a descriptive model for analysing the flow of materials in the construction sites, which provides with a systematic way for describing the generation of waste during the building processes. Ming Lu et. al (2006) indicated that the model fails to show the matching, queuing, and transit of various resources and the intricate interdependencies between different processes. Instead they used the free flow-mapping model as a basis to develop a process mapping technique that could represent the intricate logical and technological constraints and complex interdependent relationships between components of a typical handling system in construction.

In the case study of Costa Rica, the free flow mapping technique is chosen for observing and drawing the movements of the materials (wood, steel and concrete). Attention will be paid to matching, queuing and transit of the various materials trying to reduce the gap between the simple mapping of the materials and the failures stated by Ming Lu et. al.

Material Mismanagement

Mismanagement of materials on site emerges as one of the main causes of waste. Substantial losses are caused by inadequate transportation, unloading and stacking of materials, unsuitable packaging, poor ground conditions, equipment mal functioning and due to craftsmen’s errors. Field data indicate that most material wastes came from one of 2 sources: leftover from cutting stock materials to fit and nonreusable of materials that are not part of the building (nonconsumables) (Skoyles 1976, Gavilan and Bernold 1994, Formoso et. al 2002, Shen et. al 2004, Ming Lu et. al 2006).

Research Proposition 4: Material management has a positive influence in the reduction of construction waste.

Research Proposition 5: Waste is produced due to a combination of events rather than an incident occurring in one operation.

The aim of this sub-study is to examine the flow processes of construction materials (wood, steel and concrete) on site by using a free-flow mapping presentation technique and a checklist. The information in mapping includes 5 elements: material supply, waste source, waste facilitator, waste processing and waste destination. The observations with the checklist and discussions (with site management staff or building workers) on the practices will be oriented to the following topics and other ones arising during the study: coordination and information, waste handling and sorting actions, reduction, reuse and recycling of waste practices, pollution and safety.

3.4 Quantitative analysis of waste production

Waste in the construction industry is important not only from the perspective of efficiency, but also concern has been growing in recent years about the adverse effect of the waste of building materials on the environment

Various researchers have provided different approaches for the quantification of construction waste, which are presented in table 1.

Example Table 1: Summary of approaches to analyse quantities of construction waste

AUTHOR	*APPROACH*	*LIMITATION(S)*
Skoyles E R (1976)	*Difference between specified by contractor and the quantity of material delivered to site (less any material credited or transferred).*	*Requires the records of material credited or transferred, therefore it needs support of the workers.*
Picchi, F.A. (1993)	*Analysis of how much entered to the site based on BoQ, and the built being measured. The difference makes the construction waste.*	*Some materials might be re-use and is presented as waste. Solution, to weigh the waste removed at the landfill site.*
Gavilan R M and Bernold L E (1994)	*Approach 1. “Cradle to grave”* *Individual building material is traced from the time they are delivered to the site to the time of their final disposal as either part of the final structure, as a solid waste or as surplus. This would be the most accurate way of making the observations.* *Approach 2* *The waste would be inspected and the sources of waste determined by careful scrutiny, questioning of the work crews, and deduction. This approach is practical because it starts at the end of the material’s life.* *Approach 3.* *It is a modification of approach 1. Instead of tracing the path of every material through the process, a selected number of bricks, or lumber pieces, could be marked and traced from the start to the end. This would place proper emphasis on the flow of the material through the construction process as well as providing a sample of manageable size.* *Approach 4.* *It focuses on workers and not on materials. A worker would be observed for a given period of time and the amount of waste s/he produces and the reason could be carefully tracked. The advantage of this approach is that it is simple and that the causes of the waste will be very easy to identify.*	*Approach 1.* *It would require the ability to observe every mat at all times. It would not have been sufficient to simply watch every worker at all times. This could be done, if there is one person per site.* *Approach 2* *It won’t be possible always to determine the origin of the waste and most waste piles are difficult to assess.* *Approach 3* *The problem with this approach is that the causes of construction waste are not necessarily uniformly distributed throughout a stack of materials.* *Approach 4* *The problem limitation is that the waste produced during construction is not simply the sum of the wastes produced by each individual worker.*
Forsythe P and Marsden P K (1999)	*Waste is determined by subtracting insitu quantities (taken from drawings or site measurement) from ordered materials taken from delivery and order documents.*	*Some materials might be re-use or recycled and is presented as waste.*
McGrath C (2001)	*BRE developed a waste auditing tool called SMARTWaste (Site Methodology to Audit Reduce and Target Waste).*	*Special equipment is needed for recording the data.*
Formoso et. al (2002)	*Each site is directly observed during the period of the processes. At the beginning of the period (date A),*	*Requires participation of observer almost on a daily basis.*

	initial data collection is carried out by observer. This involved measuring all construction work in which the 3 materials participated) as well as existing inventories for those materials. At the end of the period (date B) a similar data collection is undertaken. Between dates A and B, data is directly collected during the working hours. The amount of materials delivered or withdrawn from the site before date A is obtained by material supply records.	

The method chosen for the quantitative analysis is the one provided by Formoso et. al (2002). An observer will be at the site during the process of the construction of the sub-structure, super-structure and the roofing.

3.5 Pilot test

A pilot case study has been chosen in order to refine the data collection plans with respect to both the content of the data and the procedures to be followed. It would allow to observe different phenomena from many different angles or to try different approaches on a trial basis.

4. Conclusions

The objective of the presentation of this paper is to discuss with researchers, working in the field of construction materials stewardship, the propositions and the tools that have been prepared in order to analyse the different subsystems present in the process of building an edifice.

Another objective is to present the information collected with the pilot test case, which has already provided useful information in relation to some procedures that should be modified. The free-flow mapping was complicated to draw, the observer didn’t have clarity on what he was expected to do. The checklist prepared for the interviews seemed very useful in order to check all the variables that are part of the research. The measurement of the construction waste has been easy since the workers were supportive in setting the waste in the right container. The amount produced was small because the house chosen has been built with pre-fabricated components.

The questionnaire has been tested with a group of 15 professionals and it has been placed on line until the 30th of March 2010. The invitation to participate has been sent to 419 construction companies of the Great Metropolitan Area and 52 have been received complete, which represents 12.5 % response rate.

There are no conclusions yet, but as mentioned by Formoso et al (2002), measuring waste is an effective way to assess the performance of production systems because it usually allows areas of potential improvement to be pointed out and the main causes of inefficiency to be determined. That is the main goal of the whole study, to determine construction waste generation in a newly starting industrialised setting using Costa Rica as a case study.

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