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SBE 16 Cairo Conference

It is a great honour to have SBE16 Cairo under the auspices of **HE Dr. Mostafa Madbouly**, *Minister of Housing, Utilities, and Urban Communities*, and **HE Dr. Ashraf El-Sheihy** *Minister of Higher Education and Scientific Research.* This is a strong message and demonstration for integrating Industry with Research as the way forward for prosperous future.

It is our pleasure to host for the second time in a row the sustainable built environment conference in Cairo. While SB13 Cairo main aim was to redefine urban challenges in Egypt and the region, and further identify and prioritise potential innovative practical solutions; SBE16 Cairo is considered the logical step forward after SB13 Cairo.

Major challenges facing Egypt and the region include, but are not limited to, the provision of energy and water. Nevertheless, to ensure efficient and sustainable use of the scarce resources, our practices towards the built environment should be revised to be proactive to accommodate the rapidly urbanized region. This proactive measure should be coordinated not only on a national and regional, but also on the international level to ensure sustainable developments.

SBE16 Cairo is action oriented rather than merely a scientific gathering; and thus, puts emphasis on the importance of 'integrating' stakeholders, processes, and technology for a sustainable living for all.

'INTEGRATE', the main theme of SBE16 Cairo, prompts not only the action of 'integration'; but most importantly it prompts determination, and thus, is an urgent call for 'speedy' actions.

SBE16 Cairo is part the current Sustainable Built Environment (SBE) conference series (2016-17) http://www.sbe-series.org/ that will be concluded by the World Sustainable Built Environment Conference WSBE17 Hong Kong in 2017.

Conference Chair

Prof. Dr. Tamer El-Khorazaty
Architecture and Urban Design
The German University in Cairo

Preface

From the Assistant to the President of Egypt for Strategic and National Projects

It gives me a great pleasure to welcome the SBE conference series once more in Egypt.

While in the first round during SB13 Cairo, Egypt was embarking on a new era of Democratic transition, during this round Egypt is steadily heading towards economic reforms.

Egypt's vision is to achieve an investment climate that fits the aspiration of Egyptians and meets the needs of the investors during the coming years. Major national projects have been launched inclusive the development of the Suez Canal Corridor, the establishment a new generation of new cities, reclamation of one million and half feddans, the development of the Western North Coast, as well as industrial, tourist, urban, agricultural and power generation projects, to name but a few.

In addition to the development of the Golden triangle in Southern Egypt, with the aim to establish an economic, mining and tourist area on the coast of the Red Sea, among others.

Furthermore, a road network is currently being implemented all over Egypt with a length of around five thousand km. This is anticipated to provide a good infrastructure to attract more investments and consequently create new job opportunities.

There are definitely challenges, but the opportunities far outweigh these challenges.

I believe the theme of SBE16 Cairo 'INTEGRATE' is timely as this is what we need for a prosperous future for Egypt and the Region.

Eng. Ibrahim Mahlab

From the Minister of Housing, Utilities & Urban Development

It gives me great pleasure to welcome you all to the Sustainable Built Environment Conference SBE16 Cairo, one of the international conference series for 2016-2017 and which will be concluded by the World Conference WSBE17 in Hong Kong.

Currently Egypt is embarking on ambitious developmental mega projects targeting economic growth, and this conference is indeed a true reflection of what we need in Egypt right now, namely the integration.

The projects are multifaceted they include existing rural and urban as well as new urban areas. These range from developing unsafe/slum areas within two years, and the provision of social and low income housing, infrastructure such as the National sanitation and sewerage projects, roads networks etc,. boosting the real estate sector, the Administrative Capital among others.

Egypt has a strategic geographical location, and this allows us to collaborate with our neighbours and partners for a better future for all. There are ample opportunities in Egypt to invest in sustainable development, and the right time is now.

Egypt’s youth is a fortune and is our strength, integrating them in the sustainable development is the answer to overcome any developmental challenges.

I am glad to see SBE16 Cairo integrating Research with Practice, this is the way forward. It is of utmost importance to integrate our efforts, through our people, improve our processes, and make benefit of the state of the art technologies to improve the quality of life of Egyptians.

It is about time to be pro-active rather than being re-active.

I wish you all big success in your conference, and am looking forward to the fruitful results.

Dr. Mostafa Madbouli

From the Minister of Higher Education and Scientific Research

Higher education in Egypt aims to support human development to effectively contribute in the development and implementation of Egypt's economic development plans with the support of the state of the art technologies to achieve a knowledgeable society.

We are aiming to support the market with skilled graduates capable to compete in the local, regional, and international market.

In order to achieve this, higher education should have close links with the Industry and Research and Development. This is of importance to keep up with the pace of the changing environment. It is important to promote learning which is not merely about 'how' to conduct a particular 'job' rather 'why' vis-à-vis the 'knowledge' that is needed for the job. In other words, there should be a transition from 'doing' to 'knowing' to achieve a knowledgeable society.

Industry-Academia collaboration has long been promoted Worldwide to improve industry and market practices, and furthermore to improve education offerings. Industry-academia collaboration allows learners to be exposed to real-world practices and help learners to gain experience and insight into future career responsibilities.

I am glad to see SBE16 Cairo keen on bringing Industry and Academia together to create a platform for knowledge sharing and furnishing grounds for potential further collaboration.

I wish you all a fruitful event for a better future for all.

Dr. Ashraf El-Sheihy

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Theme I

A Rapidly Urbanised Environment

Human Behaviour and Psychological Needs in Cairo's Urban Spaces

A case study of downtown Cairo

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Abstract *The paper discusses the needs and characteristics of human behavior that should be applied practically to the design of urban space, in Cairo, the second largest capital and congested pattern international wide, Aiming to reform a decision matrix that assists local urban designers in shaping up and designing urban spaces that respond adequately to human physical and psychological needs. The analysis of the behavioral influential factors that underlie and shape up the impact of different spaces are analyzed, and the behavioral elements that people expect from local urban spaces are discussed in terms of a questionnaire study.*
El Attaba Square and Abd El Aziz Street are studied using behavioral mapping techniques through using drawings, photographs, design data, interviews and surveys which could be indispensable data to any architect interested in urban designs, who wants to create places that really work for people.

The outcome is a set of criteria that could be measurable, meeting the psychological needs of locals in urban spaces. Thus creating a place identity that creates a sense of belonging between local people and the urban spaces, in addition to the presence of social activities to anchor people to their urban experience and upgrade the social interaction, coming up with basic recommendations to have better local urban places that satisfy human psychological needs.

Keywords: Environmental behaviour, Environmental psychology, Place identity, Urban place

1. INTRODUCTION

The study will start by defining and showing the importance of environmental psychology and stating the different aspects of environmental psychology that include place theory that consists of place identity and attachment in addition to other physical attributes. In addition to the quality criteria needed to have a successful urban place. Analysis took place in one of the famous streets in Egypt which is Abd El Aziz Street located in El Attaba Square, Surveys and interviews took place in the studied area to understand and evaluate the level of satisfaction and the needs of people in an urban place. And finally a group of recommendations were conducted in addition to a matrix showing the hierarchy of needs of people in an urban space which is considered the main finding of this research.

2. PAPER STRUCTURE

2.1. Introduction

The paper will study different elements that make a public space more appealing to the human being like place familiarity, presence of clear paths, nodes and landmarks, place identity that create a sense of belonging between people and the urban space, in addition to the presence of social activities to attract people to the urban spaces to upgrade the social life and interaction and also applying different techniques to keep the human being within his environmental comfort zone.

2.2. Literature Review

2.2.1. Human and their surroundings (Environmental Psychology):

"Historically, the first discipline to express a concern not simply with physical space, but with the way physical space is related to or influenced by human activities, is Environmental Psychology in the 1960s" (Bannon,2004) .

Environmental Psychology (EP) study is generated as an area of study due to the increasing interest on psychological studies as the connections between behavior and physical surroundings. Environmental Psychology is concerned with the quantification of environmental stimuli and with establishing a functional relationship between such stimuli and behavior (Bannon, 2004).

Although it is difficult to establish "patterns" of behaviour and their one-to-one connection to features of the space interesting findings have been generated from early EP studies. One important issue is the occurrence of discrepancies between the rational planning of physical settings and their actual use: this shows that people's perception and reactions to a space might be unexpected and different from the planners' intentions. This draw the attention to the importance of focusing not only on the plain physical structure and features of the environment, but also on the connection between the space and it inhabitants, and also the necessity of undertaking empirical studies of how actual spaces are used. Another interesting observation made by Proshansky highlights the fact that: "the physical settings and the broader structures that encompass them are themselves expressions of correspondingly inclusive social systems. The physical space is integral part of social practice" (Proshansky, 1969). The continuing social practices shared by the users of a space influence the space in addition to contributing to its shaping (Bannon, 2004).

Consequently, this link between the physical environment and the social environment, made the organization of the physical setting a dynamic one. Seeing the environment as an open, dynamic system is not only limited to its connection with people, but it also spreads to the relationships amongst its elements (Proshansky, 1969).Environmental psychology has different elements that define it. According to Garling and Golledge (1993), Kaplan and Kaplan (1982) these elements are:

Attention: Firstly it is needed to understand how people perceive their surrounding environment to understand their behavior which includes what the human being notices willingly or unwillingly.

Perception and cognitive maps: The natural and the built environment is one of the fundamental feature of environmental psychology as data is stored in the human being's brain in the form of cognitive maps which creates a link of experiences with what an individual perceives the ongoing ideas, emotions and actions.

Ideal environments: Individuals tend to look for places that make them feel self-assured and make them familiarized with the environment. It is researched that it is important to make people have a sense that things work together in the environment in addition to walking in an environment without being lost. In order to have an ideal environment it must enhance his/her behavioral effectiveness and his/her sense of well-being.

Environmental stress and managing: Research has recognized various behavioural and cognitive results including poor physical health, reduced selflessness and weaknesses, as well as paying no attention to the environment. Individuals can adjust their physical or social surroundings to create a more supportive environment (e.g. smaller scaled settings, territories, privacy, personal space) where they can supervise the course of information or stress inducing stimuli. Individuals can also seek to understand or make sense of circumstances as a way to resolve its stressful effects, often sharing these interpretations with other individuals as a part of their culture.

2.2.2. Place Theory

Place is used to examine the environment and breaking it down into conceptual components. Since space and environment is too general then it is difficult to examine (Tolley, 2012).Environmental psychology could be understood when; the meaning of place theory is established as people interaction with their physical environment is a principal. The place theory is concerned with three features which are human activities ,physical attributes and conceptions (Canter, 1997).

A place is considered to be a form of a harmony which is the resultant of the relation between the physical attributes of the environment and conceptions and human activities. However, Castello (2006) states "that place is a unit where physical form and human experiences and are bonded together, creating a united context" There is a vibrant relationship between place and people which could be figured out from the concepts of place attachment and Place identity .In fact the interaction between people and their environment create a sort of a link that gives a specific meaning to their environment (Castello, 2006).

2.2.3. Place Identity

Human identity could be formed by many factors as identity is a result of the psychical environment (Hauge, 2007). Place identity, according to Proshansky (1987), can be defined as" a sub-structure of the self-identity of the person consisting of broadly conceived cognitions about the physical world in which individuals live".

The places where people belong to may increase their environmental preferences and self-esteem. Place attachment could be a result of place identity, as individuals feel attached to the same environment as an individual define himself within the environment (Dixon & Durrheim 2000).

2.2.4. Place attachment

Every person has his own bond that is developed towards certain places throughout a specific period of time. Place attachment varies according to the level of belonging of the individual and is different from one place to the other (Knez 2005). Therefore, the level of attachment a person has to a specific place determines the level of satisfaction of the person and his/her perception to a certain place. Although the attachment to a certain place grows over time yet still there should be an interaction with the community and a positive one to keep and increase this attachment (Tolley, 2012).

According to Milligan (1998) place attachment could be defined as: "Place attachment occurs when a particular interaction was accompanied by significant meaning" However place attachment, according to Knez (2005), can be defined as:"The affective positive bond between a person and a place; more specifically, a strong tendency of that person to maintain closeness to such a place".

It is therefore clear from the definition that place attachment is meant to be an emotional bond that the individual form to a physical setting due to the meaning given to the location through the interactions between the person and the environment (Casakin & Kreitler, 2008).

According to Halpenny (2005), could be formed place attachment when place satisfaction of individuals with their environments is present therefore they protect that place more. Payton (2003) and Warzecha et al (2000) state that place attachment is divided into two main theories which are functional place attachment and emotional place attachment.

- **Functional Place Attachment**

It is to what extent resources meet the needs or targets of individuals. Furthermore, functional place attachment is linked to the kinds of activities that users track as some activities are general while others are more complex and need specific aspects (Warzecha et al, 2000).

- **Emotional Place Attachment**

It is meant to be the emotional features of a person-place relationship and how that place itself helps in shaping an individual's identity. In fact emotional place attachment is based on emotional bonds and links to a certain place and increases over a certain period of time through many interactions with the environment. According to Warzecha et al (2000), emotional place attachment may also be expressed as an identity with a symbolic meaning or idea.

2.2.5. The Three groups of Quality Criteria in urban spaces:

Based on pioneering research by Professor Jan Gehl the quality criteria for a successful public space are divided into three groups: Protection, comfort and enjoyment and they vary from the human scale to details of the physical environment.

- **Protection**

It concentrates on how to decrease unpleasant experiences as unpleasant climate conditions, traffic accidents and crime.

- **Comfort**

It focuses on the quality of stay and walking in a specific place. It is concerned with sitting, standing and walking in addition to talking, playing, seeing, and hearing.

- **Enjoyment**

It is concerned with the human scale; it is about the positive aspects of the experience and the climate and how to enjoy it (Gehl.J, 2006).

2.3. Research Methodology

The methodology of study consists of both qualitative and quantitative in order to collect and analyse data. In this study, data were collected during the analysis phase to have more valuable findings .Behavioural mapping, Surveys and interviews were conducted. The research will study the relation between human behaviour and urban spaces design. A matrix of psychological factors in an urban space will be generated through the literature review then questionnaires, surveys and observational mapping were conducted to update the matrix.

Literature review
↓
Matrix (based on literature review)
↓
Surveys, questionnaires on studied areas
↓
Updated matrix
↓
Recommendation

2.3.1. Criteria of Case study Selection:

The study area of the case study will El Attaba square, focusing on Abd El Aziz Street one of the most famous streets in Cairo, Egypt. This area and especially this street have been chosen due to:

- Presence of landmarks as Omar effendi old commercial store.
- Being a commercial street made it easier to deal with different people of different social standards.
- Being in the heart of Cairo.
- Being a well-known place that has a place identity.
- Being a street of a unique character and has locational challenges.
- Considered an interactive place where different activities take place.

Analysis was made of Abd el Aziz Street in El Attaba square. It is unique in its character, urban fabric and landmarks. Nevertheless, it has many problems in orientation, and is full of locational difficulties. It shows another example of an area with several high-density residential districts as shown in fig1.

Figure 1: Maps showing the urban fabric and street analysis of el Abd El Aziz Street and its surrounding (Ahmedy.Y, 2013)

Land use study concluded that the street composes of different buildings. Most of the buildings are mixed use. It has commercial stores in lower floor and residential in upper floors. There is a minimum area of green spaces as shown in fig2. Although the regulations prohibit the use of side walks for goods display yet still most of the shops display their goods at the side walks.

Key:

- Mixed Use
- Educational
- Commercial
- Religious
- Governmental

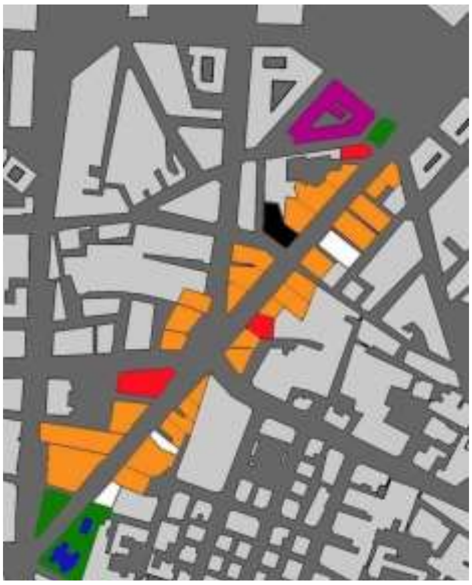

Figure 2: Land use map of Abd El Aziz Street (Ahmedy.Y, 2013)

Data were collected on days with temperatures between 28C and 36C from late April through early August in 2013.Observations were carried out between 7:00 AM and 11:00 PM spread out on weekdays and weekends as shown in fig3.

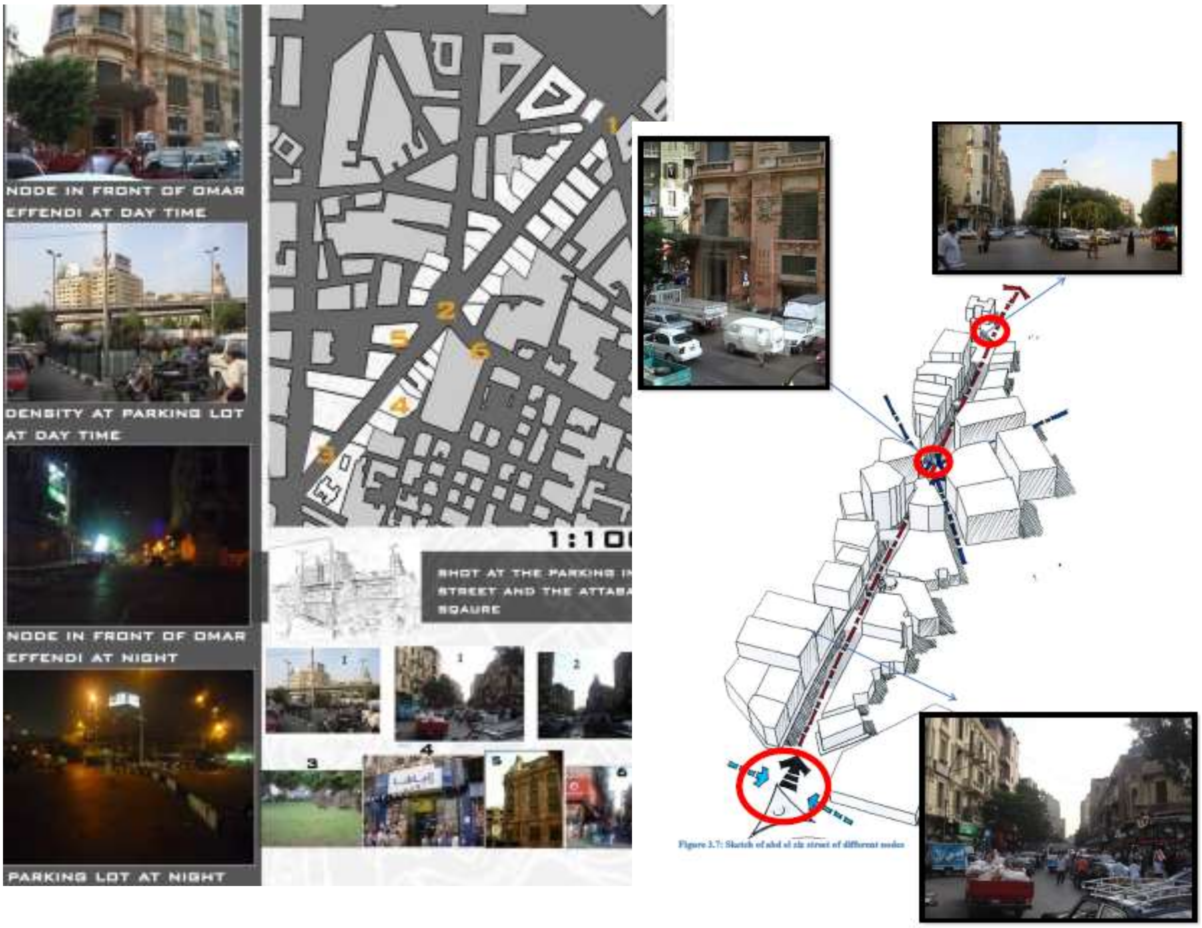

Figure 3: Behavioural map and Sketch of Abd El Aziz street of different nodes (Ahmedy.Y, 2013)

After observation it was deducted that the main problem for the street is that there is no walkways for people to walk but cars and people both move in the street itself. There are no crossings for pedestrian which threatens pedestrian safety in addition to lack of presence of parking lots as shown in fig4.
There are no delivery stops as trucks stop in the same street where cars are moving.

Key: Low Dense Cars

High Dense Cars

Pedestrian

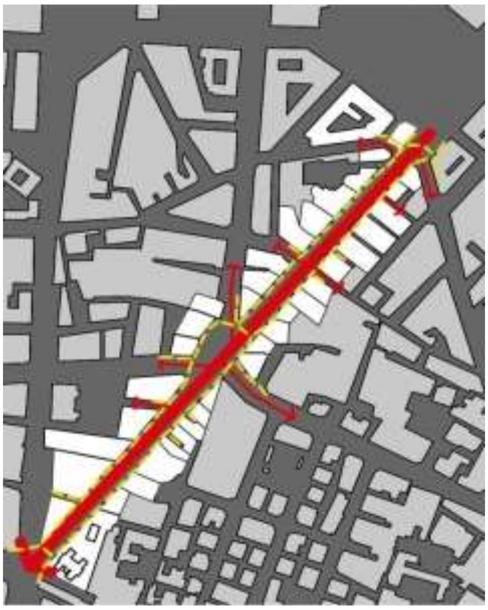

Figure 4: Pedestrian and traffic map of Abd el Aziz Street (Ahmedy.Y, 2013)

A survey in Abd El aziz street was conducted it was developed to measure peoples' attitude towards different environmental factors. It is an 18 item questionnaire used to evaluate the beliefs about nature and society, and the importance of different environmental factors. Respondents are asked to rate the extent to which they agree or disagree on certain items.

The scale responses are answered on a 5-point scale, ranging from 1 (strongly disagree) to 5 (strongly agree). In addition interviews were also conducted in the studied area.

2.4. Discussion and conclusion

2.4.1. Social Activities

Walk-by on weekends and weekdays figured out that almost two-thirds of the people in the studied area were engaged in social activities either talking, eating or drinking, window-shopping or vending. There was a solid relationship between the locations with stationary social activities and locations with stationary activities. Therefore in order to design successful neighborhood commercial streets it has to be able to afford social activities.

2.4.2. Behavior Settings for Interaction, Play, and Relaxation

Some shops at the street created behavior settings that supported social activities and behaviors, which could be extended to the street. The presence of too many shops that offer different services, along with the patterns of organization and configuration of buildings, floor, provided the opportunity for social activities and behaviors on the street.

2.4.3. Accessibility and Use of Physical Elements

There were three distinct zones of activity, the first zone was along the edges of buildings and was essentially used for entering and exiting, window-shopping. The second zone was were omar effendi commercial store was located which is considered now a landmark in the street in addition to being a central space for intersecting streets while the third zone is lowest in density where an unused garden is located. The presence of more than one entrance and exists created ease of accessibility which is one of the fundamental factors of a successful public space. Also according to the survey that was conducted to rate different items the results indicated the importance of clear paths and presence of landmarks in way finding.

2.4.4. Sense of Belonging: Community Places

Through interviews in the studied areas people showed that the identity and history of place and the presence of old buildings as Omar effendi departmental stores made them have a kind of sense of belonging to this place as being one of the famous commercial streets in Cairo that offer different services. Therefore place identity; place attachment and presence of landmarks are important in having a successful urban space. According to the survey results indicated the importance of having a place identity and familiarity of space.

2.4.5. Environmental Comfort on the Street

Since the street is not exposed to direct sunlight and shade is provided due to the presence of buildings that provide shade, the vending process is almost taking place throughout the whole day especially before sunset and more people are engaged in different social activities.

Accordingly, observations proved that temperature caused by direct sunlight should be with the human being comfort zone to be present in a space and shaded areas should be maintained.

2.4.6. Pedestrian-friendliness.

In the interviews it was stated that the major problem of the street was traffic and absence of pedestrian walkways. Since shops put their good on pavement and there is no roam for people to walk therefore they walk in the street with cars. The level of pedestrian friendliness of a street was an important factor in determining the level of physical comfort it provided to its users.

2.4.7. Sense of Safety on the Street

According to the walk by observations, it was obvious that there were many people occupying and spending time in the street throughout the whole day and none of the properties was vacant. Interviews were conducted on the level of security in the street but people didn't mention major cases threatening security but mentioned that security is one of the needed issues in the street.

2.4.8. Attractiveness and Interesting Appearance

The articulation of the building façade, the openings at street level the presence of Omar effendi commercial store of its unique architectural elements made it an interesting and attractive landmark in the street leading to an ease in way finding and creating nodes for social gatherings.

3. CONCLUSIONS

Environmental psychology discovers the communications between people both individuals and groups and their physical setting, it concentrates on both the effects of environmental circumstances on behavior and how the individual perceives and acts upon, environmental psychologist believe that psychological processes are always place related and also place dependent.

According to Salmi (2002) there are key points to look out for in organization of space. These points include:

- Cognitive experience is increased through the Architectural features of buildings.
- Findings paths is important and therefore connecting spaces must be there to assist in connecting large spaces.

Fine places for walking and staying should be delivered, so that the design can satisfy the needs of the people. Public spaces should be welcoming for all users passing through good interaction while sitting or standing or even walking and interacting with other people. Therefore in order to have successful urban spaces three aspects should be satisfied which are protection, comfort and enjoyment that have been mentioned before as a set of quality criteria.

When these criteria are fulfilled in the design of a space, then an improved place has been formed for environmental psychological satisfaction.. In fact after the analysis of Abd El Aziz street and the answers of the interviews and the walk by observations in addition to the results of the survey that showed a high level of agreement on the proposed factors it has been proven that place identity familiarity and emotional attachment , safety and control, noise and pollution control, surrounding architecture and buildings arrangement, landmarks, clear paths and nodes in addition to other factors are fundamentals in the process of psychological satisfaction of people in a place.

The attitude of people towards public spaces, their behavioral responses and perceptions were examined in this research. It also tried to attempt to understand the elements of the physical setting, the different nature of urban spaces in addition to places that has community's collective meanings. As a result an exploration of different ways to understand, management and the design, of these public spaces is there.

In fact, it is important to understand that public spaces need more than just the basic needs like for example shades to protect people from direct sun light or comfortable seating it has to go beyond this, it has to consider the enjoyment part of the human being to make visiting these public space a journey in itself resulting in increasing the level of joy of the human being leading to a high level of psychological satisfaction and comfort. The research also showed that the surrounding architecture and the building arrangements are considered a visual preference that affect people's preference for an environment.

In public spaces people need to have a sense of safety, a sense of belonging, a sufficient level of environmental and physical comfort, in addition to a sense of belonging and attachment and a level of social interaction and pleasure. In order to have a satisfactory urban place these needs should be there.

A survey was conducted to ask people of different backgrounds to what extent they agree that the presence of the factors deducted from the literature review is important in their psychological satisfaction. According to their level of agreement the hierarchy of importance of these factors was deducted.

Table 1: Matrix for urban spaces Characteristics (Ahmedy.Y, 2014)

	Urban Space characteristics	Category			
		1	2	3	4
1	Familiarity of space (emotional attachment)			75%	
2	Presence of landmarks	90%			
3	Presence of personal space			70%	
4	Presence of surveillance and control		89%		
5	Presence of suitable environmental conditions	96%			
6	Presence of place identity		82%		
7	No presence of pollution	98%			
8	Presence of clear paths and nodes		82%		
9	Presence of eligible surrounding architecture	97%			
10	Presence of wide space				67%
11	Presence of suitable buildings arrangement		85%		
12	Presence of people attract people		84%		

Very high High Meduim Low

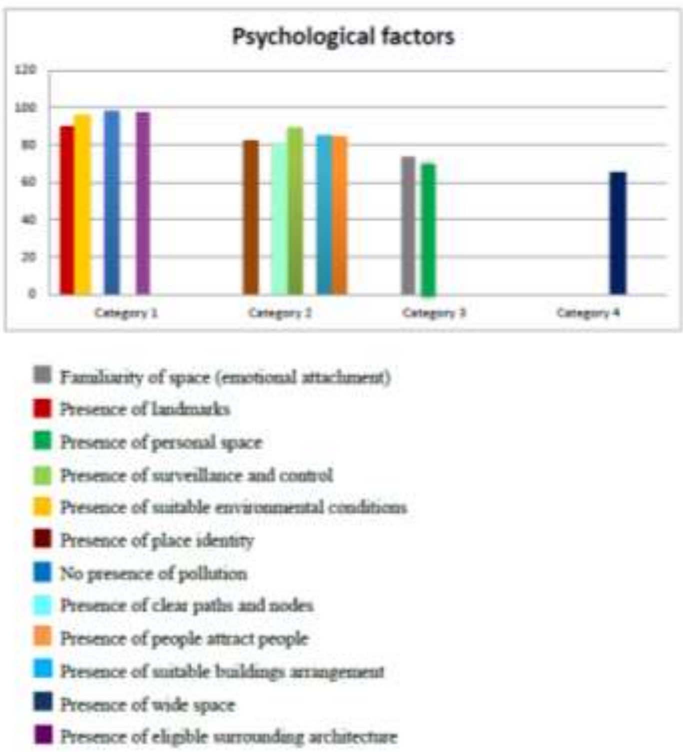

Figure 5: Psychological Factors affecting urban spaces (Ahmedy.Y, 2013)

4. Recommendations:

4.1. Protection:

In order to satisfy the aspect of protection control and surveillance on urban spaces should be there in addition to pedestrian security. For places to be safe there have to be people around engaged in different activities in order to have lights from windows and people nearby throughout the whole day.

Another factor that deals with protection against unpleasant experiences is environmental pollution and noise pollution. Having green areas absorbing carbon dioxide emissions from spaces and laws to regulate noise could be a solution to achieve the aspect of protection.

4.2. Comfort

Comfort deals with the quality of staying in an urban space. It involves presence of social activities to attract more people as people attract people, presence of adequate seats, presence of shaded areas for environmental comfort in addition to the emotional comfort like having a sense of belonging and clear path and way finding strategies. In fact presence of landmarks could also help in place identity which is one of the fundamentals factors of satisfaction.

In order to satisfy the aspect of comfort there should be

- No narrow sidewalks or obstacles.
- No blank walls.
- No long boring distances.
- Main gateways: to influence people to identify it as a distinct entity
- Nodes for social activities
- Shades for environmental control.
- Presence of an adequate urban space.
- Presence of appropriate seats.
- Landmarks should be highly visible and distinctive.
- Preserve buildings that make good landmarks.
- Landmarks should be placed at major decision points in the road system.

4.3. Enjoyment

Enjoyment is indicated through exceeding the human satisfaction of a place, Presence of positive and creative aspects of climate, experience and joy through design and activities occurring in space. Details are an important factor to satisfy the enjoyment aspect. In order to satisfy the aspect of enjoyment there should be:

- Good organization of different building forms.
- Creative utilization of attractions in an urban space.
- Create spaces on a human scale, with fine details, good materials and good street furniture.
- Fine views and vistas with an aesthetically pleasing surrounding architecture.
- Having written quotes on walls that deliver hope, joy and happiness could touch the emotional part in the human being and could create a kind of space attachment.

After deducting different elements that should be there for psychological satisfaction in a space, these elements could be categorized according to the different aspects of quality criteria.

Table 2: Table for different categories of psychological aspects according to quality criteria (Ahmedy.Y,2013)

Different aspect of psychological satisfaction in urban spaces	
Protection	• Presence of surveillance and control • No presence of pollution
Comfort	• Presence of place identity • Familiarity of space (emotional attachment) • Presence of landmarks • Presence of personal space • Presence of clear paths and nodes • Presence of people attract people • Presence of wide space • Presence of suitable environmental conditions.
Enjoyment	• Presence of eligible surrounding architecture • Presence of suitable buildings arrangement

4.4. Limitations and Recommendations for Future Research

There are practical limitations of time and resources that were considered as constraints in the research. In this study, the analysis was limited to only one neighborhood Commercial Street. The street is in an urban area that has a high population density. Although it was perceived as being mostly safe yet it has transit problems and lacks the entertainment part that needs to be found in a successful urban space.

Additionally, although the people observed on the neighborhood commercial street represent a wide range of age, gender, and class but still the social standard of people occupying the street made them do not really look for the enjoyment part and see it as luxury which could be a different vision if the study was conducted in another street of different social standard.

The social interaction that took place in the street, which was the case study doesn't indicate the cultural behavioral patterns worldwide. There are different variations according to different cultures due to differences in race, gender, climatic conditions social standards and class. Therefore in order to have more validated findings then more commercial streets should be studied in different cities and towns as they will be located in different cultures taking into consideration cultural variations.

Finally this study does suggest some factors that emerged from the findings and found that they are critical in the understanding of neighborhood commercial streets or any other urban space and in achieving a quality of neighborhood public space that is conducive to stationary, lingering, and social activities. Further, this study may help in understanding the public environment and therefore designing and managing different spaces the meet people's needs.

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Affordable Living and Adaptability in Old Cairo Slum Areas

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Abstract: *Informal settlements and slum areas are arousing in developing countries which have daunt the cities' urban, visual and aesthetic conditions. Researchers and Professionals found out through their urban journey there are two concepts, which are called environmental justice and sustainability that have provided new aspect in terms of public policies. Both have prospered long-term potential in changing urban planning outcomes. However, some argue a critical overlapping should occurred in relations with social drive, so planners can generate convenient sustainable societies for users who can live in(Mike, R. 2005; Campbell, S.1996; Jabreen, YR.2006).*

Affordable and Adaptable Living particularly in developing countries, have a remarkable share of importance to give upgrading solutions in informal settlements and slums that are problematic for city's infrastructure and public facilities, and has aesthetic/visual problems. With the proper design, affordability may produce benefits to areas like the area of Darb El Ahmar, which will be the main case of study and Haret Khoukha as aiding example.

In order to carry out this paper, analytical study was applied along with observation of the case studies aiming to come out with factors that reflect on the urban development and element needed to be involved in achieving a suitable strategy to be carried on in the future.

Keywords: *Adaptability, Affordability, Old Cairo and Sustainable Development.*

1. INTRODUCTION

Authors and researchers have risen common concerns to both environmental justice as well as sustainability as they were conducting their search such as land use planning, solid waste, residential energy consumption that would be considered in any urban design and urban planning process.A lot of debates occurring whether there is ability to find a proper solution in terms of justice and equity without overcompensate any factor of social equity , economic growth and environmental protection on the regional and metropolitan , city, community and building level (*Jabareen , Y,R.2006*)& (*Conroy,M.,M., and Berke,P,R , 2004*).

Al Darb al Ahmar will be the area of study in this paper that “lies south of the prestigious al-Azhar Mosque and the popular Khan al-Khalili, historic Cairo's principal tourist bazaar, and is bound by al-Azhar Street, the Darassa Hills”(Siravo,2004). The study area suffers from insufficient infrastructure and lack ofbasic services, although it contains many listed historic buildings as well as Haret Khoukha. Therefore, in order to achieve a long term sustainable community development, the research paper addresses the adaptability and affordability schemes in their strategies.

2. LITERATURE REVIEW

A lot of existing theoretical plans and schemes have presented solutions taking into consideration the balance between sustainability and environmental impartiality as well as taking into account community in the decision making process and relating economic policies in order to reach a balanced environmental justice in all forms of pollutions and social righteousness towards sustainable urban community development (*Evans,T and Agyeman ,J; 2003*).However, in real life a lot of conflicts occurred during the process of implementation (figure 1). Nevertheless, there were some practical initiation towards creating more sustainable future urban developments with the attempt to reduce the gap between theory and practice.

Figure1 by the researcher

2.1 Sustainability

In practice, the selection of the elements that influence decision-making differs from the theoretical field which was clearly expressed by researchers and specialists in the urban environment, where we can shift the aspects and priorities between environment, justice and sustainability.

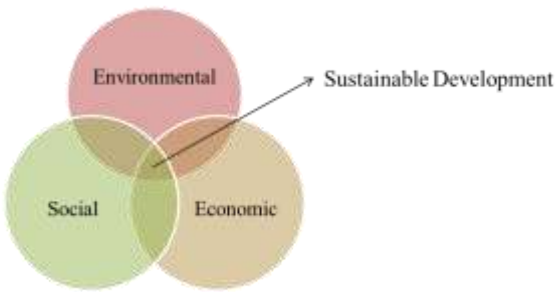

Figure2 by the researcher

Four main categories are common concern to both environmental justice and sustainability. Land use planning, solid waste, toxic chemical use, residential energy uses are very important issues that should be respected and considered in the sustainable urban plan equivalence,whichseeks to protect and enhance the use of energy, water and natural resources successfully. When it comes to practice, “sustainable community or society” which play extreme importance, should meet the social needs in terms of place, space and buildings. In addition, the “economic success” which enhances the creation of vibrant local economy is an important element to achieve sustainable communities,and shows the three major factors and influences that affect the sustainability of any community development scheme.

Those three factors that would reflect on sustainability when it comes to development especially in Egypt. Therefore, developers should involve their strategies with the following aspects:

Firstly, participation where it allows involvement of the community engaging throughout the project. However, an officer /coordinator and local resident trust relationship is needed in order to proceed. This was traces throughout Al DarbAl Ahmar developments occurred by the consultant of the Aga Khan Dina Shehayeb where they mobilized the community in two stages;the first one was targeting five houses to be developed through marketing the idea of rehabilitation and matching funds. The second stage was working on engaging the community constantly throughout meetings and debates in the site office. On the other hand, they need the approval of 75% of the residents in one building before doing anything in it.

Secondly, flexibility which is one of the important elements that allows sustainability to be implemented in long term schemes. It is important to have a flexible strategy that can adapt with different variables and concerns, especially when it comes to development by involving society and finance. This was traces throughout the Al DarbAl Ahmar developments where a flexible structure like for instance Al darb Al Ahmar community company was formed to deal with the needs and changes of the project separately away for the Aga Khan Trust for trust as well as a micro credit.

Thirdly, since urban development projects aim to solve different aspects together, partnership is very important element. Usually there are constant factors that every scheme will come across. 1) Private sectors, where the investments come from in Egypt. Private sector plays a strong part which collaborates in social responsibility and consultancy. 2) The public sector, especially in this case, where several governmental departments were tangled together like the ministers of education, culture and endowment. Last, but yet the most imperative factor when it comes to development is 3) Civic Society, where NGO’s role and facilities are placed.Also, Universities create series of workshops and programs to develop the local community skills and economy.

2.1.2 Informal Settlements and Sustainable Development

Berke (2002) cites Brund tland’s definition of sustainable development in the World Commission on Environment and Development (1987) as “Meeting the needs of the present without compromising the ability of future generations to meet their own needs” emphasizes that sustainable development should ensure that environmental, social and economic issues are considered and sustained for an unforeseeable future and this will be achieved in the informal areas by:

- Creating an economic climate that encourages sustainable human development.
- Raising the efficiency of government agencies, performance and responsiveness.
- Enabling individuals and achieving a democratic political system.

- Protecting the environment.
- Reducing the gap between the rich and the poor.
- Encouraging cultural diversity and social integration.

Egyptian informal areas present a great potential when it comes to social, economic and environmental conditions. The reasons are that housing in the informal areas is reasonably affordable as there is a wide range of choices that`s why people choose to live in poorly serviced informal areas, rather than planned ones *(Rahman, 2014).*

Surprisingly, informal settlements have many potentials such as productive activities and small industries, thus are highly attractive areas since they offer a large pool of labour within a walkable radius *(Shehayeb, June 2011)* and residents can find many types of jobs (workshops-markets-collecting garbage) and it`s normal that more than half of the residents are employed within the area itself *(Abdelhalim, 2010)* so they can go to work in a walking distance as in some cases the workshop is in the same building of the resident apartment *(Shehayeb,2009).*

So we can conclude that the basic potentials for applying and practicing new urbanism' principles are to an extent in some sort of implementation in the informal residential patterns but need sustainable measures to be applied such as affordability and adaptability.

2.2 Affordability and Adaptability in Community Development

2.2.1 Affordability

"Affordability is not only a major consideration but also a solution to create a liveable and a humane space addressed by a combination of technology, knowledge and skills, in construction and financial resources." *(Coalition, A., & Rights, H.2010).*

In order to achieve sustainable affordability, some policies must be adjusted by the government entity.Therefore, a joint venture between the private, public and civic society must be made available to come with an affordable strategic approach. As an example, KIP in Jakarta was adopted as an efficient and affordable way to improve the life of urban poor families through fundamental development of infrastructure.This project won the Aga Khan Award for Architecture in 1980*(Coalition, A., & Rights, H.2010).*

Levels of affordability are determined by a range of factors such as income levels, social skills and available resources, so when it comes to providing a service, it comes with expenses such as (labour, materials …), which make it difficult to reach a suitable affordable strategy *(Hoffmann, J., Galloway, I., Head, M. W., & Nolte, C.2013).* However, to solve this problem alternative technologies and materials could be used as a way to achieve affordable solutions.

On the other hand, Dina Shehayeb in Al Darb Al Ahmar project worked on reaching the affordability and as an example she said "We had a case where we start with certain instalments and then the husband dies. He died on her and she had a new-born baby and she couldn't work and she had other kids and was not so young. And all of a sudden, what can we do to help her continue paying the instalments for the housing? So we introduced other mechanisms to compliment the housing finance, programs of social assistance, micro-credit to increase income, whatever is needed to help such situations. There were complications in tenant-owner relationships." (Shehayeb, D. & Barthel, P. ,2011).

2.2.2 Adaptability

Until lately, local economic development policies were about firm-centered or incentive development for example the "Keynesian approach" which depends on proceeds redistribution and welfare policies to inspire difficulties in the less fortuned areas. In addition to this, Imperative approach have been retiring in terms of inspiring sustained enhancements in the economic affordability of the less fortuned areas. On the other hand, failed in providing self-sustaining growth. Summing up the common between the two approaches is adjusting the top -bottom policies while applying their ideologies. Other refers to it as Authoritative intervention where believe that self-interest of the developer is most suitable strategy to change communities *(G.f. Summers.1986)*

Commonly, people resist change while trying to hold to the familiar known life and situations, however, to maintain the benefits of circumstances, one need to be adaptable or to have flexible mind set. *(C.Gallozzi .2009).* In another words, the bottom-up approach and long term polices need to be practiced by the developers to explore a sheltered economic competitiveness by activating the endogenous possible of the less fortuned regions therefore to progress for the local supply need chain. Some recall this approach as "Client Centred intervention" since the people control the process of the development. *(A.Amin. 1999)&(G.f. Summers.1986).*

Constantly, communities require the capacity to adapt towards the changes on order to maintain their socio-economic possibility and environmental sustainability. Adaptability means to focus on community development that distinguishes and builds on community resources, sustenance for guaranteeing the sustainability of the environment along with a feasible local economic base with adequate flow on standards and job generation measurements and the ability of people living in the community to participate in and sustain revolution.

Several approaches were practiced under the act of attempting to reach the ultimate developing outcome of the regions or communities with their measurements to adapt to anticipate new industrial and commercial prospects.

Researchers and developers mentioned how hard to create a frame or a tool for the communities to be able to achieve what they call "community adaptability" however, some took the challenge to generate a chain of communication for publics to get the information they need and use by the developers and investors taking into justification the many characteristics of adaptability.

Usually, there are two types of tactics used when it comes to urban heritage. The irst tactic, deals with a long-term plan where specialist inclines towards the physical heritage and consider it as the main aspect that controls the process of development the concept was all about protection of the monuments while neglecting the deterioration in the Social and economic

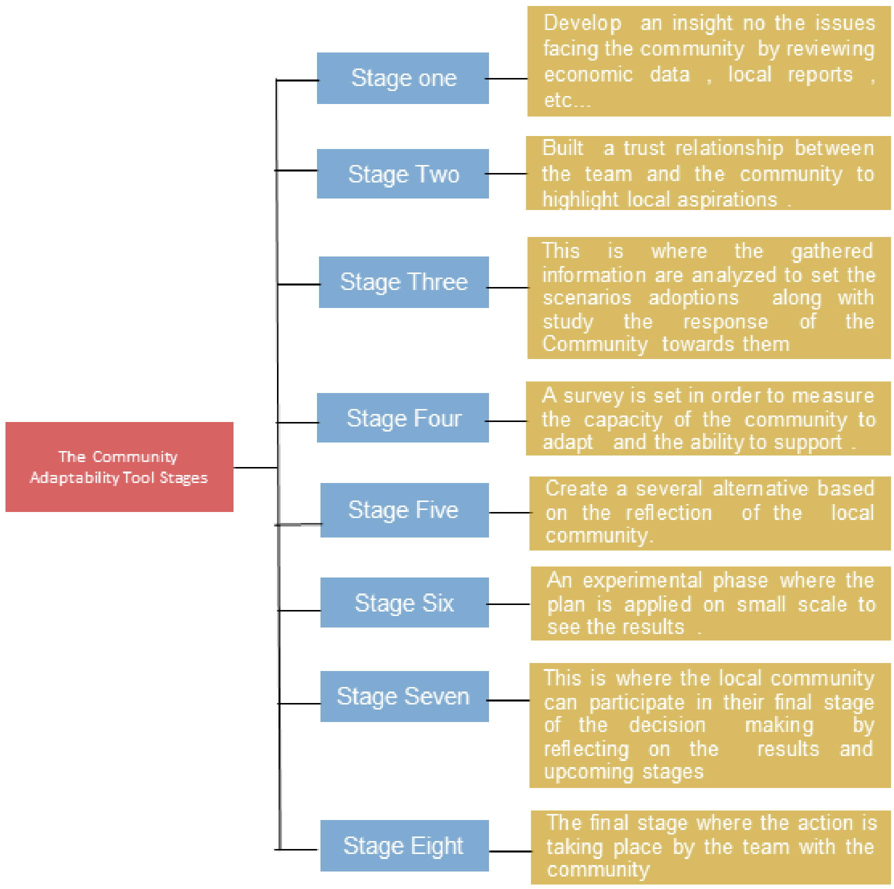

Figure 3 by the researcher developed from Hogan,A., Carson,D., Cleary,J, Donnelly ,D, and et al(2014).

perspective. As for the second tactic,it deals with the complication of conservation and urban rehabilitation where physical monuments are the only thing needed to rehabilitate, also taking the social and economic aspect in consideration. In another words an integration between social, economic, cultural as well as institutional and technical procedures.

As for the Drab el Ahmar, development strategy which was dealing with both historical and social implication where series of projects were introduced involving a direct participation of the community. Therefore, the Aga khan has implemented the second tactic of the integrated approach as it was dealing with social and physical improvements along with economic factor. For example, a micro – credit program were acquainted to help with business and rehabilitation development also for restoration purpose *(Nour , H. 2010)*

First, one need to understand the concept of the integrated approach which is as the following:

Figure4 by the researcher

2.3The strategy for developing a project in Egypt

The strategy of the Project should deal with two main dimensions (physical and non-physical). The physical one where it deals with the district along with built environment and non-Physical dimension like social and financial aspect.

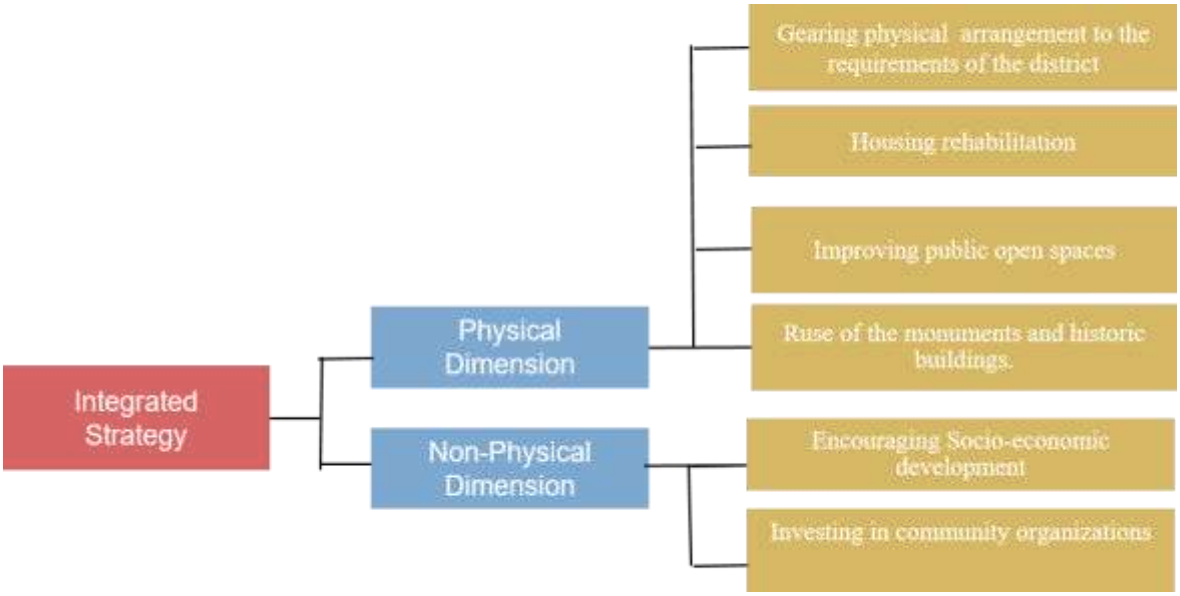

Figure5 by the researcher

The Egyptian authorities still place the historic buildings as the first priority above any other factor during decision making which means they are still using the traditional approach. Consequently, AlDarb Al Ahmar case is considered as special as it is one of the few examples of integrated approaches in Egypt.

2.3.1 A planning strategy for the district of Al Darb Al Ahmar

Al Darb Al Ahmar which is a part of Old Cairo that contains more than 114 historical Islamic monuments for example "ZainabKhatoun House" , " EL Hawary House", and " Mosque and school of Um Al Sultan" and many others and around these old monuments residents of this area lives in a deteriorated life conditions due to long term of neglect In addition to some environment problems like drugs and unemployment.

> "As al-Azhar Park was taking shape, the AKTC adopted re-use of deteriorating buildings to help revitalize the neighboring area of al-Darb al-Aḥmar. The AKTC's work at No.7 ZuqāqAybak and No.27 Bāb al- Wazīr illustrates the potential of adaptive re-use" (Tadamun,2015).

At the beginning of 1996, the Aga Khan Trust for Culture (AKTC) and its local subsidiary, the Aga Khan Cultural Services-Egypt (AKCS-E), expanded the scope of its activities in the area and embarked on a comprehensive urban rehabilitation programme for al-Darb al-Ahmar.'

The AKTC's long-term strategy focuses on the physical upgrading of the building stock and the socioeconomic development of the community, two complementary objectives aimed at the general revitalisation of the entire district*(Siravo, 2004).*

The main aim of the project was to be sustainable independent without any need of external inputs. This strategy was funded AKTCs/ Ford foundation/ the World Monuments Fundand Egyptian Swiss Fund "Socio-economicand physical rehabilitation of al-Darb al-Ahmar." . On

Photo by researcher, Google earth,

Figure6by the researcher

the other hand, the aim of the long-term strategy was to civilize the economic climate, improvement the area and addressing community development issues. The developing plan was to provide “sustainable employment opportunities for unemployed young people, providing health andeducational facilities, particularly for women and children, and, above all, strengthening civic groups and local institutions that will steer and sustain future actions in the district in order to reach affordable and adaptable living in this area.

For instance, In Al DarbAl Ahmar case, they used two approaches since they were dealing with multiple factors when it came to gathering the requirements. The Aga khan team has to deal with the authorities to be able to understand their strategies for the area along with understanding the differences between the nature of the space and the modern cities surrounding. Therefore, many detailed surveys were conducted to cover both social economic and physical principles. On the other hand, they have to sit down with the local communities to come with strategies that can be adaptable with their needs as well as affordable. this approach was the first time to be used where the local are invited to be part of the decision making process with the authorities which was hard to gain their trust especially when it comes to Darb AL Ahmar where the residents have suffered from top-bottom approach for years.

Another major factor that has played a role in this project which is developing socio-economic aspect which can be divided into; employment since is one of the main problems that is facing this district. According to the governmental statistics of 2005, the number of unemployed residents in AlDrab Al Ahmar is around two thousand as a result generating opportunities for the local in order to adapt and afford the changes that will happened due to the new strategy by the Aga Khan. Two parallel approaches took place, the first was a deep analysis was implemented to figure out the reason behind the high percentage of unemployment and the actual need of the market therefore a counselling unit was created to provide affordable opportunities can be created for the local residents especially the young generation and to increases the employability. While the second, forming the micro – credit to support the local communities and help them to adapt by helping them to open their own work space or expanded and improve the upcoming generation income. For example, in 2006 loans have been provided for almost one thousand six hundred people for small business and crafts projects. (H.Nour , 2010)

This leads to another significant factor that was introduced in this project, devoting in the community organizations. From the beginning of this project a lot of awareness campaigns and training centres along with community workshops were held by the Al Darb Al Ahmar community company where it is funded by the community, and creating its own strategies with the aim to create affordable opportunities and services also to help the residents to adapt to the upcoming future. According to (H.Nour , 2010)in 2008 , around of one hundred and fifty craftsman and local residents were benefit from the workshops and programs that were held by the NGO’s and community company .

As an aiding example Haret Khoukha was chosen for implementation of our methodology. It is an informal settlement located in a historic area next to the monumental wall of the

Citadel. Apparent forms of transgression of the informal residential buildings builtattached to the monumental wall of the Citadel of Salah el Din and supported by its stonewall. Some transgressions that were close to the main northern gate of the Citadel, linking it to the city, led the government to close it for decades.The result was the deterioration of the economic, physical and social formation of the settlement. The area of study is considered as unofficial region, which means illegal possession of land with illegal construction. This appears in all buildings that have been constructed and restored starting from the revolution period of 1952 and the following political periods till now.

The main objective of this study is presenting a way for creating a sustainable community taking into consideration the cultural, heritage, social and economic conditions of the residents in ordertowill be achieved through providing affordability and adaptability.

Haret Khoukha represents a potential for sustainable development. The use of sites surrounded or nearby heritage and historic sites has environmental, social, and economical benefits, which are important dimensions of sustainability. The site is a focal point and landmark in its vibrant and historic location.

Photo by researcher, 2014

The study dealt with the area through developing the principles of new urbanism implemented in the informal manners which are quality of living of the local community, walkability, connectivity, mixed use and diversity, traditional neighbourhood structure and green transportation. HaretKhoukha as an informal area has the potentials to achieve principles of sustainability and new urbanism to implement the aim of affordable and adaptable living.

3.RESEARCH METHODOLOGY

This paper was built by analytical method approach. First, theoretical approaches were viewed and analysed under the literature review to coverwith sustainability and new urbanism typologies and related with affordability, adaptability factors. Second,imperial studies wereenclosed where the history of area of Al Darb Al Ahmar and HaretKhoukha were analysedwith the aim to find the balance between the environmental burdens, the needs of the community and economic demands where the idea of compactness, sustainable transport, density and mixed land use were introduced as concepts for urban containment to deal with the diversity of the needs of urban development plans to discover the principlesthat is needed to be used by the developers to implement a sustainable long term development scheme.

4. DISCUSSION AND CONCLUSION

At the end, after several projects that have been ducted, it shows that community participation should be included in decision making process with local government and developerswith ideas of upgrading informal settlements when it comes to land use planning and residential design.Studies have also shown that the current planning programs that involve NGO's trials for community based participation and government association sometimes meet failure.As a result, unsustainable economical solutions can also be seen as the reflection to these limitations towards challenges ahead for environmental justice and sustainable movements *(Evans,andAgyeman, 2003).*Some proposed that by using affordability and adaptability schemes may help in solving the current situation .therefore, the concept of developing a community is needed to find a balance between them.

Informal areas suchas Al Darb Al Ahmar and Haretkhoukhaaredifficultto be monitored from an outside view therefore, they should be examined in an unexpected way. Although it contains extraordinary potentials concerning social relations. Informal settlements are made and planned by their occupants as indicated throughtheir needs; however, a percentage of the current structures needs to be modified and developed. So, architects, engineers and decision makers, should move there viewpoints or perspective from criticizers and controllers to spectators and learners, an set a plan to improve lives in these areas *(Rahman, 2014)*, Where lands and units proposed by the government are no longer suitable for all social categories.

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Alternative Concepts and Housing Typologies for a Socially Inclusive Sustainable City

Potentials of the private real estate sector for socially inclusive, sustainable housing production and urban design in Cairo, Egypt

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Abstract Urban Egypt especially Cairo is facing various problems whereby the most striking and the dysfunctional housing market. Social housing programs despite all efforts do not meet the needs of low income groups. Most formal housing production of the private sector is concentrating in the New Towns on the desert fringes around Cairo which exclusively targets higher income levels. As a result no formal opportunities exist to obtain suitable and affordable housing for broad levels of the population which are thus forced to settle informally on precious agricultural lands which represents 65% of the whole housing production. This trend leads to strong spatial and social division which is worrying as it runs the risk of social unrest and is not sustainable.

Correcting or halting this development requires large scale interventions on a long term. Improving the situation within a conceivable future thus requires strategies on a smaller scale. A starting point is the mobilization of underutilized potential of the private sector to produce lower income housing. For a case study in New Cairo, an urban extension east of Cairo, architecture students were asked to develop strategies, urban concepts and typologies which overcome spatial and social segregation and meet the needs of the private market economy. The proposals were analyzed regarding a) the used strategies of social integration (spatial and non-spatial) and b) the characteristics of the applied urban layout as well as building and apartment typologies. Furthermore the feedback and evaluation of experts with different areas of expertise (real estate development / housing and sociology) was collected and analyzed.

Tracing back the interviewees feedback and putting them into relation with the used strategies this paper aims to better understand which factors generate incentives for the private real estate sector in Cairo to invest also in lower housing market segments.

Keywords: affordable alternative housing, private real estate sector, segregation, social integration, sustainable society

1. INTRODUCTION

Cairo in Egypt, like most Cities in emerging or developing countries shows strong social disparities within the city or the metropolitan area. Unequally distributed chances amongst people and the lack of social mobility fuels unrest and insecurity. The „happy few“ start to fear the „others“, lives start to separate, distrust is spreading. As a result governments address public resources more towards inner safety and security instead of investing into infrastructure, public services and productive investments. Private foreign or internal investments are discouraged by unpredictable conditions. Destabilized societies hinder economic growth and public welfare and therefore are unsustainable (UN Habitat, 2008/2009).

In Cairo within the period of 1996 and 2006 urban housing was mainly produced by the following sectors: public sector with a share of 10.5 percent, the private sector with a share of 24.3 percent and the informal sector with the biggest share of 65,2 percent (UN Habitat, 2015). The Private housing sector is comprises market driven urban development mostly carried out in the New Towns and New Urban Communities on desert land around Cairo and targets families of middle or higher income. As a consequence the new urban communities turn into mainly „rich“ neighborhoods.

Subsidized governmental housing is available either on remote desert fringes or in partitions within the new towns that are otherwise upper class areas. The allocated social housing areas and typologies stigmatize their residents and often create a ghetto-like atmosphere. The remote location, lacking public transport and exclusive residential use turns the life in such areas into substantial struggle for low income families and results in vacancies from 50% (Sheikh Zayed 2) to 80% (Badr City) in social housing areas in the New Towns.
Affordable housing for low and very low income families neither exists amongst the social housing programs nor amongst the private sector products. The most attractive option for limited income families therefore is the informal sector that fills the gap of affordable housing. Informal housing to rent or to buy is mostly available along the ring road on precious agricultural lands.

Past and current urban planning strategies in Cairo foster the development of new towns in adjacent desert areas to protect valuable agricultural lands from further urbanization. The national strategic planning report states: *„The GC (Greater Cairo) needs to encourage new development centers outside its borders to attract population, redistribute population within its borders, direct GC future population growth to its new urban communities, provide a better standard of living for all segments of residents […] “(GOPP 2012)*

The urban design of the new towns around Cairo is strongly influenced by the ideas of the Functional City developed by Le Corbusier and CIAM in the 1930ies (The Athens Charta 1933). Car use is prioritized and land use is strictly separated by functions (residential, service, educational,etc.).Low densities of people and buildings are enforced and any kind of flexibility is abolished to fended of informality. Ample unattractive, insecure streetscapes without urban life encourage car use even for short distances.

Land subdivisions in the New Towns result in three main plot types: small plots for individual villas or multi family homes, huge private investor areas and social housing areas. Most areas develop into upscale residential housing areas interspersed with ghetto-like islands of social housing. Older urban areas like Mohandessin or Dokki in the center of Cairo are mixed use, dense vibrant areas of a long and successful history of social sustainability. With population growth congestion, overcrowding and the lack of recreational open spaces these areas became less attractive over the last decades. As higher income classes recently started to migrate towards the new towns to live with fresh air, less pollution and population these areas socially destabilize.
Social disparity that manifest itself in physical borders and spatial separation is an overall trend that can be observed in big and small scale in Cairo. New Cairo is a valuable case study for this typical urbanization process and therefore is subject of this research.

It has been broadly recognized amongst professionals and politicians that incentives should be generated for the private sector to take over a major role in the housing production for lower income households. Any sustainable urban development must avoid urban inequality or social disparity and must offer possibilities for all social levels. These ideas are not reflected in current private developer projects and therefore are not sustainable.

Within the design studio at the GUC, Architecture and Urban Design Program in spring 2016 focus was given to the above mentioned urgent matters of sustainable urban design and architecture (spatial and social division, housing gap, environmental damages). Students examined possible solutions as case studies and focussed on the Integration of different social groups while addressing real estate developers needs.

The aim of the design project is fourfold. Firstly to develop alternative concepts that integrate different social classes and generate enough earning for a private investor. Secondly to identify and examine spatial and non-spatial strategies and their capability to be socially integrative. Thirdly to raise awareness for the topic of social sustainability and the structural problem of the housing gap in Cairo amongst students, professionals and the real estate market. And finally to give impulses to the real estate sector to shift their interest from upscale markets towards lower income groups to foster socially integrative solutions.

2. LITERATURE REVIEW

Governments around the world are facing big challenges to keep up with the demand for affordable housing in areas of rapid urbanization. Comprehensive literature looking at social housing, housing policies, governance and steering instruments (Devas, N. *et al*., 2004; Buckley, R. and Kalarickal, J., 2005) in the developing world is available.

Various Urban public housing strategies conventional and non-conventional have been applied and tested in developing countries during the last decades. A shift from government facilitated housing towards the mobilization of the private sector took place in most countries of the global south (Wakely, P. 2014).

Though incentives for the private sector market have been made effective the private sector remained limited to middle and low-middle-income housing which still is more profitable than low income housing. Often private sector housing aiming for low-middle income families shows little understanding for the importance of social values and therefore suffers from social destabilization (Wakely, P. 2014). Low density urban forms and remote locations effect the quality of such housing projects negatively.

The recent popularity of gated communities as urban form can be considered as consequence of a market driven development which meets the demand of urban residents for security and protection. This recent phenomena and its effects on urban societies to be inclusive or exclusive has been broadly analyzed and discussed (Bagaeen, S. *et al*., 2010). Resulting urban inequality has been identified as a motor for insecurity (UN Habitat, 2008/2009). Therefore urban diversity which caters social mix (Harlander. T., Kuhn. G., 2012)and integrative models which are capable to involve broad social strata of the urban society are much sought after.

Proving that the involvement of low-income society levels into a private real estate product is not a downside but a valuable motor for urbanity which generates economic gain could raise the interest of the private sector to contribute more to the production of affordable housing for low income levels.

3. METHODOLOGY

The aim of this research paper is to identify correlations of spatial and non-spatial design strategies of urban design and architecture for social integration and earning capacity. This is important as the public housing sector especially in developing countries is facing difficulties to provide sufficient affordable housing to lower income households and therefore needs to activate the potential of the private sector.

The data presented stems from the following research methods:
[1] A design studio conducted with students of architecture of the 6th semester at a university in Cairo required to analyze, understand and interpret the correlations and problems of urban planning, architecture, economy and social responsibility within the context of a site in New Cairo a new urban community east of Cairo. The new urban Communities are the official solution (GOPP 2012) to the housing crisis in Cairo but developed into a resource wasting, disjointed city without urbanity, complexity or identity, separating people by class and fostering social unrest. Students were asked to create a vision, concept or typology that builds a sustainable and diverse urban community. They had to confront themselves how architecture and urban design can foster networks of relations beyond social boundaries, how a feeling of community and belonging for different kinds of people can be achieved and how these goals can made compatible with the logics of the private real estate market. In response they developed proposals for an urban concept, as well as for building typologies that were examined in exemplary depth.

[2] The results of that design studio were then viewed. Out of fifteen projects nine which showed valuable ideas were chosen to be thoroughly analyzed and classified. This analysis covered the following categories: type of access; type of building morphology; conditions of open space and used strategies of social integration.

[3] Interviews were then conducted with two experts of the field of architecture. Expert A is an architect with broad experience in housing and sociology. Expert B is an architect with a strong background in private sector real estate development. Both experts were asked to evaluate the potentials of the students proposals. As both experts have different vocational background and viewpoints their perceptions of value differs. The aim of the interviews was to link back the experts value perception to the projects typologies and strategies of integration and to identify the impact and the effectiveness of them.

4. OVERVIEW OF NINE CASE STUDIES IN NEW CAIRO

The case study site upon which this paper is based is located in the investors area south of street 90 in New Cairo. The surrounding is characterized by smaller mostly compound settlements and individual plot subdivisions with fenced residential buildings. A high percentage of residential buildings is sold but not yet inhabited. An adjacent area reserved for services and commercial uses is still unbuilt with exception of a mosk. Kiosks or convenient stores can be reached by car in relatively far distances. A few workers are moving in the streets, the area seems abandoned and unsafe. Public transportation (Minibus lines) does not extend to the area yet. Neighbors of the site are walled compound settlements whose residents do not communicate beyond their private property thus a sense of neighborhood and community is lacking. Repetitive patterns of winding roads are the prevailing urban layout that is missing distinctive character. Buildings show classicist or baroque architectural styles.

Typically different themes for architectural and open space design construct identities with representative gardens and golf courses. Walls, fences and gates separate residential spaces from the public street which then functions as space of transit and transport only. Social housing which often is badly deteriorated contrasts with upscale housing areas . Inequality manifests in physical boundaries and architecture which stigmatizes and separates classes or social levels.

The case study site in New Cairo has been shaped by a long planning history of New Town policies. Effective masterplans strictly separate uses and prioritize road networks for cars. It is usual practice to develop big pieces of public land as isolated patches of social housing or selling big pieces of land to real estate developers which mostly establish enclosed residential compounds. Spatial and social division are intensified. Correcting the plotted path is challenging and only effective on a long term. Thus alternative solutions that operate within the existing framework on a project scale are sought after as they have potential to improve the situation in short term.
Students approached the design task in three stages. First they had to come up with a Vision which verbalizes a programatic strategy, the so called ***„software“*** of the project. Secondly they had to come up with an urban layout and architecture (building, access, apartment typology) which represent their vision spatially as ***„hardware“***. Exemplary building and apartment typologies had to be developed into depth. *Figure 1* shows model photos of the case study projects within the urban context.
For a better understanding the characteristics and typology attributes of the projects have been analyzed and organized as overview in *Table 1*. The following characteristics and typologies have been identified and marked out:

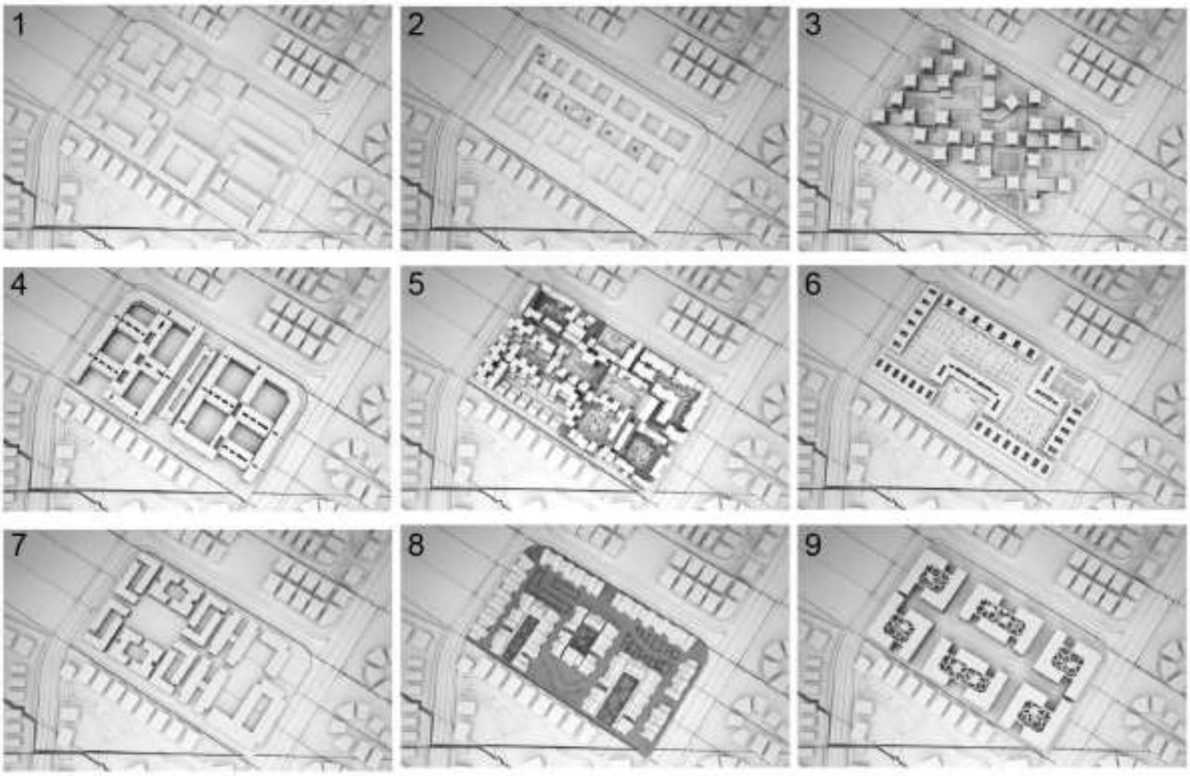
4.1. Typologies of urban layout („hardware“) identified with case study projects

Amongst all projects some basic typologies of spatial configuration could be identified. They are applied isolated or as a mix. Mostly they are chosen to achieve a certain kind of spatial structure that supports the students programmatic vision.

a) *'Super block':* large scale courtyard building which clearly defines „inside“ and „outside“
b) *'Sponge'*: large scale building interspersed with courtyards of smaller or/and bigger size
c) *'Maze'*: fragmented, small scale buildings organized as complex spatial structure
d) *'Urban Block'*: building blocks of different sizes and shapes enclosing a courtyard of small or big size
e) *'Solitaire'*: composition of solitaire buildings distinguished by their height, size or shape

4.2. Typologies of access („hardware“) identified with case study projects

Amongst all projects certain basic typologies of access could be identified which mostly are used isolated or as a mix. It can be observed that gallery types are frequently used not only to provide access to apartments but to provide spaces of encounter and interaction.
a) *‚Gallery'*: corridors, mostly open to the air which give access to apartments on one side but often function as privatized balcony, common walkway or space of social encounter as well. Galleries can reduce the amount of vertical access points and thus can be economic.
b) *‚rue interieure'*: internal road, mostly enclosed within the building and without light, gives access to apartments on two sides, often is combined with stacked duplex typologies, internal roads can reduce the amount of vertical access points and thus can be economic.
c) *'vertical access points'*: Cores with stair and elevator accessing two to four apartments per floor (carriages). The more apartments per floor are accessible the more it is cost effective. This type clearly defines a small building community as neighbors and can be representative space for upscale housing.



4.3. Strategies of integration identified with case study projects

To achieve the integration of different classes as a key value four main strategies amongst all students projects can be identified. The projects often involve one or more of such strategies as a mix. Table 2 gives an overview of applied strategies of integration which can be classified as spatial or non-spatial strategies as follows:

4.3.1. non-spatial strategies („software“)

a) Integration through activity

This type of strategy proposes activities that are shared or performed together either in common facilities or shared spaces (open or enclosed). Such activities can be vocational, business related, recreational or leisure. In context with vocation knowledge and working power of different social levels is brought together and pursues a common goal. Reward and success benefits all and form a substantial contribution to everyones livelihood. Thus business undertakings have a certain gravity and significance beyond earning they establish value, meaning and self esteem. Mutual help develop strong social ties that shape a community. Leisure and recreational activities develop ties of unsolicited character based on personal preferences. Most probably such activities do not have the same integrative power than vocational activities.

b) Integration through education or development

School, university, formation center or culture center are spaces of social encounter and exchange. They bring people together who share the wish to learn or who support people to exceed. Different social classes pursue the common goal of personal development. They meet as education seekers and education givers. The common goal equalizes differences as education always is perceived as positive and desirable. This social condenser is most effective if the roles of education seekers and givers are not fixed to special social classes and avoid hierarchies.

c) Integration through shared identity

These kind of strategies are characterized by the feeling of belonging to a distinguished identity or a brand which is defined with a common goal or culture. Shared identities establish a strong group feeling which integrates different social, income and cultural groups. A Brand or a theme as umbrella for work, production, manufacturing, living or business results in positive self-esteem, group favoritism and overcomes discrimination.

d) Integration through lifestyle

These strategies define a framework of lifestyle which is expressed with common activities, interests, values, opinions and behavior. This framework defines what is tolerated and what not. Rules ensure a common sense and facilitate cohabitation that might lead to integration over time. Depending on the framework of lifestyle such strategies can develop strong integration power (broad framework) but also can be very exclusive (tight framework).

4.3.2. Spatial strategies („hardware“)

Table 1: Overview of characteristics and typology attributes of the case studies (author, 2016)

		PROJECT CHARACTERISTICS			**TYPOLOGY ATTRIBUTES**		
project number, title, author, data		*vision*	*urban space concept (structure of open, public, semi-public, private spaces)*	ground floor interface	*access type*	*building typology*	*apartment typology*
1	‘Citadels of Interaction’ *Mohsen. R., Ashraf. M.* *FAR: 2.2 70% resid use*	the citadels seclude different communities which each share an identity, theme or lifestyle (the family, sport or student type, different social levels on each citadel), the ground floor as vibrant public space where people and live styles mix (shopping, strolling, etc)	the urban block (citadel) as island surrounded with public space	commercial + services as interface with the public live; no residential use	vert. access points (2 carriages) accessible via community platforms on the 1st floor	‘Urban Block’; ground floor with parking, services, workshops, offices; apt. starting on 2nd floor	mixed sizes; stacked duplex; townhouse; regular apartments; student housing; offices or studios (ground floor) can conjunct with apt. as work-life models
2	‘Custom Palace’ *Anwar. M., Yasser. A.* *FAR: 1.5 80% resid.use*	different apartment sizes for different income levels; an introverted community in a compact building structure; couts with arcades offer shadow in arid climate; aim is a minimal consumption of residential square meters per person allocating more space and quality to outside shared space	a network of small scale semi-private courtyards with high intimacy shared by residents structure the urban block, no spatial hierarchy; the “quiet back” a hidden public space for the neighborhood	elevation of ground floor level for privacy; arcades or galleries as buffer for privacy and the option for occupation (gardens, seating zones) and encounter	gallery / arcades + vert. access points	‘Super block’ with courtyards; ‚Sponge’	mixed sizes (50m2, 100m2, 200m2), stacked duplexes and gallery apt. types
3	‘Dwell & Expand’ *Ayman. A.* *no data*	a new urban center for the area surrounding the plot, attraction for young people (either students at the surrounding universities or whoever is interested in a 48m2 unit that is expandable), urban space as recreational, sport,	ample public space surrounds buildings, building layout encloses spaces and open pockets towards the streets, open spaces on the plot borders very public, inner parts secluded semi public, no private outside spaces	various public uses and workshops in the ground floor: activities extend from the interior to outdoor courtyards, yards are a lively spaces with	vert. access points (4 carriages)	‚Solitaire’	flexibility to “grow” with the resident’s needs, expansion horizontal and vertical depending on the residents needs and

		leisure or cultural space		overlapping activities, semipublic space that is negotiated and shared			financial capacity, smallest unit size 48m2
4	‘Reclaiming our Identity’ *Adel. B., Alaa. M.* *FAR: 1.3 68% resid.use*	establishing a productive community of mixed classes that unite in crafts, education, design, production and trade; a community center, crafts vocation center as social condenser; housewives/hobby seekers/children/young adults can learn a craft, craftsmen can teach, designers can develop new products with local workforce, local production and market	spacious semi public courtyards with different themes (jewelry, tissue, glass, etc.) are shared by residents, shop- and workshop owners; a public recreational strip along the neighboring compound with cultural and commercial uses as a public backbone for the whole area, clear spatial hierarchy	shops and workshops in the ground floor: activities extend from the interior to outdoor courtyards, yards are a lively semi public spaces shared with overlapping activities	gallery / rue interieure + vert. access points	‘Super block’ with courtyards	stacked duplex and apartments organized with a gallery type and shared community spaces, shops and workshops (ground floor) in conjunction with apartments as work-life models
5	‘A City Rediscovered’ *Sami. C., Anis. M.* *FAR: 1.3 68% resid.use*	the compact and mixed city developed after the ideal of a self contained city (diversity of uses, people and spaces); development of a typology that can be afforded by a broad spectrum of people, offering space for work, business, production and living to be the source of families livelihood	a basic module additively used forms a complex building entity; characterized by narrow, maze-like passageways, intimate yards and public squares than can be discovered within the site.	workshops, service or commercial uses as public interface; residential uses in ground floors provide gardens or private space as buffer from public to private	gallery + vert. access points	‚Maze’	work – life units: ateliers combined with apartments, duplexes or single units
6	‘Everyone’s Community’ *Mohamed. N., Mohsen. M.* *no data*	offering different types, sizes of apt for differing budgets; Introducing a social condenser: a garden for everyone in the community courtyard or on the roof	The super block cleary defines outside(public) and inside (semi public and private); inner courtyard with private gardens; setbacks of the super block generate public spaces with public facilities on the edges	commercial, service uses along public squares; cultural uses along a public recreational strip; residential uses in ground floors with a buffer (private gardens)	gallery / vert. access points (2 carriages)	‘Super block’	upscale living (big apt. with 2 carriage access points) and community typology with interaction courtyard zone (small apt. size, gallery access)
7	‘La Platforme’ *Amr. M., Gamal. A.* *no data*	a formation center as social condenser; different social strata are brought together and mutually benefit from each other: lower income groups living or working in the area take courses taught by residents (students of universities in New Cairo) for no fees, students who are teaching receive discount of rent, higher income apartments ensure the earning power for the real estate developer; social responsibility is cross financed by apartments for the upper end	Urban blocks define public streets, courtyard as semipublic shared space, a main strip widening into squares connecting northeast to southwest as “public backbone”, no private outside spaces	purely residential, transition private-public realm not solved well	gallery+ vert. access points	‘Urban Block’ with school typology	mixed apt. types: studio 70m2, family types 200m2, student housing, no social mix within one urban block

8	'Viva les Steps' *Essam. A., Karam. A.* *FAR: 1.36 83% resid.use*	offering different apartment sizes and rentable work, shop or office spaces	framing the plot and setting up residential courtyards within the big courtyard; establishing public open spaces and shared community spaces; stepping as strategy to offer each apartment a view to the surrounding open spaces and a big terrace	the ground floor of the outer ring offers non residential uses: office, shop, services; central areas: residential use with private gardens in the ground floor (privacy, buffer to public open spaces)	gallery+ vert. access points	'Super block' + 'Urban Block' as terrace typology	basic unit that expands, shrinks with stepping
9	'A True Community' *Mohamed. H.* *FAR: 2.2 85% resid.use*	offering several unit sizes that can fit several kind of social strata / flexible apartment sizes as the building structure is a framework that can be filled with differing unit sizes; a central community area in the courtyard as zone for private or community activities (hanging gardens etc.)	high density, clear definition of public space in between the buildings; central internal (commercial-recreational) strip as main public space; semipublic community space within courtyards, no private outside spaces	commercial and service uses, partly residential	gallery+ vert. access points gallery	'Urban Block'	apartment sizes adaptable to demand (units expandable horizontally and vertically); access galleries with semiprivate entrance zone in front of the apt.

a) Integration through unintentional encounter in physical space
The existence of physical space which is public, semi public or oscillating between such definitions allows the appropriation by communities or groups of people. Open or enclosed public or semi public space of different scale encourages common activities. The use of such spaces evokes negotiation, communication and organization amongst all. Boundaries of classes might be overcome by shared activities in such spaces (compare 4.3.1.a) but need a clear definition of rules to avoid conflicts. Management and maintenance need to be put in place to avoid the dominance of certain groups in such spaces. A careful definition of spatial hierarchies and the design of distinctive character can help to suggest certain uses and to prevent others. The careful organization and design of the interface to surrounding buildings or adjacent private spaces is a crucial factor for the success of such spaces. Public or shared community space can be a strong motor for urbanity, interaction and integration and community development. This strategies have been adopted by students on a small scale for example as gallery (access typology) or on a big scale as public open space (typology of urban layout).
b) Integration through unintentional cohabitation, physical proximity:
Such strategies offer inhabitable space that is suitable for a variety of purposes, life stages or lifestyles. Such typologies do not try to specialize on certain target groups. Spatial concepts allow flexible apartment sizes, flexible uses (life-work types) or incremental growth as tailor-made solutions that results in the cohabitation of people with very different social backgrounds. Encounter as neighbors is possible but not enforced. Cohabitation has a great potential for integration but also can raise conflicts and thus need careful management and design.

5. EXPERTS FEEDBACK

Two experts with different professional backgrounds were consulted to evaluate the students projects. Expert A is an architect with broad experience in housing and sociology. Expert B is an architect with a strong background in the private real estate market. *Table 3 and 4* show an overview of the feedbacks of Expert A and B based on the conducted interviews.

Table 2: Case study projects and applied strategies of integration (author, 2016)

		NON - SPATIAL				SPATIAL	
Project number and title		*via activity*	*via education, development*	*via shared identity*	*via lifestyle*	*via physical space*	*via cohabitation*
1	'Citadels of Interaction'	x		x	x	x	
2	'Custom Palace'				x	x	x
3	'Dwell & Expand'					x	x
4	'Reclaiming our Identity'	x	x	x		x	x
5	'A City Rediscovered'	x			x		x
6	'Everyone's Community'	x			x	x	x
7	'La Platforme'		x			x	
8	'Viva les Steps'					x	x
9	'A True Community'					x	x

5.1. Interpretation of experts Feedback

The aim of this section is to link back the experts feedback to the used typologies of urban layout, access and buildings as well as strategies of integration (non-spatial and spatial) and to identify the impact and the effectiveness of them.

5.1.1. Criteria of experts

Asked for their critics and comments the experts pointed out various aspects and qualities that were not equal but showed intersections. Both experts assign high relevance to those intersecting aspects but justify them differently.

For example both experts positively marked out the potential of a project to develop identity. For expert A building a common identity is a strategy for integration whereas expert B considers identity as value because it improves the chances of a project for marketing and selling. Diversity of a project including a mix of uses and people also was mentioned by both experts. Expert A explains the relevance of diversity with its capacity to blend and integrate people like in CDB (central business districts) areas. Expert B perceives diversity as a challenge that typically is not manageable with the classic private real estate development but admits that it adds value to a property and can generate gain if the developers business model is extended or altered. Both experts refer to the physical structure of the projects. Expert B rates projects with small units and small scale open spaces as valuable because such projects offer clients the feeling of their own house. The same aspect is positively referred to by expert A as manageable sizes of physical space which allow a community to develop the feeling of neighborhood and familiarity. Collating the interviews more intersections that both experts refer to can be found. Comparing the experts justifications it shows that one aspect can be perceived as integrative by expert A and as profitable by expert B. This finding contradicts the common opinion that public and real estate market interests are incompatible.

Reasons why an aspect is of high relevance mostly can be traced back to the aim of high gains or clients satisfaction in the case of expert B. This confirms the common perception that incentives of the private real estate market are solely orientated towards earnings. Expert A in contrast evaluates aspects based on their effectiveness for social integration and community building. This shows that expert A understands architecture as public responsibility to built a sustainable society. Table 5 compares the experts evaluation of potentials and shows that projects which received high ratings of expert A also received high ratings of expert B.

Thus it can be assumed that:

a) Ways to comply with public and investors interests do exist.
b) Certain characteristics of urban design, architecture or building typology can contribute to social integration and produce economic gain at the same time.

Table 3: Overview feedback Expert A based on interview (author, 2016)

Relev -ance	CHARACTERISTICS, CRITERIA, VALUES	EFFECTS
5	definition of a lifestyle	effect of including or excluding society layers, marketing
5	implementing urbanity, CBD (central business district) scenario	contributes to identity building, tolerates different lifestyles to blend, adds value to a property, fosters complexity and variety
5	establishing complexity and variety of uses and mix of people	diversity has proved to be an economic value
5	encouraging social encounter	contributes to identity and community building, feeling of belonging
5	providing shared space	encourages communication, negotiation, fosters encounter
5	establishing mutual or common learning	learning as an integrative activity: capacity to involve people without social, class borders
5	set up of a common identity	capacity to integrate different social, income, cultural groups into one group that shares an identity (defines by common goal, culture, livestyle) results in positive self-esteem, group favoritism; overcomes discrimination
5	aiming at social integration	crossing lifestyle boundaries cannot be successful, behavioral differences
5	architecture that copes with indicators for classes (laundry, colorful balconies, personalization)	a typical behavior, personalization that reveals the class provenience, can cause conflicts and needs to be managed with architecture, Variety within uniformity, architecture as blender
5	structure of spatial organization	spatial isolation vs. spatial integration, individuality vs. community
4	physical spaces of manageable sizes (amount of people sharing)	the capacity of human beings to know and remember people is limited, therefore shared spaces of community encounter or interaction should have a size that relates to that capacity
4	people meet under umbrella of work	capacity to integrate different social, income, cultural groups as equal business partners

4	community, neighborhood	social networks improve the feeling of safety and belonging
4	establishing social diversity	a challenge and a chance for complexity
4	implementing activities as „blender“	class differences do not necessarily show with income and can be overcome by common activities (work, leisure, social activities, learning)
4	offering diverse specialized spaces (private, semi-public, public, group specific use)	gives people the chance to have higher privacy, special spaces, spaces that are not shared, design communicates which behavior is required in a space, special activities in special spaces with behavioral mechanisms can manage mix of people
4	sharing (space, business, activity)	mutual benefit (knowledge, education, health, environment value, identity, community building)
3	encouraging negotiation over space	the use of space can be regulated or open, either ways negotiation and communication will result from it
3	allowing custom design	personalization helps to identify with a place, to feel belonging, can cause conflicts as it expresses class proveniences
3	encourage cohabitation, sharing facilities	people that do not share a common lifestyle can still share some facilities
3	designing architecture of uniformity	can generate the feeling of belonging to a group or a common identity or can be perceived negatively as leveling compulsion
3	designing architecture of diversity	has the potential for displaying individuality but can also be perceived as chaotic

Table 4: Overview feedback Expert B based on interview (author, 2016)

Relevance	**CHARACTERISTICS, CRITERIA, VALUES**	**REASONS**
5	feeling of the own house	highly demanded by clients of all target groups especially for upscale housing
5	identity, distinctiveness	decides about competitiveness on market, attracts clients
5	security, safety, social control	basic value of upscale housing
5	privacy	a cultural requirement (arabic culture) and rare value in dense urban Cairo
5	privacy of different income groups	fear of conflicts resulting from culture, social, lifestyle clash
5	low maintenance and operation costs	interest of investor and clients
5	earning potential	main interest of investor
5	needs of target groups, client	the client as main source of income
5	spatial separation of different income, social groups	fear of conflicts resulting from culture, social, lifestyle clash
4	good orientation, way finding	ensures a feeling of home, safety
4	short term investment vs. long	real estate market wants fast returns, as once a project is finished it

	term investment	does not generate much gain
4	variety of apartment types	reduces marketing risks, attracts broad clientele
4	variety of apartment orientation	reduces marketing risks, attracts broad clientele
4	variety of architecture, styles under an umbrella (same same but different)	reduces marketing risks, attracts broad clientele, contributes to identity
4	variety, distinctiveness of urban layout, building typologies	contributes to identity building
3	sense of home, belonging	contributes to identity building
3	community, neighborhood	contributes to identity building, well being, feeling of home
3	access typology	approriate depending on target groups, representational, financial considerations, clients satisfaction
3	flexibility	to react on clients needs
3	job opportunities	setting up uses other than residential, can generate earning and adds value to a site which investor can directly benefit from
3	people meet under umbrella of work	a strategy to reduce culture, social, lifestyle clash, lifestyle trend of integrative societies
2	ecology	clients are more and more interested in this trend
2	local supply with everyday goods	crucial for life quality
2	modern architecture	often requested by clients as status symbol
1	social awareness	lifestyle trend
1	climate adequacy	related to operational costs, clients progressively want to control these costs
1	seclusion (walls, gates)	too provide safety and privacy for different income, social groups, progressively perceived as obstacle for operation and maintenance
0	repetetiveness	perceived as cheap, not individual, solution for the masses
0	incremental growth	perceived as informal, negative
2	complexity and variety of uses and mix of people	requires complex and expensive management structures, not a core business of real estate market but is developing as a successful long term business model (the real estate developer as municipality) that adds value to a property

5.1.2. Strategies of integration (non-spatial and spatial)

Project 4 ‘Reclaiming our Identity’ received the highest ratings of expert A and B. *Table 2* shows that the project applies five out of six possible integration strategies including spatial and non spatial strategies. Project 3 ‘Dwell & Expand’ on the other hand received significantly lower ratings and applies only two out of six possible integration strategies which in this case are only spatial strategies. Project 5 ‘A City Rediscovered’ also received the highest ratings of both experts and applied only three out of six possible strategies whereof two were non spatial and one was a spatial strategy. The three highest ranked projects (4, 5, 1) all use the non-spatial strategies of activity to achieve integration; two of them also activate the physical space as spatial strategy (1, 4); one (5) applies cohabitation instead. Two (1,4) of the three highest ranked projects use a common identity as integration strategy (non-spatial). One project applies lifestyle as only spatial strategy and was ranked high by Expert B but not by Expert A as the capacity for integration showed to be less

significant. All projects at least involve one spatial strategy and amongst the best rated five projects all apply one up to four non-spatial strategies out of five.
It may be deduced from these results that:

a) In order to achieve a high capacity for integration it is advisable to apply spatial as well as non-spatial strategies.
b) it is advisable to use several strategies whereby success is not necessarily linked to the amount of used strategies.
c) the effectiveness of non-spatial strategies varies
d) those strategies aiming to achieve integration through activity (non-spatial) are most effective followed by strategies that establish a common identity (non-spatial)
e) non-spatial strategies are not effective without spatial strategies
f) lifestyle used without other non-spatial strategies is less integrative
g) project strategies which do not strongly tie lower income classes to the project sacrifice capacity for integration for higher gain

Table 5: Experts Evaluation of potentials based on interview (author, 2016)

		EXPERT A				EXPERT B					
Project number and title		*p. for identity*	*p. for community building*	*p. for integration*	*p. TOTAL Expert A in %*	*p. for identity +destinctiveness*	*p. to satisfy, attract clients*	*p. for earning capacity*	*p. for competitiveness*	*p. TOTAL Expert B in %*	***p. TOTAL Expert A + B in %***
4	'Reclaiming our Identity'	3	3	3	**100.0**	3	3	3	3	**100.0**	**100.0**
5	'A City Rediscovered'	3	3	3	**100.0**	3	3	3	3	**100.0**	**100.0**
1	'Citadels of Interaction'	2	2	3	**77.8**	3	3	3	3	**100.0**	**88.9**
2	'Custom Palace'	2	2	1	**55.6**	2	3	3	3	**91.7**	**73.6**
6	'Everyone's Community'	1	2	2	**55.6**	2	2	2	2	**66.7**	**61.1**
8	'Viva les Steps'	2	2	0	**44.4**	2	2	2	1	**58.3**	**51.4**
9	'A True Community'	1	3	1	**55.6**	1	1	2	1	**41.7**	**48.6**
7	'La Platforme'	1	2	2	**55.6**	0	0	1	1	**16.7**	**36.1**
3	'Dwell & Expand'	1	0	1	**22.2**	1	1	0	0	**16.7**	**19.4**

5.1.3. Typologies of urban layout , access, buildings

Amongst the four highest ranked projects (1, 2, 4, 5) three (2,4,5) apply external galleries combined with vertical access points as access typology; three (1, 2, 4) show large scale building typologies ('Urban Block'; 'Super Block'). All of them propose several apartment typologies whereby all offer stacked duplex types. Also amongst the four highest ranked projects three (1,4,5) propose a special kind of work-life typology where workshop, office or studio spaces in the ground floor either directly can be linked to apartments above or rented out to residents of that area. Amongst all projects the three high ranked projects (1,4, 5) show a residential share of ca. 65-70% whereas others have ca. 80% residential share.
It may be assumed from these facts that:

a) Gallery access types encourages encounter [integration]
b) Large scale building typologies deliver the feeling of community [integration]
c) The reduction of residential share in favor for other uses (cultural, services, commercial, etc.) results in diversity [integration] and adds value [gain].
d) Stacked duplex types deliver the feeling of the own house [easy to sell to clients] and in conjunction with gallery access this typology favors encounter and communication [integration].
e) Work-life typologies offer possibilities of life and work at the same place and thus are attractive for different groups, especially for lower income groups who often depend on small family business [integration]. Such typologies are a unique feature which helps to compete on the market [competitive].

5.1.4. Incentives for private real estate sector

Deducing from the interviews with expert B it can be said that private real estate intensions are mainly profit driven. Any kind of concept which adds value to a property and opens up to untapped consumer segments is perceived as interesting. It shows that other interests than economic gain are pursued only in favor of the client for whom the private sector feels accountable. For example topics of paramount importance like ecology and sustainability are dealt with mainly upon clients requests or if it proves to pay (economizing operation and maintenance costs). It is common to develop specialized tailor-made products to be competitive on the market and to comply with clients needs. Thus architecture and urban design are it acknowledged as unique selling proposition. Conflicts with clients resulting from class differences are feared and therefore diversity is avoided although its potential for earning is recognized. Mixed uses are interesting too as they can generate high gain on a long term (rent). Complexity resulting from mixed use and alternative typologies promise earning capacity but are considered as risky because they require new business models of management on a long term whereas short term investments are favored.
The real estate sector thus can be motivated by (incentives):
a) added value
b) satisfaction of clients needs
c) tapping new consumer segments
d) additional earning capacities beyond the classical real estate development
e) enabling competitiveness

6. CONCLUSIONS

This study identifies strategies to generate incentives for the private real estate market to target lower income groups and achieve social integration. Thus it is essential to understand the mechanisms of „software“ and „hardware“ of urban design and architecture and their effectiveness to achieve these goals.
Based on the comparison of interviews conducted with experts and the analysis of typologies this paper firstly identifies strategies which achieve social integration: ***non-spatial strategies*** *(„software“)* including Integration through a) activity, b) education or development, c) shared identity, d) lifestyle; and ***spatial strategies*** *(„hardware“)* including a) unintentional encounter in physical space, b) cohabitation.
Secondly this study shows how the identified strategies are physically implemented as typologies of urban design and architecture (building, access, apartment).
Thirdly the findings of the analysis are compared with the evaluations and comments of experts. It was found that strategies are most effective when they are used as a mix. It shows that spatial strategies are of high importance but do not succeed to be integrative without non-spatial strategies. Finally this study shows which strategies have been identified by expert B who has a strong real estate development background as potential earning opportunity and why.

Thus it can be concluded that in order to develop projects that are socially integrative and attractive for the private real estate market it is essential:

a) to achieve enough earning power for real estate investor (incentive)
b) to strategically develop a vision, the „software“ of a project and to carefully assign strategies which serve the vision
c) urban design and architecture, the „hardware“ (building, access, apartment typology) should support the „software“ with spatial strategies
d) to tie lower income households as indispensable key actor to the project by ensuring that they add value to the project
e) to extend the classical short term real estate development towards a long term real estate management which requires new models of urban governance (the real estate developer as municipality)

A big potential to motivate the private real estate market to produce also low income housing can be identified. Projects of that case study which showed such potential are very diverse and thus would require complex management on all planning levels.
It has to be admitted that the private real estate market and local authorities do have little experience with such complexity. Further research is necessary to understand how authorities, the private real estate developer, architects and future residents can work together towards a successful implementation of such complex undertakings. A methodic framework for such development processes is needed.
This study does not look in detail into relevant methods of acceptance and community building amongst the future residents. Though recently it has been broadly acknowledged that participation models which explore the real needs of users are a valuable method. Further research could clarify how such methods could be implemented.

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Industrialized Building systems for sustainable

(re-) generation of new communities

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ABSTRACT

Prefabrication in Architecture is a term that has long attracted suspicion. Many failed attempts to prefabricate houses have given the term a rather negative aura. Therefore, the more advanced and positive sounding label "Industrialized Building Systems" (IBSs) has been introduced in Malaysia to describe the process of moving as much as possible of construction projects to off-site factories, the products of which can be quickly assembled on-site. A Model project is being developed along-side this research paper which aims to serve as an example of global best-practice of IBSs based on historical lessons and others from the ship-, airplane- and car- manufacturing industries.

The project's function is tailored to address a specific problem in Egypt. Since the 1970s the Egyptian state has been advocating the reduction of population density in the Nile delta and guidance of urban development into the vast empty desert. However, most of the housing units there still stand mostly vacant, while recent government-subsidized social housing projects despite fiscal deficits indicate the urgent demand for affordable housing. As presented above, IBSs have been the solution to such immense housing demand in many countries. By developing this project, the potentials of IBSs sustainably affecting Egypt's desert-cities' developments are analyzed and found to be very high. The developed prefabrication strategy suggests an innovative combination of precast concrete elements and re-used shipping containers. The successful development of a new model for demand-driven housing provision using local IBSs can have a huge positive impact on the deteriorating Egyptian economy and is therefore very worthy of continuing research and development by government, industry and academic institutions.

Keywords: Desert Cities, Industrialized Building Systems, Modular Construction, Prefabrication, Sustainable Urban Development

1. INTRODUCTION

This paper is part of an ongoing research and design process by the author to present the potentials of IBSs (used interchangeably with "prefabrication" throughout this paper) for residential and mixed-use projects in Egypt and the actions necessary to achieve them and advance the industry. The paper starts by portraying the problems of current housing construction practice. In the following section, it illustrates the situation in the local context. In the final two sections of the introduction it demonstrates the theoretical framework based on which the research objectives were chosen. The Literature review in chapter 2 clarifies misconceptions about prefabrication and illustrates the large variety of results the industry has achieved. It delves into the lessons learned from the many architectural experiments of the 20th century and contemporary practice to prefabricate and mass-produce houses and residential complexes, some successfully and others less so, covering a large variety of materials, concepts and strategies. The literature review then covers some lessons from the car-, ship- and aircraft industries based on the theories of architects Kieran and Timberlake (2004). The information gathering process described in the research methodology chapter is then used in combination with the literature review as a design guideline for the development of a model project, presented in the final chapter.

1.1. Reviewing traditional construction processes

Construction materials are usually produced and packaged to achieve the highest profit to the producer, with the least consideration given to their future usage as parts of a completed building. In the most common housing construction method in Egypt of Reinforced Concrete (RC) column-and-beam system, steel bars are cut on site and the cement, gravel, sand and water are mixed to create the concrete and the mortar. The final RC structure is most commonly built through temporary wood Formworks fastened around the previously arranged and fastened rebar. The concrete mixture is then poured through a pump or more often by intensive labor-work into the formwork. Similarly - in the traditional wall infill construction - sand and cement for the mortar and the bricks are procured separately. Supporting labor is required for mixing the mortar and transporting the bricks to the bricklayer. After the wall has been built, the electrician, plumber, plasterer and the painters or cladding-installers (depending on the finishing design) further need to complete their work. This process requires the daily commute of at least 7 craftsmen and labor groups and sub-contractors to the site. MEP and interior finishing works excluded, the amount of materials imported to the site requires tens of trucks to transport.

A site-visit to the vacant plots planned for future development in 6th of October city (*see Fig.*1) shows that those vast areas are filled with piles of construction waste. Additionally, the daily transportation of materials and labor to construction sites inherent in traditional construction techniques consumes immense amounts of energy, and concrete spills ever-so-often patch and destroy roads and highways. Apart from the coordination work required for each project by the general contractor for this lengthy process, it entails an often taken-for-granted overhead financial and environmental cost.

1.2. Industrialized Building systems (IBS)

Egypt is by no means the first country in modern history to face housing shortages and high demand for effective urban expansion. Colonization, Post World War I and II reconstructions, population booms and mass migration are all epochs in which industrialized countries have faced similar needs. It is also during those times that new methods to more efficiently provide houses for the masses were highly in demand. While prefabrication per-se is not a new concept – the transportation of building elements across the Mediterranean for roman temples in North African colonies being among the oldest noted examples – advances in manufacturing and mass-production techniques during and after the industrial revolution have given this concept a whole new potential (Bergdoll & Christensen, 2008). However, few – if any – true innovations in housing provision processes are being developed in Egypt.

1.3. The local context

The Egyptian state has been actively seeking to reduce the dense population distribution along the Nile River Valley and sea shores by planning urban expansion into the desert surrounding existing metropolises and cities since the 1970s. The excess population of Cairo – Egypt's largest and capital city - alone has been planned to be absorbed by at least 8 new desert cities. However, even if we use "NUCA's [New Urban Communities' Authority] generous counts, not a single new urban community has reached its target population and the vast majority have not even surpassed the 50% mark". (Tadamun, 2015)

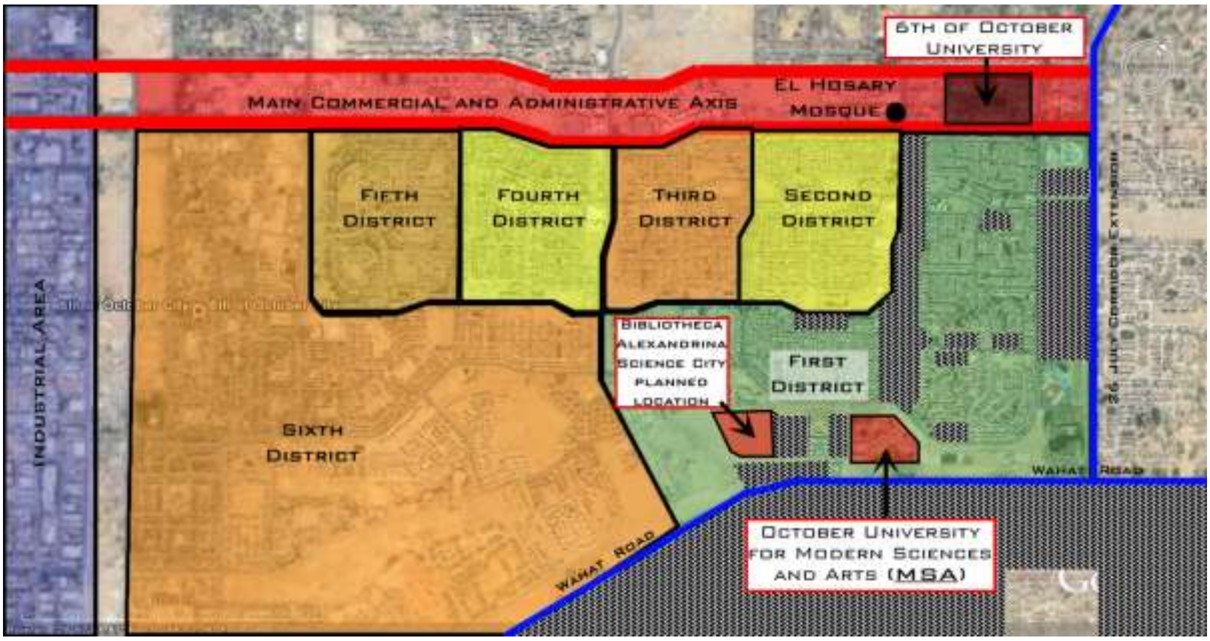


Figure1: Map of 6th October city. The hatched areas are mostly vacant and underdeveloped Satellite image by Google Earth © 2016, Overlay by the author.

"6th of October" city with specific focus on its first district is the main residential area of analysis in this research. While the city's ability to promote housing construction has by far exceeded that of any other new community, their occupancy rate remains extremely low, despite the existence of two large universities in relatively close proximity to this neighborhood; namely the 6th of October university along the main axis and nearby the city center / El Hosary square and the "October University for Modern Sciences and Arts" (MSA) - facing south towards the Wahat road. However, those universities' surrounding urban areas show big differences as portrayed in the following paragraph.

Both formal and informal public transportation is concentrated along the central commercial, office and entertainment artery which connects the far west industrial area of 6th of October city to central Cairo. While this encourages the development and occupancy of the residential land plots nearby those arteries, it also makes the predominant individual housing subdivisions further away – even if closer to the MSA - only poorly connected to the rest of the city. The lack of proper infrastructure such as safe lanes and shading as well as long distances between residences and various services discourages walking and Non-motorized transport. On the other hand, low occupancy rates mean little attractiveness for the emergence of new informal transportation routes through or close-by those neighborhoods. The result is a vicious cycle that further hinders their growth. (see Sims (2010))

This stagnation makes the area rather less attractive to the more than 4000 persons who daily come to MSA for studies or employment, especially those who can afford a private car or longer commuting hours in return for a higher living standard. This is considered as a case study for similar residential neighborhoods in desert cities of the individual land-plot division type.

1.4. Theoretical Framework

The theoretical framework of this paper follows the tripartite model of architectural research proposed by Till (2008) to (and approved by) the Royal Institute of British Architects (RIBA). This model suggests the separation of architectural research into three stages: Architectural processes or the pre-design stage (for example issues of representation, theories of design, and modeling of the environment), architectural products or the construction design stage (for example issues of aesthetics, materials and constructional techniques) and architectural performance or post-construction stage (for example issues of social occupation, environmental performance, cultural assimilation). This work will illustrate research into the urgently needed Architectural Performance of projects in the chosen residential area to inform the type and urban function of the Architectural Product. Research into Architectural processes and theories that promise more sustainable construction project deliveries will be conducted to reveal details of the design considerations and construction system by which this Architectural Product should ideally be produced.

1.5. Research objectives

This paper has three main objectives. The first is to identify the type and urban function of a project that falls within the specific environmental context (*see* Smith (2010) *in 2.5.4)* that is necessary for the use of IBS to be most rewarding. This type of project should also address the problems of the local context described above and a specific location for its construction must be suggested. The questions to be answered to reach this objective are hence *what* to build and *where* to build it. The second is to further explore the spatial design requirements (the use and size of spaces) for this identified type of project. The third and main objective is to set the IBS strategy by which this project is ideally to be constructed: the degree of prefabrication implemented (*see 2.3),* the materials used and the suppliers of prefabricated elements to be involved.

2. LITERATURE REVIEW

2.1. A brief historical overview of Prefabrication

Inventors such as Buckminster Fuller or Thomas Edison, famous Architects such as Le Corbusier, Walter Gropius or Frank Lloyd Wright, factories such as the Beech aircraft factory or the Portland Cement Works and Policy Makers such as Nikita Khrushchev in the Soviet Union or President Truman in the USA have all had their influence on the development of prefabrication in the 20th century. Almost all traditional building materials have been experimented with in the many attempts to provide new models of off-site manufactured houses. Models and strategies have been developed for single- and multi-family houses, residential blocks and high-rises and whole neighborhoods, such as those developed during the Japanese metabolism era, which further inspired western designs such as Habitat '67 by Moshe Safdie and Metastadt in Germany. Large variety also exists in the extent of success the many models and systems have achieved. (Bergdoll & Christensen, 2008)

2.2. Prefabrication – Process not product

Given the presented brief historical overview of prefabrication it is not surprising, that the very definition of prefabrication remains rather vague. The term has falsely become more associated with a certain category of non-permanent homes and *products* such as Trailers and caravans, giving it a rather negative aura in regard to its quality as a residence. The variety of models and designs presented in this research however, indicates their developers' intention to rather enhance the *process* by which their dwellings were to be designed and constructed. The fact that this process is until now more often used for trailers, caravans and other non-permanent houses does not mean that this is the highest quality or only residence type achievable through this process.

Especially among the non-specialized public, architectural processes, -products and -performances, are often seen as directly related. However, in reality they rather inform than dictate each other, meaning that similar processes may lead to very different products, while similar performance can be achieved through very different products. Hence, successful historical processes were often disdained due to the initial products that have resulted thereof. For example, Bergdoll & Christensen (2008, p. 100) describe the soviet system generically named "Khrushchovkas" as follows:

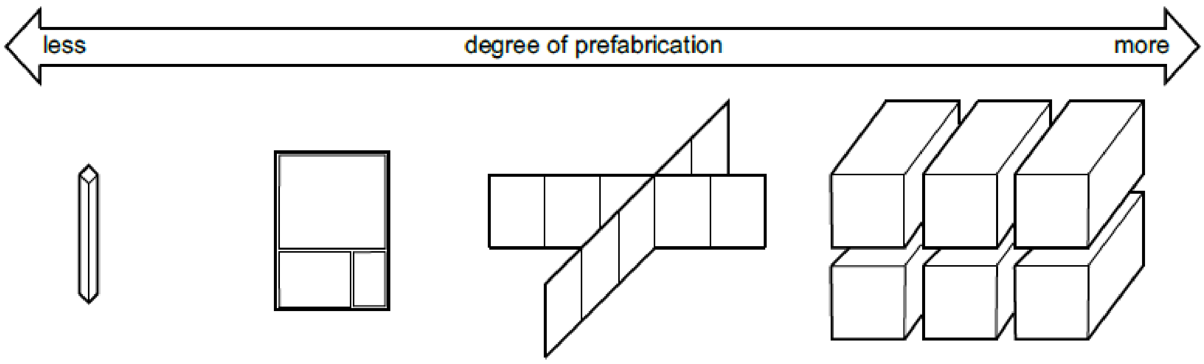
> "Regardless of appearance, the system proved to be one of the most cost-effective and rapidly deployable prefabricated building systems to date, even among neighbors in Europe with a much longer prefabricated building tradition. Perhaps nowhere else did a prefabricated building system become so intrinsically intertwined with a political epoch."

With the fall of the Soviet Union and despite its initial success, this system has failed to continue flourishing and to be copied and adapted by developing countries perhaps for that exact reason, that it was often seen as related to an outdated political system.

Prefabrication however simply involves the *fabrication* of building elements using advanced manufacturing techniques *prior* to their fixture at their final location, as opposed to – for example - building and finishing walls directly at their final location using the traditional brick and mortar, plastering and painting techniques. Prefabrication can occur on a designated area *on* the construction site or in off-site factories in which more advanced manufacturing equipment and machinery are permanently located. This study focuses on off-site prefabrication techniques.

2.3. Categorizing IBS:

Being a process and not a certain product, prefabrication in building construction is rather a spectrum than a fixed set of categories. However, the following categorization serves to enable the later discussion and identification of potential suppliers who could feed into the different categories of the value chain of the proposed turn-key project. This research uses four main IBS categories:



1-"Prefabrication can be classified by the extent to which elements are completed prior to assembly onsite. From left to right: materials, components, panels, and modules. Generally, the benefits of prefabrication can be realized as projects move to increasingly greater degrees of prefabrication." ***Source:*** **(Smith, 2010)**

2.3.1. Processed Materials

Examples of prefab houses made of off-the shelf processed materials include the Eames House (also called the "Case Study House No.8"), built by Charles and Ray Eames. "Every element was ordered by catalogue or purchased from an industrial manufacturer, including the structure's steel beams and trusses, siding of various materials and colors, glass, asbestos, and Cemesto board, all laid out on a grid that made concern over tolerances obsolete" (Bergdoll & Christensen, 2008). Corrugated sheets are another processed material which were used for the Quonset Hut and various types of temporary and mobile houses.

2.3.2. Construction Components

The form of Industrially Processed Materials is often dependent on maximizing production and transportation cost-efficiency. Those materials only become Construction components when they are machined, molded and/or joined to other parts of different or same materials to form parts of a bigger building. Most construction projects require the import of some kind of ready-made components before their turn-key handover, even if the building structure and skin are constructed using traditional on-site methods. Examples thereof include windows and doors, Mechanical, Electrical and Plumbing (MEP) equipments and general furniture.

2.3.3. Panelized Construction

Panelized construction seeks to increase prefabrication by mass-producing whole two-dimensional space-defining elements, such as walls and partitions. In some advanced contemporary examples, the walls arrive on-site fitted with multiple finishing components such as wiring, hoses and pipes for MEP equipment. Among the very successful examples of 20th century prefabrication experiments is the Balloon Frame system, about which Bergdoll and Christensen (2008, p. 41) write:

> "The balloon frame method of wood construction is arguably the first incarnation of a prefabricated construction system since it regularized the production of houses into a palette of ready-made units that could be assembled in various configurations rapidly and affordably. […] The system eliminated mortised beams and fittings, replacing them with two-by-fours and two-by-sixes set close to one another in increments of approximately one foot spaced horizontally. [...] Wooden sheathing would subsequently be placed over the frame. Most importantly, the members were held together with manufactured cut iron nails [which] allowed for the connection of wooden members with greater ease and efficiency over crafted joineries. The entire wall unit could be delivered to a site and simply tilted upright, allowing house construction to occur in a matter of days. [...] The system has been infinitely reproduced, altered, and tweaked and remains one of the most common systems for house construction in the United States as well as other countries and regions with abundant timber resources such as Canada and Scandinavia."

Although of a different material – namely precast concrete panels in the horizontal and vertical axes - the former East German "Plattenbau" system proved itself as another successful example of panelized construction. As Bergdoll and Christensen (2008, p. 122) describe it, "It remains one of the most ubiquitous prefabricated building systems throughout Europe" and it "actually enjoyed a high level of popularity for its relative value and spacious and clean interior accommodations".

2.3.4. Modular Construction

Among the specialized researchers, institutions and businesses, the term modular construction is used to describe the manufacturing of room-sized modules with the highest degree possible of final interior and exterior finishing. The walls of two adjacent rooms are by default of more or less the same size, and connecting two parallel planes of such size merely requires their proper positioning next to each other, making those modules very modular by the above definition. The exact dimensions of those modules have varied throughout the many examples, yet they are usually determined by the traffic rules and regulations. Examples thereof are the Nakagin Capsule tower, Habitat '67, the more recently popular trend of shipping container architecture or mobile homes, caravans and trailers. While this category requires heavy machinery for the transportation of the modules, it is this category that shifts the highest amount of labor from the site to the controlled environments of the factory. It is the category which allows the largest percentage of tasks for the turn-key production of a building (such as furniture, plumbing and electrical works) to be included in the off-site produced modules prior to transporting them to the site. Among high-end developments it is the interior finishing and furnishing phases that amount to the highest cost of a turn-key project, especially when advanced MEP systems, home-automation and luxurious finishing materials are used. Hence it is also the category of prefab designs that allows the highest exploitation potential of the benefits of prefabrication.

2.4. The Advantages of Prefabrication

The advantages of factory-built construction, which seeks to minimize assembly time and amount of work on-site, are many. Among them are waste reduction, quality assurance, reduced construction schedules and improved working-conditions in the relatively safe environments of factories.

To compare the environmental sustainability of the highest degree of prefab – namely modular construction - Quale et al. (2012) assessed the life-cycle environmental impact of three Modular and five conventional house constructions in the USA. The results showed that "modular construction has fewer impacts, on average, than on-site construction for all environmental impact categories", noting however, that significant differences exist even among projects using the same construction method. Furthermore, Quale et al. (2012) repeatedly stress that:

> "It is well established that the largest proportion of environmental impacts associated with buildings is related to the occupancy or use stage of the life cycle (Adalberth 1997; Scheuer et al. 2003). For example, energy used for heating, cooling, lighting, equipment, and appliances typically far outweighs the energy demand of other life cycle stages, such as construction and the production of building materials. These proportions will likely change with time as building designs and operations improve in terms of energy and material efficiencies."

It has indeed been found that emerging contemporary house manufacturers and prefab design initiatives are increasingly gaining a competitive advantage over on-site built houses through their incorporation of zero- and plus-energy technologies, making them more likely to acquire LEED and other green building certifications.

2.5. Lessons from the history of IBSs

Smith (2010) presents five lessons that can be learned from the historical development of prefabrication so far:

2.5.1. Proprietary systems do not work for mass production

Smith (2010, p. 40) mentions ten 20th century prefab experiments which failed to expand or even remain in business and which illustrate that point. The most famous of those are Buckminster Fuller's Dymaxion and Wichita Houses (1928, 1944), Frank Lloyd Wright's Usonian "assembled house" (1932), Gropius and Wachsmann’s "prepacked house" (1942), Moshe Safdie's Habitat (1967) and the Japanese metabolists' capsule such as that used in the Nakagin Capsule tower (1968). Many of those represented indeed brilliant innovations and were qualified and ready for the market. However, the uniqueness of elements they depended upon demanded a continuously updated production line, for which the number of clients was simply too low to make this economically feasible. Manipulation and maintenance further become extremely limited. Fuller's proposals for example would have needed a complete stock to maintain it. The propriety and uniqueness also limits research and development on those systems to the one original producer. Hence, as the more successful example of the balloon frame - which uses standard dimensional posts - further underlines, it is of crucial importance to use readily available components and materials.

2.5.2. Prefabrication Is About Design and Development of a Technology

The goal of this technology is to produce high quality buildings that can compete with traditionally built constructions in terms of quality and durability and to assemble them to permanent structures quickly and affordably. Colin Davies is quoted as stating:

> "It takes real experts to develop a building technology, preferably with hands-on knowledge of materials involved and tools used to shape them. New technologies designed in isolation on the drawing board are very unlikely to be successful. Technologies have to be developed, not designed, and you need a factory to develop them in."

Additionally, site specificity and authorship are identified as the two essential impediments of Architects to include prefabrication in their designs. The first represents the false core architectural belief that each project needs to stem uniquely from its site, while the second implies that "Prefabrication can only thrive in a culture of collaboration" in which the individual authorship of the architect is shared among industry and designers.

(Smith, 2010, pp. 42-44)

2.5.3. Prefabrication Has More to Do with a Business Plan Than a Product

The necessity of proper marketing and financial planning was underestimated in many advanced and ideal designs and models of houses, such as the porcelain- enameled steel houses company by The Lustron corporation. Although the home was Ideal, used technology from the airplane industry during the War and was made of a steel structure that was easily cleanable with a regular garden hose, unprofessional financial planning and the lack of funding led to its demise. Gropius and Wachsmann’s prepacked housing proposal was also well designed with full drawings, details, construction system including supply chain, fabrication, assembly line production, shipping, and installation", yet the infatuation with the production proper made the architects forget that their customers' interest was less the brilliance of the process, but rather the final house, the common desirable characteristics of which (such as durability, conveniences and resale potential) Wachsmann and Gropius failed to include and address in their marketing strategy. (Smith, 2010, pp. 44-45)

2.5.4. Situation Should Warrant Prefabrication:

The type, client, location and labor context of each project has a large impact on the decision of which degree of prefabrication to use. Under project type, Smith (2010) lists the following four aspects that can greatly encourage the use of IBSs: Duration, Repetition, Uniqueness, and Procurement. Projects that require short construction durations can achieve this through preparing the site and pouring foundations while modules are being manufactured off-site at the same time. Repetition in the design of many spaces, such as is usually the case in hotel rooms, bathrooms and kitchens or turn-key rental apartments, strongly calls for the use of IBS.

On the use of IBSs in unique projects, Smith (2010, p. 50) explains:

> "Architectural Products that employ unique forms, unique sustainability requirements, or unique programmatic solutions demand a higher degree of control of the end product. […] Dimensionally accurate, geometrically complex projects use prefabrication to remove tolerance and quality control off-site.[…] Offsite fabrication is given the research and development prototype funding required for delivering the system".

The procurement or delivery method and contract type of a project further influences the ability to make a positive decision to use prefabrication. The limited scope of this paper however, does not cover a proposed contract type, and hence this aspect will not be further discussed.

2.5.5. Must Come from an Integrated Process

The decision to increase the degree of prefabrication used in a project must come in the early stages of design. A high level of collaboration between the client, the designer, the contractor and the manufacturer is of utmost importance, to guarantee that the designs put on paper can be transformed to reality. Turn-key technical drawings must be fully decided upon prior to contracting, due to the non-linear nature of the manufacturing process in comparison to traditional construction. This will be further illustrated in section 2.6. Furthermore, Smith (2010, p. 46) quotes Alastair Gibb as stating, that "an overall strategy for offsite fabrication is required because the benefits of prefabrication are not in the individual elemental cost, but are realized in possible secondary effects of saved time on site, reduced financial paperwork, RFPs, change orders, and so forth."

2.6. Lessons from other industries:

Kieran and Timberlake (2004) present the following lessons from the Ship-, Airplane- and Car Manufacturing industries that have helped them develop a much more efficient product delivery process over the last century allowing them to offer clients advanced technologies and superior quality at an affordable price. Architecture on the other hand - especially its residential production - has failed to similarly develop, and hence continues to inefficiently fail to deliver affordable quality housing to billions of people around the world.

The production process enhancement applied by those other industries greatly relied on the improvement of the connections and joints between the separate parts of the final product, in term of their tolerance and durability as well as the speed by which they allow the separate parts to be connected. With Starr's (2010) definition of the term modularity as the "interchangeability of alternative parts of a product" in mind, the performance of those connections and joints will hence be a measure for the modularity of the parts they connect. In other words, the faster, stronger, for longer time and with less tolerance for error the connections and joints between different parts of a product allow those parts to be connected, the more modular those parts become, the better the process by which the final product is delivered.

2.6.1. Shipbuilding:

The most important lesson from the shipbuilding industry is that the construction process is no longer linear and it no longer proceeds solely from the bottom up. Shipbuilders no longer use "the slow conventional process of laying the keel, framing the hull, and outfitting the ship. They introduced prefabrication and grand block assembly to allow more simultaneous production that dramatically reduced completion times" (Kieran & Timberlake, 2004).

For military purposes, the joining concept in construction is interface, not integration. The first puts more importance on the possibility of exchanging parts, no matter how large or technologically complex their connections may be. The latter is more concerned with the combination of the parts with less concern about the future possibility of the exchange. Hence, by the above definition, modularity is the desired characteristic of the parts in the military shipbuilding industry, namely focusing on the interface.

2.6.2. Airplanes:

Size is of little importance in the airplane industry. However, "the work of monolithic design initiatives is the same everywhere: to aggregate many parts into fewer modules before the point of final assembly. The purpose is to achieve higher quality, better features, less time to fabricate, and lower cost: more art and craft, not less" (Kieran & Timberlake, 2004, p. 81). Even if those parts were whole airplane tails or wings, the investment in huge machinery that can handle such large parts is compensated for by the improved production process and ability to outsource the production of those parts to places that can be less expensive. In economic terms, those investments allow the transformation of marginal costs into static one-time costs, resulting in a more cost-effective final product.

Another important lesson from the Airplane industry is that substituting materials can often lead to eliminating some parts and enhancing the integration of the remaining parts. Kieran and Timberlake mention Boeing's tail assembly as an example thereof. According to them, the change of design to composite materials has allowed an overall reduction of parts by nearly 800 and to reduce the weight by 1650 pounds, and increasing the flight range by 78 miles - a characteristic of crucial importance in this industry.

2.6.3. Cars:

Perhaps the most important lesson from the car industry is that when responsibility for the car is fragmented into modules, there are more entities assuming primary responsibility for their quality. Sub-contracting those modules allows for the simultaneous research and development of each of them, as long as their connections to other modules (which together form the final product) are standardized.

Integrators are those suppliers who have added value to their parts' supply by including assembly work in their own factories, instead of being sub-contractors to assemblers. "For those willing and able to become integrators, many opportunities have opened to move up in the food chain and become more than a parts supplier" (Kieran & Timberlake, 2004, p. 89).

Furthermore, the responsibility increase in the tasks of those integrators has encouraged them to re-design their parts and modules, to more efficiently deliver parts and modules that fulfill the required functions. For example, by combining and integrating previously separate functions, the structural beam of the car can also be an overall lighter duct for the heating, cooling and ventilation system.

Therefore, the overall lesson is as follows: The changed locus of joining the same number of parts into modules before the point of final assembly transforms a very complex problem into a series of smaller, less complex ones.

2.7. The required interventions in stagnant neighborhoods

2.7.1. The need for diversity:

Sims (2015) presents that in 2006, 62.8% of the 142244 housing units constructed in 6th of October city remained unoccupied. This clearly indicates the low level of effectiveness of housing construction. It is rather surprising that more than a decade before the initiation of the New Urban communities program, Jane Jacobs (1961) had first published "One of the most remarkable books ever written about the city" (William H. Whyte – author of "City: Rediscovering the Center" on the back cover of Jacobs (1961)). The planning methodologies and strategies applied in Egypt's new cities almost suggest a conscious intent to kill them before their birth. Strict separation of land-uses is the norm while diversity in primary uses is the most important documented indicator of healthy neighborhoods (Jacobs, 1961). To generate such diversity within neighborhoods, it is of utmost importance to directly link day-time attractions to their surrounding residential neighborhoods, to achieve a closer work-residence relationship.

2.7.2. The impact of universities on local communities:

> "There is a self-evident need for local authorities and universities to collaborate to soften the blow of economic change, yet how many universities are closely involved in identifying local needs, arresting decline, getting involved with local manufacturers and bringing them into the world? How many local authorities plan with universities to create targeted courses that relate to local needs? Yet the kind of links established between Stanford, local entrepreneurs and venture capital is what made Silicon Valley."
>
> (Landry, 2008)

A community dialogue held at the American University in Cairo (AUC) on November 2nd 2015 titled "No University is an Island", presents the effect that Universities can have on their local communities. Discussions with business owners in the downtown area – the former location of the AUC – have shown their disappointment with the relocation of the campus to New Cairo. The large number of students and academic staff had been the primary clientele for their businesses, which have remarkably declined since the AUC's relocation.

2.7.3. The need for density and its positive effect on sustainability

As witnessed by the author during the 7th World Urban Forum organized by the UNHABITAT in Medellin – Colombia in April 2014, it is by now commonly agreed upon that high density is a characteristic of more environmentally sustainable models of urban development. Furthermore, more people per area of surrounding residential space equal more potential clientele per sq. meter of high-cost commercial space, equal more potential profit equal higher economic sustainability. Jacobs (1961) has clearly described the necessity of differentiating between density and over-crowdedness. The first refers to the number of residents in a given area (usually a neighborhood, district or any defined residential area) divided by the total land plot area and is usually measured in number of people by square kilometer. The amount of crowdedness is measured by the number of people living in one housing unit or room. The increase of the first is desirable while the decrease of the second is an indicator for a higher living-standard.

3. RESEARCH METHODOLOGY

The literature review represents the main methodology used for data acquisition to achieve the objectives of this research. It has been complemented by field trips to the residential area under discussion. Furthermore, scanning of the available industries with the potential to feed in the value chain of the proposed project was based on the author's previous experience and professional networks in Egypt.

A report published by Mc Graw Hill Construction (2011, p. 6) shows that "The number one reason engineers and contractors give for not using prefabrication or modularization is that the architect did not include it in the project design". Therefore, realizing that architects need to be educated on and encouraged to use prefabrication in their future projects for the industry to develop, the author tutored a one semester academic course at the faculty of engineering - department of Architecture at MSA University (ASE 433pf – Prefabrication in Architecture) which was attended by eighty 400-level students, many of them in their final graduation semester. The requested final project consisted of the full design of a student dormitory for their university in its immediate vicinity in groups of up to 6 students. Hence, a variety of 16 projects using IBSs was assessed based on their application of the lessons presented in this paper and are documented in the portfolio of this course, available from the author upon request. This has greatly contributed to the inspiration and design progress presented in the following discussion.

Furthermore, the author has participated in the design, manufacturing and installation of multiple container architecture projects during his internship in 2014 at the container architecture project labeled "2x20ft" run by the German design office "ArtDepartment Berlin". Witnessing the transformation of used shipping containers to usable and comfortable spaces in person, this hands-on experience has enabled the author to gain a deep insight into what works and what does not and the necessary technical precautions in this process.

4. DISCUSSION AND CONCLUSION

The quote by Landry (2008) in point 2.7.2 has been the main driver of the author to undertake this research. Being a member of the academic staff at MSA university, the daily dispersion of all those who daily commute clearly appeared as a counter-intuitive to the immense effort being put by the HR department to strengthen the community feeling among them. Shared apartments of usually up to 4 rooms are the most common nearby residence type of students and staff who do not already live with their families in 6th of October or Sheikh Zayed city. However, the supply of quality apartments in the immediate vicinity is scarce. Most of those visited and found on online real-estate networks were of low quality.

The research has thus shown that a mixed-use dense project directly associated with an academic institution – such as a student house or dormitory with service and commercial ground floor - and within reasonable walking distance or even on campus has the potential to revitalize the surrounding neighborhood. The concentration of private University students and staff as potential clients has already attracted food and beverage businesses and other service providers to the confinements of the MSA campus during day-time hours. Providing residences tailored to the spatial and quality needs of those potential clients in the MSA's proximity could attract other services and entertainment businesses with longer working hours to the area. The project's association with a popular university assures a continuous availability of customers both for the surrounding neighborhood and the project itself.

Examples of student houses in Europe and the USA built using IBSs seem indefinite and more are continuously being built. The Hillside Commons in Oneonta, NY, USA presents an excellent example of how modular steel frame systems can be made to aesthetically match traditional construction through cladding with plasterboards. The Keetwonen project by Tempohousing in Amsterdam, the Netherlands, was built using one thousand purpose built 40ft containers which have been outfitted into elegant 28 sq meter studio apartments in designated factories in China. In fact, after having exceeded its planned duration, the project is for sale and deployable almost anywhere in the world by December 2017. Buying this project after close inspection and relocating it to the immediate vicinity of MSA University is one easily feasible idea that could emerge from this paper.

It is not surprising that so many student dormitories are being built using IBS. The characteristics of this project type perfectly matches those presented in Section 2.5.4. A short construction schedule is highly desirable by the potential investor, since each semester that passes and each batch of students that graduates represents a missed group of potential clients. Repetition of different residence sizes (such as studio, 1, 2, 3 and 4 apartments) as well as their included service areas (such as bathrooms and kitchen) is inherent in the design requirements of student houses. Uniqueness in quality and an innovative interior design is required especially in this case study to compete with the alternative options which staff and students have for their residence.

Student dormitories are commonly designed using minimal room-sizes resulting in higher density to reduce their prices and to achieve a higher return on investment for their developers. Smart furniture is continuously being developed that can be transformed into bed, desk or sofa, depending on the user's current need, to maximize the space –usage efficiency of small rooms. The tiny living trend is also progressing quickly, making use of those furniture developments to provide both small mobile houses and space-efficient permanent residences in dense city cores where the cost of living space may be very high.

The shipping container module not only represents a spatial module that is easily acquirable in Egypt (especially by its Suez canal receiving lots of governmental attention) but also one which falls into the prefab category of modular construction, which has already been presented as the category of highest potential. The process of re-using old containers and modifying them into habitable units is often labeled "up-cycling", giving the project a higher potential for deserving green building certification. The increased demand for used containers through their use in this and other IBS projects in Egypt has the potential to open up a whole new market along the Suez Canal. This market can provide hundreds of entrepreneurial jobs in services such as container maintenance, insulation, steel- and ironworks.

Precast Concrete factories have been found to be the most advanced providers of IBS products in Egypt. The most basic of those produce Hollow building blocks. More advanced factories use multiple horizontal casting beds to produce precast walls of up 4m high by 6m wide. The largest precast projects built by the most advanced local factories are new factories, designed in the form of hangars with spans up to 30m. This is done using T-, TT- and/or Rafter beams. Pre-stressed Hollow-core slabs are used for roof construction.

The proposed Project consists of a similar Precast concrete structure and building shell, decorated aesthetically similar to the MSA university buildings. 20ft shipping containers are the proposed module types for the residences, arranged side by side, so that only the first and last modules require exterior covering. Full interior and exterior design drawings for this model have already been drafted and developed (and are available upon request) by the author and a team of young entrepreneurial architects and interior designers. Those designs include various studio, 1, 2, 3 and 4 bedroom apartments. Solar-power generating rooftiles are included in the design. Furthermore, other parts of the roof shall be covered with aquaponic systems, as a means to provide fresh food to the community with minimal water usage. The Ground floor is to consist of service spaces, shops, restaurants and cafes. A small amount of rooms for residents with special needs and wheelchair accessibility must also be included. The roof of the ground floor should ideally be constructed using pre-stressed hollow core slabs that can carry at least 3 levels of containers above.

The proposed scheme suggests subcontracting the supply of smart-furniture through open competitions to involve the furniture manufacturing cluster in Damietta and encourage its development and cooperation. The strategy and its use of readily-available materials implies the clustering of the construction industry in Egypt into a mass-producible product. The nascent industry to evolve from the model project must involve industry, researchers, academia, designers and – most importantly – national government as important stakeholders. Therefore the following recommendations are suggested:

- Educate Architects on the advantages of using large Prefabricated modules through private and compulsory academic courses and seminars.
- Organize global-scale exhibitions in new communities to import knowledge from international modular and prefab designers and manufacturers.
- Encourage developers to use Prefab through tax cuts and subsidies that can be compensated for through higher tax returns due to higher sales of bigger factories.
- Organize workshops for industry and designer cooperation to exchange ideas and experience, especially after the completion of IBS projects.

Finally, on the way forward for Prefab architecture, Smith (2010, p. 46) brilliantly cites Joel Turkel of Turkel designs:

> *"The future of prefab is an increasingly non-architectural problem. Traditionally, architects have tried to design things to be prefabricated using either existing or new means, as opposed to designing functional and integrated delivery methods…Real development for the industry will come from young (professionals) who are able to… think in terms of complete front-to-back business models. They are aware of the needs and limits of manufacturing processes but also are versed in new technologies, entrepreneurial methods, how capital works, strategic partnerships, and the important of marketing and branding. This group will not design buildings but rather solutions for distributed delivery methods…leading the way toward rationalized industry wide changes to benefit us all, rather than just promoting an individual vision or aesthetic."*

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Strategic Plans for Egyptian Cities and its role in dealing with Urban Land Use Dynamics in the Peri-Urban Areas

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Abstract: Many cities of the developing world are testing high rates of urbanization, at the same time Governmental policies of peripheral areas rarely have a clear land policy that takes into account activities of all agencies involved in land management. In Egypt one of the most visible results of this phenomenon is the spread of cities over previously rural landscapes. The dynamics of urban growth are most evident at the peri-urban areas , especially where the built-up area is continuous. On the same time General Organization for Physical Planning (GOPP) is currently active in preparing strategic plans for Egyptian cities of different sizes. These strategic plans are prepared using a participatory planning approach to define the new city limits and boundaries; proposed land uses and zoning; regulations for new developments; detailed plans based on a prioritized list of projects based on a consensus that city development partners reached; understanding the rural-urban linkages for a healthier relationship between the city and its countryside; proposing mechanisms for implementation. The focus of this paper is on the diverse mechanism behind the complexity of the governmental and legal process that recently applied all over the Egyptian cities which affect the urbanization process in peri-urban expansion areas then through a simple survey investigating the Obstacles facing current Governmental institutions on some of the main actors dealing with the process of strategic and detailed plan the paper will conclude the Obstacles facing the strategic and detailed planning process managing urbanization on peri-urban areas.

Further research shall provide deeper focus on new Mechanisms To manage urban growth operations on peri- urban expansion areas in the Egyptian cities by Community Development motivation and Community involvement initiatives into planning processes carried out by government institutions.

Keywords: Governmental policies, peri-urban areas, participatory planning, strategic plans, detailed plans

1. INTRODUCTION

Population growth in Egypt is among the driving forces causing problems in Egyptian human settlements. The distribution of population is the most important reason, where the majority of Egyptian live in the Nile Valley and Delta (GOPP, 2014). The difference between the population level and the available living space in the capital region created a significant demand for outward development, at the expense of surrounding agricultural land. Between 1981 and 1988 alone, the metropolitan area lost 340 square kilometres of arable land to an expanding urban core (El Araby, 2002). While the extent of arable land in the country has since increased, the outward growth of urban land cover on previously agricultural land continues and is occurring at a rate faster than the reclamation efforts conducted by the Egyptian government. (Robson, et al., 2012)

By shifting large scale formal urban development to the nearby deserts, the rural fringes have been left to "silently" absorb people and the dense and small-impact informal residential neighbourhoods they create. It wasn't planned that way. The rural hinterland was supposed to freeze as it was, and practically all population growth was to occur in the deserts. But the economics of housing and livelihoods for the mass of inhabitants has prevailed. (Yousry.,2013)

Even if the inevitability of cities expansion is accepted under the pressure of the Population growth and urbanization needs. It remains very important to manage this expansion efficiently. In the perfect situation expansion areas should present great opportunity for addressing the city needs from housing and service, a great chance for new enterprises for generating income opportunities and better living condition for residences. Yet in reality peri-urban expansion areas are partly fuelled by land speculation. As speculators hold on to parcels around the city, new developments occur in a haphazard manner, often pushed to locations farther away from the central city creating a pattern of scattered development. (M. Salem, 2015) .This process of rapid urbanization accompanied by informal urban development, which has become a predominant feature of urban expansion in the last four decades.(Nada, M,2014)

Most of the General Strategic Plan for 221 cities and 4600 villages indicates expansion on adjacent agricultural areas. It is expected that Egypt will lose formally around 66,300 and 13,8000 faddan of the best fertile areas surrounding Egyptian cities and villages respectively by the year 2027 . During one and a half years after the 25 January revolt of 2011, Egypt has been lost between 10,0000 -120,000 faddan. (Soliman, 2010) . GOPP stated in "The National Urban Framework In The Arab Republic Of Egypt, 2014" that erosion of agricultural land Represents one of the main challenges that were taken into consideration in the preparation of the Strategic National plan for urban development (2052).(GOPP, 2014)

Despite the issue of erosion of agricultural land in Egypt relate to many of the social, economic, aspects however the interest in this paper is on the institutional and legal framework for the planning process in the Egyptian cities through recognizing the formal actors dealing with peri- urban expansion areas, by Demonstrating legal process for the strategic and detailed planning in order to identify the Shortcomings afflicting the process. Concluding suggested reform that could adopt the process to make it more efficient.

2. RESEARCH METHODOLOGY

The methodology applied in this paper is a mixture of desk work research and analysis of a simple survey applied by the researcher investigating the Obstacles facing current Governmental institutions through the process of strategic and detailed plan and its role in managing urbanization in peri- urban expansion areas. The paper is divided into two parts.
The First part is a Literature review of the main issues including: urbanization process and the problem of informality and its effect on the Peri-urban areas in Egypt. Illustrating main factors influencing land use polices Governmental institutions and legal framework dealing with urban expansion and land use dynamics in Peri-urban areas. With quick review of the building Law no 119 for the year 2008 regarding the application of the strategic and detailed plans.

The second part is designed as a simple survey that examine the acceptability of the current planning process dealing with urban expansion and land use dynamics in Peri-urban areas in Egypt . To outline obstacles facing the strategic and detailed planning process. The designed questionnaire is targeting urban planning experts, officials from the General Department for Planning and Urban Development in Qalyubia and Giza governorates, urban planners from the general organization of physical planning. In order to have a clear image about the problem and to identify the weakness points of the current institutional and legal situation.

3. Peri-urban areas In Theory and Practice:

Peri-urban areas in theory have various definitions, Peri-urban areas are considered transitional zones between the city and the countryside, where urban and rural activities are juxtaposed and the landscape features are subject to rapid transformations induced by human activities(Allen, A.,) ٢٠٠٣. There are many forces that affect land uses in peri-urban areas and stated social, economic, political and cultural forces as main factors. Moreover, they included housing and land markets, planning decisions, ownership patterns, land use characteristics, infrastructure and transportation structure and roles of actors within these processes.(Masuda, J.R. & T. Garvin, 2008)

Different governments have come up with a range of public policies and regulations in managing land uses. These regulations constrain landholders' options for the use of land, and thus influence present and future market values of land. Governmental policies that promote infrastructural. Development may also influence the use of land. Furthermore, policies such as those related to land rates and taxes influence landholders' financial calculations and therefore influence the way they use land (Maconachie, R., 2012)

In Egyptian context many Literature use different terminologies may be used for these areas like "semi-informal settlements ";"illegal housing"; "un-planned areas";" Informal extensions"

3-1The problem of informality in Peri-urban areas in Egypt :-

Housing on agricultural areas is the most popular and common type of housing in the Egyptian cities for many reasons: First, the inhabitants of semi-informal housing have the advantage of legal land tenure. Second, such housing is not only relatively cheap, but it generally retains its value. Third, the inhabitants within such areas may acquire their land by means of incremental payments. Fourth, such housing has been provided by private developers who have flourished using informal processes of subdivision and land commercialization. Fifth, such settlements offer greater security of tenure than other types. Finally, land subdivision in such areas follows the geometry of former agricultural use, resulting in a pattern of mostly straight roads although they may be narrow (4-6 meters) and longer than standard requirements. This pattern has allowed the state to install basic services. Private developers acted as decision-makers for setting up the street network of the areas and relieved the municipality from paying additional costs for such arrangements.(Soliman, A. ,2007) El-Hefnawi identified that this pattern causes a lot of problems such as El-Hefnawi, (2005):

- Incompatible mixture of land uses, lack of green areas and peripheral public conveniences.
- Unplanned use of land and lack of local services and open spaces.
- Unhealthy, deprived high-density informal areas.
- Intensifying formal and informal areas which exert strain on services
- Environmental effects as the pollution resulting from solid waste management where the internal roads, has become open dumping areas, in addition to the overflows of drains and canals with all types of construction waste.

3-2 Governmental institutions and legal framework affecting Peri-urban expansion areas through the formal process for strategic plan

In this part, the paper will define the Main actors dealing with peri- urban expansion area and demonstrate legal process in order to have a clear vision about how these actors work together

3-2-1 Main actors dealing with urban expansion and land use dynamics in Peri-urban areas: There are a variety of actors that has a stake of dealing with urban expansion and land use dynamics in Peri-urban areas. The governmental sector can be divided into two levels:

<u>Central level:</u>

General organization of physical planning (GOPP) and its regional offices: was established according to presidential decree no. 1093 year 1973 to be the sole official authority for planning human settlements in Egypt. Law 119/2008 gave GOPP the responsibility of formulating public policy planning and sustainable urban development; and preparing plans and programs for this development at the national, regional, governorate levels, then review and approve urban plans at the local level in the framework of the objectives and policies of national, regional and local planning and sustainable urban development.(GOPP, 2014)

<u>Local level</u>

Governorates: Egypt is divided for administrative purposes into 27 governorates. The Governor is the head of the Local Administrative Units at the governorate level and is appointed by the president. In each governorate there is a General Department for Planning and Urban Development (GDPUD) which is mandated to prepare detailed plans for cities and villages, through experts and consultants that are registered at the GOPP. The head of this department reports to the governor. (Nada,2014)

The City Council: Represents the executive authorities through representing the lines of different sectorial ministries. Each ministry is represented by a unit within the city council, which follows the specific ministry regardless of the demands of Local Popular Councils. The role of the City Council is unclear when it comes to planning; this reflects, however the lack of coordination at the central level between the sectorial ministries. (Nada & El-Megharbel ., 2012)

The Local Popular Councils (LPCs): In each governorate, a local popular council shall be formed (Article 10 Law 43/1979). It is formed from directly elected representatives. The main function of the LPC is to hold the executives accountable for the delivery of the basic services and infrastructure in accordance with the competencies granted for each LGU. They are also responsible for approving the proposed budget and the proposed socio-economic plan of their administrative unit, as well as the detailed plans, including the plans for urban expansion areas. Prior the 25th of January Revolution, the LPC were abolished along with these councils just after the Revolution.

3-2Peri-urban expansion and strategic planning process:

General organization of physical planning (GOPP) is the state agency responsible for developing the general policy for planning and sustainable urban development, GOPP is currently active in preparing **strategic plans** for Egyptian cities of different sizes. The aim is to increase the capacities of these cities to host the additional five million inhabitants expected by the year 2022.(GOPP, 2014)

Strategic Plan is defined as the plan that determines the prospective vision of the urban development whether at the national, regional or governmental level as well as the city or village level. Such plans shall further identify the goals, policies, socio-economic development plans, urban environment necessary to realize the sustainable development, future needs for the urban expansion, use of different lands, implementation programs, priorities and mechanisms and sources of finance at the planning level (Article 2 Law 119/2008). one of the most important outputs of any city strategic plan is **the Urban Growth Boundaries (UGB)**.

UGB: is a common planning tool used to demarcate limits for urban expansion over a particular period of time, generally 20 years (Calthorpe & Fulton, 2001). According to building law, the process of specifying the delineation of the UGB is done as an integral aspect of undertaking the city strategic plan and it circumscribes the entire urbanized area and demarcates new areas that will be added to the city for future urban expansion. These newly added areas are added based on an estimate of the expected population growth of the city in the coming 20 years as well as its current density.(Nada, M,2014) As a result of the change in the delineation of the UGB, new expansion peri –urban areas are added. These new areas are defined in the building low as expansion areas which need to be designed to fulfil the future urban needs of the city or the village through the detailed plans. Institutional and legal framework defined by building Law no 119 for the year 2008 can summarized in figure (1)

strategic plan. The plan also contains all integrated urban design development projects, land sub-divisions and landscaping projects whose execution is suggested in the general strategic plan. After the official approval of the strategic plan of the city or the village the General Department of Planning and Urban Development (GDPUD) subordinated to the local governorates are responsible for preparing the detailed plans for the city or the village, under Supervision and support of the Regional centre for Planning and Urban Development subordinated to (GOPP) by consultants registered at the GOPP. Local governorates are facing real challenges in following the law since the vast majority of cities do not have approved detailed plans for urban expansion areas. According to the Building Law; cities and villages will not be able to issue a statement for locations' validity for building or issue building permits without the existence of an accredited detailed plan. (Nada, M,2014)

Beside the Local governorates inability to undertake the detailed plan as stated in the Building Law. The governorates inability is not only restricted to financial resources, but also in relation to human resources required to undertake the detailed plan. There is real shortage in number of well-trained technical staff. On the other hand land owners of the added areas want to get benefit from the added value of their land, so they usually sell it to small-scale to moderate-scale constructors. Who make their own sub- division to the land regardless to the legal regulation, and sell them back to the people. New land owners try to get permit to have legal license to build on their lands from the local government. These requests usually are rejected or postponed in the best case. Eventually land owners decide to build illegally. Figure (2) defines the process of urbanization in peri- urban expansion area

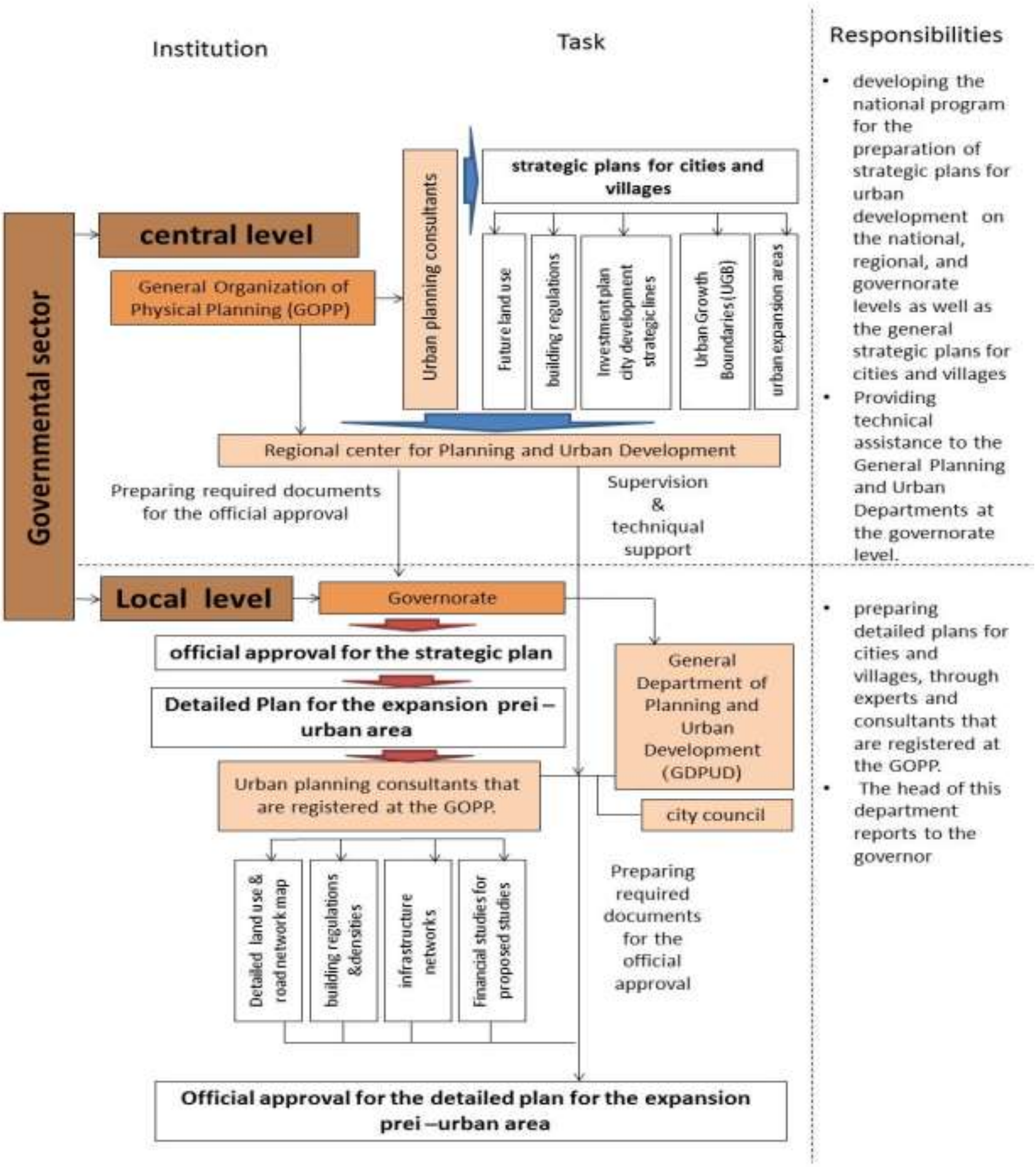

Figure 1: Institutional and legal framework defined by building Law no 119 for the year 2008 (Author, 2016)

3-4 Detailed plans for peri –urban expansion areas:

Detailed plan: is defined by Building law as the executive plan for the building and planning regulations. It presents the different land uses and infrastructure suggested in the city or village

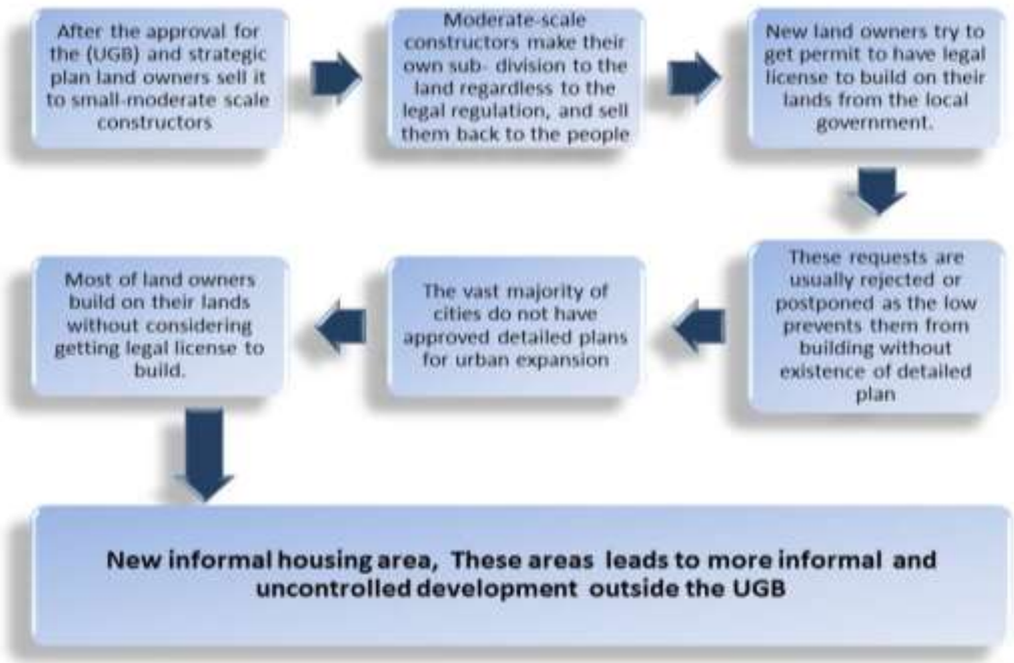

Figure 2: process of urbanization in peri- urban expansion area (Author, 2016)

4. Obstacles facing the strategic and detailed planning process

In a practical attempt to identify the main technical, and institutional conflicts facing planning process affecting the peri-urban expansion area , the paper conducted a survey targeted small sample from the main actors involved in both strategic and detail planning process including experts 32 % , urban planners from the General Department for Planning and Urban Development in governorates23% , urban planners from general organization of physical planning 45 % to investigate the main challenges facing Governmental institutions which can be summarized in the following part of the research

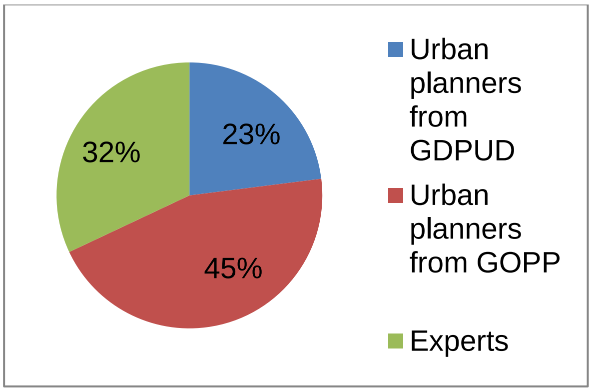

Figure 3: Sample percentage of targeted participants on the survey (Author, 2016)

4-1 The Egyptian culture in Participatory planning:

The participatory planning in Egypt dates back to the 90s that was began in a close cooperation with a number of multilateral and bilateral agencies including USAID, UNDP,UN-HABITAT & GTZ. The scale of the experience ranged from a pilot project implemented at a neighbourhood level till upscale national program of participatory planning led by the General Organization for Physical Planning (GOPP) and implemented at all Egyptian cities and villages. (Yousry. S,2013) The process holds great participation principles; however it remains clear that actual application of the process seldom carry equal values. Especially with the lack of appropriate database and capacity of local authorities.

4-2 Weak administrative system of Land registration:

Among the key constraints facing the preparation of the detailed plans and their relevance is related to land registration. Two important actors are involved in land registration; they are the Real Estate Publicity Department (El Shahr El Akary), and the Land Survey Authority (Hayaat El Mesaha). The first actor is responsible for property title/deed registration, while the second is responsible for cadastral surveying. The coordination mechanisms between the General Department of Planning and Urban Development and the actors involved in land registration are very weak.(Nada, M,2014) The absence of accurate, updated and systemized database for the information regarding the ownership of the land in represents a core challenge to the process.

4-3 Lake of financing resources:

Financing the different governorates occurs through the minister of local development. Each governorate has special finances including taxes on vehicles, governmental subsidies and contributions and wills approved by the prime minister. (Madbouly,2009)The very limited collection of local taxes presents a different perspective in relation to the impact of the fiscal centralization on the motivation of local government officials to collect local taxes. The dependency of local government on central transfers and their inability to use them in a flexible manner (between budget line items and between years) created a powerful disincentive to collect these taxes. (Nada,,2014) . On the other hand the Building Law spatially integrates between the interventions of the different ministries in a spatially sensitive manner but with no clear specifications on how their programs and the interventions will be financed. (Moustafa, , Doha, 2015) About 80% of the total governorate budget comes from the central level and the remaining 20% generated from the local taxes and fees. A small percentage can be used by the governorate according to its own discretion (Sims, 2012). Peri-urban areas is growing rapidly, while centralized budget allocation system doesn’t put in concern the needed services and utilities for these areas. Hence during the annual budget allocation Peri-urban area do not take their share (Madbouly, 2009)

4-5 Consumed Time in strategic and detailed planning process:

One of the most problematic issues in urban planning for Egyptian cities the complexity and time consuming involved in planning process; the main reason for this delay relates mainly to the current rigid bureaucratic system witch consume time in collecting and discussing data; which could be important but it is not giving the real image specially with the shortage of the land registration data of peri-urban expansion area. The informal sector in most cases is faster than the formal sector. This can be seen clearly in many cases in which the city had an approved (UGB) and strategic plan, most of land owners of the peri – urban expansion area co-operate together to reach their own land sub-division informally, some of them build on their lands without considering getting legal license to build, as they know that they are going to face the bureaucratic system and the low that prevent them from building their own property without existence of detailed plan. In which they don't know whether it will be matching with their needs or not.

5- What is the developing countries experience to solve this problem?

International experiences that succeeded in managing this dilemma or in the process of solving it, the research done about the international experience showed the following lessons

- Developing countries applied innovative instruments in managing the conflict between urbanization and agricultural land protection initiatives; among these instruments incremental land development, relaxed permits, some of these countries applied transfer of development rights as in Johannesburg.
- Asian countries were more developed; they have showed institutionalized efforts to overcome and control the encroachment on agricultural lands. They used innovative instruments such as land-readjustment schemes, land sharing, innovative taxation, mortgage community programs, land gain charges and relaxed permits, innovative coordination mechanisms, use of participatory planning, with different success and failures stories due to legal and institutional problems. Japan led these countries with its land re-adjustment policies that began in Japanese cities.

An overview of the information in these different case studies illustrated that these case studies have been successful because they had a strong social consensus about the need to manage the land in a right way, and the political will to act upon this consensus. The common factor of a successful system does not appear to be the actual approaches used, but instead how those approaches are used in a political-policy environment, which wants them to succeed. (El-Hefnawi, 2005)

6. CONCLUSIONS

Egypt is like any developing nation suffers from urban sprawl problems and the absence of both planning control and urban management over the built environment. This situation has led cities into urban informality, Which requires a national policy to preserve agriculture land and to face the main challenge of how to manage this vast urbanization process? A close look at how informal system of the private sector work , and the ways in which the evolution of housing markets shapes the physical environment in the peri-urban areas should be taken into consideration . Private sector works and deals informally faster more than the governmental authorities can handle as it has actual information about land ownership and the ability of planning and design according to the actual needs of the residents which don't match with the existing Legislations.

In spite of the efforts in Changing planning policies, from master to strategic planning in order to give more stakeholders chance to participate in planning process however, the availability of human capacities, information and enough financial resources will be amongst the biggest challenges in addition to the limited capacity to manage urban development in the local level still one of the major challenge facing planning process . On the other side there is a big gap between the experts of central authorities and local authorities on the reality of urban expansion in peri- urban areas. The aim is to provide sufficient flexibility in the Planning process to enable real stakeholders to participate in the detailed planning of future development and growth. In order to do that, there are many issues to be solve:

- The Existing building law needs to be revised, in relation to the preparation of detailed plans for areas expansion areas and to provide better opportunity for landowners to participate in the planning process either by providing information, mapping of these areas or participating in Conceptualizing urban plans for these areas.
- Making real change in the local authorities Capabilities. Local authorities shall be (technically - financial and institutionally) empowered to be able to play its role in facilitating a realistic participatory planning process dealing with all stakeholders.
- Planning process and techniques for Egyptian cities and its expansion areas needs to be more creative and more oriented to the real needs of the these cities resident, it shall get benefit from the abilities of the informal economy .
- The current process for detailed plans needs to be reviewed. The researcher believes UGB approval and detailed plans should not be separated by a long time margin. As the large time margin encourage more informal building process.
- In the short run the government should not seek to develop a fixed detailed plan, but it is more efficient to set regulations to organize construction process, and to oblige landowners to submit land sub-division plans Subjected to the approved regulations. Moreover the government should facilitate the construction permits for the owners as long as the submitted plans are consistent with the approved regulation. On the other hand the approved regulations need to be more practical and related to the socio- economic status of the city or village residents.
- In the long run a new mechanism is needed in order to enable the Development Authorities to think and plan at both the macro level and at the micro level with a powerful process which involves not only a detailed land appropriation, land readjustment, and infrastructure development plan but also a mechanism for financing and implementing the plan, thus involving the landowners in the process.

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Re-considering Al-Fustat: Urban Development in Old Cairo in Reaction to Mega Projects

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Abstract: *One of the promising potentials of mega projects in a specific city is to provide floor for further urban development projects. Stemming from that, the National Museum of Egyptian Civilization placed in Al-Fustat can be considered a core mega project for further re-development of the old city of Cairo. The location, scale and attractions the project presents can introduce a series of urban development projects to the city fabric. The location of the project is intermediate between the West where the old city of Memphis and the pyramids lay, and the East city witnessing the development of Coptic, Islamic and Jewish civilization in Cairo. In addition to this, the museum itself is located amid the important context of Amr Ibn Ala's mosque and the ruins of the old Fustat city and lake. Furthermore, around the site borders are many important touristic attractions, for instance the citadel, old Islamic Cairo and Mainal Palace.*

The paper aims to explore the possible urban regeneration development which can be added to provide a sustainable urban revival to the whole district creating what is considered a touristic node. In order to achieve this, the site of the project will be explained according to the current state, the physical features, attractions present and the surrounding fabrics. The proposed projects aiming to create the urban node will be analyzed according to the concept of development and the ideas for development. The paper concludes by a cross-analysis of the potential urban development proposal and other similar international projects.

Keywords: National Museum of Egyptian Civilization, sustainable urban development, touristic node

1. Introduction:

Al-Fustat, the direct context of the development projects which the paper aims to discuss, is generously full of historical relevance. However, the main focus of the paper is to highlight the possible criteria for development not to deeply analyze the historical potential of the context. It is important to note that the analysis presented hereafter was conducted by the author in 2009 while the plan for development was updated in 2016 based on the methodology to be explained later in the paper. Thus, the methodology of the paper will be based on qualitative analysis of the potentials of the context, followed by a descriptive analysis of the futuristic vision. After that, cross analysis from similar international projects will be implemented.

Finally, the concluding discussion will highlight recommendations for implementing the development project in Al-Fustat.

2. Site and Context Potentials of the National Museum of Egyptian Civilization:

The site of the project was the main factor generating the idea of “land-use reconsideration” due to its enormous potentials on various scales. This is relevant stemming from its central location, easy and direct access, surrounding context, natural topography, historical context, as well as the existence of the mega-project of the National Museum of Egyptian Civilization.

As explicitly presented in (fig.1), the location of the development project lies in the physical, Touristic and service centres of Cairo. Also it is connected to major traffic spines, like the Ring Road and Salah-Salem spine. It is also neighbouring the Nile waterfront, which provides a major potential.

Figure 1: Location and Macro Analysis (Author, 2009)

From another perspective, the location includes several monumental sites, giving it another dimension of potentials. This is shown in (fig. 2), which explains the various historical monuments referring to the various timelines of Cairo’s development. First, the site accommodates Al-Fustat Ruins, which is located in the middle of modern Cairo, close to the Roman fortifications of Babylon, the Jewish and early Christian settlements in the area, where the Muslim troops commanded by Amr Ibn Al-As pitched their tents, (Kubiak, 1989). Centred around the still existing mosque of Amr Ibn al-As, this camp grew into a city called Fustat. Fustat comprises a large number of ruins of villa's and aqueducts, partly excavated, partly submerged in the rising ground-water and partly covered in the debris of the pottery kilns that were active in

the area for centuries. The site has been evacuated and fenced and an attempt is made to preserve the ancient remains. In addition to this, the existence of the Bayblon Roman Fortress, which is a Roman construction was mainly built as a line of defence because of its location in a central position between north and south or Upper and Lower Egypt, (Sheehan, 2010). The purpose was the easy control of any rebellion or revolution that might occur in the country. Babylon, according to historians was originally the name of a capital city of a neighbouring country known as Babylion, but another probability refers the name to the ancient Per Habi-n-own that was the deity's dwellings in Heliopolis city, Habi was the divinity of the Nile. The fort is also known as "Qasr el Shamee" or the candles palace as the towers of the fort were adorned with illuminated candles at the beginning of every month, thus people could follow the movement of the sun from one tower to another . Six Coptic churches, a convent and the Coptic Museum are actually within the enclosure of the fortress, (Sheehan, 2010).

Figure 2: Context and Surrounding (Author, 2009)

Among the other monumental attractions is Coptic Museum founded by Marcos Smeika Pasha in 1910 AD to fulfill the needs of displaying monuments referred to that period in order to easily trace the history of Christianity in Egypt. The Museum was erected over a land that was willingly offered by the Christian Church under the presidency of Pope Kerolos V and his successor Abba Yuanis XIXth. The Museum has been renovated with the two annexes the ancient and modern aisle and opened for visits in 1984 AD. The objects displayed rise up to 1600 pieces approximately, arranged in chronological order in 12 different sections.

The site also includes a group of Coptic Churches in old Cairo, or "Masr al-Qadima". This area is the oldest part of Cairo and predates what is now modern Cairo. It is believed that there was a settlement here as early as the 6th century BC. Later, the Romans built a fortress, which we know today as "Babylon". Some of these Roman walls still exist today.

After the spread of Christianity throughout Egypt, it became a Christian stronghold, with as many as twenty churches built within an area of just one square mile. Now only five remain, along with the earliest mosque ever built in Egypt. After the fall of Jerusalem in around 70 AD, the area saw an influx of Jews, and it's here where Egypt's oldest synagogue, Ben Ezra is located. Among the ancient churches is The Hanging Church “al-Mu'allaqua”, which is originating in the 4th century. The hanging Church was built over the southern gate of the fortress of Babylon. Dedicated to the Virgin Mary, its treasures include a 1 4thcentury wall-painting of the Nativity. Also, Church of St. Sergius and St. Bacchus, which is a 5th-century basilica, built over a crypt where the Holy family is believed to have stayed during their trip through Egypt, (Kubiak, 1989).

In addition to that, the context is enriched by the presence of Amr Ibn Al 'As Mosque, founded by 'Amr ibn ai-'As, the Muslim conqueror of Egypt, in 641-2 as a hypostyle mosque near his house , the Mosque of 'Amr ibn ai-'As was rebuilt and enlarged in 673 during the reign of Mu'awiya, who is said to have added a minaret to each of its four corners The mosque does not exist in its original form, having undergone numerous additions and restorations through the 20th century. Originally a hypostyle mosque, it was doubled in size in 827 with seven aisles built parallel to the qibla (the direction of prayer) wall and defined by arcades on columns; the last column in each row was attached to the wall by a wooden architrave carved with a frieze of a late Hellenistic type. The other important monuments in the context can be stated briefly, they include the Nilometer, Manial Palace, Magra El Oyoun Wall, Ibn Tulun Mosque, Sultan Hassan Mosque, El-Refaie Mosque, Cairo Citadel and Mohamed Ali Mosque, (AlSayyad, 2011).

As to the National Museum of Egyptian Civilization as a mega project, the next part will focus on elaborating its potentials specifically. The National Museum of Civilization is planned as the only museum in Egypt to present an overview of Egyptian civilization throughout the ages, (Abdel Moneim, 2005). It should therefore be a priority for visitors (fig. 3). In order to accomplish its mission, a general strategy of the goals and policies of the museum is set out as follows:

1- An effective policy for collecting the material evidence of the Egyptian civilization throughout history to date: The Museum of Civilization will shoulder the responsibility of bringing together a complete set of antiquities illustrating Egyptian civilization from the earliest times up to the present. This target must be prioritized, as no Egyptian museum currently holds examples of all such materials in a single place.

2- An effective policy to link the current location of the museum to the heritage locations surrounding it: From the historical and cultural perspectives, the location of the museum within Cairo itself is very significant with regard to Egyptian civilization.

Figure 3: NMEC within Context (Author, 2009)

3. Analysis of the Development Project:

As shown in the previous part, it is crucial to consider the development project associated with the mega project from a totalitarian perspective. Thus, this part will expose a conceptual approach to the development, which will be further analyzed in the coming part in relation to other similar international precedents.

The idea is to create a unique place in the heart of Cairo, with good possibility to secure, protected from the surrounding urban rapid and stressed lifestyle creating a totally different microsphere, one that will be mainly historical-touristic with minimum population, plenty of attractions and maximum tourists and visitors. The aim of this project is to perceive this zone as a "Touristic Historical Node inside Cairo", (fig. 4), where all elements and services of a Complete touristic visit exist. Some of these elements already exist in or nearby the site as exposed in the previous part, such as, Amr Ibn Al-As mosque, National Museum of Egyptian Civilization, Coptic Churches complex, Synagogue, Babelyon roman fortress, Tabtaba remains, Fustat Ruins, Coptic Museum and Traditional Crafts Center.

Figure 4: Area Available for Upgrade (Author, 2016)

While other complementary elements have be introduced to be able to achieve the concept and enhance the urban context, for instance a 4 and 5 star Hotels, Commercial Spine, Cultural Facilities, Archaeological Park near Al-Fustat ruins, Historical Theme Park, Cafes and Restaurants and Bazaars. In addition, perceiving a touristic complex as such enhances the security measures for tourists and increases the occupancy rate of the hotels being gathered all together in a very attractive and rich site near the historic heart of Cairo with easy access from Cairo's main traffic spines.

This project represents the unification of the cultural, recreational and commercial services all together in one huge area. It provides opportunities from the economic point of view that can assist in operating the whole project. Moreover, a wide parking space for cars and buses is available in several zones. The investment opportunities available are, the existing National Museum of Egyptian Civilization, projects surrounding Al-Fustat lake, projects surrounding the old Fustat city, activities along the main spine linking all the projects together.

As to the detailed vision of the project; it is divided into two main streams. The first is the group of projects surrounding the lake as seen in (fig.5). This includes a touristic hotel which will have a unique location that provides a panoramic view from two sides. From one side is a view of the citadel, the old Islamic Cairo and the Mukattam Hills. On the other side is a view of the lake as well as the National Museum of Egyptian Civilization with the surrounding gardens. The first stream also includes a commercial center alongside the lake, with an area of 5000 sq.m. , a commercial area of a more oriental theme, such as Bazars and crafts workshops. In addition to this, a group of restaurant will be included inside the lake with a view of the surrounding activities and gardens.

Figure 5: Touristic Node Vision (Author, 2016)

The second stream is the group of projects surrounding the old city. This area is divided into eight zones as shown. Each of those zones is suitable for inserting touristic projects such as hotels. This can create a real touristic hub and attraction points amid the old city, with additional potentials for touristic development other than the traditional applied methodologies.

4. Cross-analysis between International Projects and NMEC Development Initiative:

In this part, the paper aims to highlight similar projects with common traits like the initiative introduced in this research in order to formulate an analytical approach regarding development projects nearby historical city centers. It was found that ideas of the same nature were introduced in other historical city centers around the world, where major complex projects with huge investments were established around the historical nuclei. These projects proved to be successful as touristic attractions & also resulted into complete renovation & upgrade of the historic areas. Some of the most popular & successful similar projects are the development projects of Acropolis in Greece and old Rome in Italy.

As seen in (fig. 6), the main concept behind the Acropolis project is that in the heart of the Greek capital you suddenly find yourself catapulted into the past and living 5000 years of history, on a promenade that is more than 4 km long and spread over an area of 140 acres, crossing parks, along lanes and over wooded hills. The park houses the main archaeological sites of the capital, as well as some of its main museums of the Acropolis, Agora and Keramikos. It covers nearly all the surface of Athens as it was more than 2500 years ago.

Figure 6: Acropolis, Athens (http://www.athens-today.com/e-parco_archeologico.htm ,2016)

In addition to this, in Rome, there were several forums. The most famous, the Roman “Forum”, was designed by the architect Vitruvius who introduced the proportions 3:2 (length to width). The Roman Forum became the spectacular showcase of the Empire filled with beautiful statues and architecture. As seen in (fig. 7) discovered elements compose a "stratigraphical unity" that is numbered progressively during excavation. They are then surveyed and positioned on a map and can therefore be laid out according to the inverse layer formation (from the most recent to the most antique). This methodology involves the management of enormous data, especially in excavations of extensive urban areas that need to be organized in chronological order. In the year 2000, an Archaeological Park is planned to be created. The Park will extend from the Colosseum to the Capitoline and Quirinal Hills, through museum itineraries in the archaeological areas. The project will also involve the revision of the present road layout. The PARCO aims to preserve, to develop and to enhance the three sides of the Archaeological Park of Rome (Palatinium, Cecilia Metella and Villa dei Quintili). The conservation programme includes within its objectives to develop the enhancement and enforcement of the topographic unit through transportation system and advanced computer systems.

Figure 7: Roman Forum Archaeological Park(murciatoday.com, 2016)

5. Discussion: Re-considering Al-Fustat:

Based on the previous analysis, the discussion will highlight some important recommendations for development in Al-Fustat. This set of recommendations is crucial to be taken into consideration in order to provide a collective developmental achievement.

1. The architectural significance of the additions in the analysed location has to be selectively studied. This is important to avoid chaotic interferences in the sensitive context. Thus, future research will be conducted to extract adequate language, elements, morphology and ratios to be implemented on the planned buildings presented in the futuristic vision. This study will be relative to historical urban regeneration projects.
2. The training and cultural upgrade of the local community adjacent to the development project is important to provide sustainable development. It also provides community based surveillance for the development project, as well as provide better job opportunities for the youth, thus creating mutual interest between investors and the community.
3. It is highly recommended to utilize all possible sustainable approaches in the new additions to avoid any environmental pollution which might be subjected. This can be guaranteed by providing economical incentives to investors by encouraging the buildings added to the site to be LEED certified.

6. Conclusion:

This research aimed to present a futuristic developmental vision for an important zone in Greater Cairo, which has been neglected in spite of its importance, either historically or due to the new addition of the mega project of the National Museum of Egyptian Civilization. As presented in the study, the urban development targets economical, social and environmental upgrade in order to fulfil the three main sides of sustainable development. The architectural details and recommendations, as well as the local community upgrade can be points of further scientific research based on previous attempts. Finally, it is very important to consider the upgrade of the historical core, in order to enhance the local economy, inject the city with new layers of touristic attraction as well as sustain the rich historical site and avoid its decay due to the deterioration of the urban setting.

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New Cairo's Urban Paradox

All-Inclusive Urbanism vs. Social Exclusion

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Abstract: The rapid urbanization of the Egyptian capital and the disappearance of the thin line separating between urban and rural areas, pushed different categories of the population to seek other places to reside. In the 90s, the new settlement of New Cairo appeared as a breakthrough. Its all-inclusive urbanism and planning trends integrated social, economic and physical aspects.

On the one hand, New Cairo was originally designed to include a wide variety of citizens and activities all assimilated together and well-defined in one plan. On the other hand, today New Cairo is a developed city where gated communities seem to outnumber free residential areas. An example of all-inclusive built environment where social exclusion is prevailing!

This paper aims at scrutinizing, as well as tracing this paradigm shift in the urban evolution of New Cairo. It starts with a thoroughly inductive analysis of the urban concepts involved originally in its planning, compared to the actual urban situation. Subsequently, we might be able to understand the emergence of a "*ghettoïsation*" phenomenon.

Keywords: All-inclusive urbanism- Gated-communities- "*Ghettoïsation*"- New Cairo- Social exclusion

1. INTRODUCTION

1.1. Historical preview

Cairo's urban dynamics obliged decision makers, since the late 19th century, to always stumble on new solutions for the capital's problems and the population growth. Heliopolis was the first attempt in 1905 to seek a viable way out into the desert, 10 km away from Cairo's center. Since its realization, especially with the existence of a transportation system, Heliopolis acted as a magnet attracting urbanization to the empty desert space that was separating it from the capital. The result was a succession of new settlements that bound Heliopolis with Cairo while transforming it from a garden city, in the middle of the desert, into an urban district (Mahmoud, 2010). Until the early 1960s Cairo had already expanded largely with considerable governmental investments in the economic/public housing domain, especially within a socialist regime installed deeply by Nasser after the 1952 revolution (Rashed, 2014). The uncontrolled rapid demographic growth (natural increase and rural migration to Cairo) has resulted in urban expansions of the capital, which varied from urban-planned settlements like Nasr City or Mohandessin, which was founded on agricultural land- to informal settlements as *Mansheyat Nasser* or *Hagganah.* Cairo's expansions continued substantially under Sadat's regime to the extent of suggesting the creation of new cities and new urban communities in the desert around Cairo, to be able to face the rapid pace of population growth.

After the mid-eighties, Cairo entered a new era, as the population growth started to slow down whilst the expansion of the informal areas increased, basically because of the governmental inability to face the economic housing demand. In the nineties, new urban communities started to be well-established, especially with the development of road networks. New Cairo, the object of our research, was one of the most important among the new urban settlements.

1.2. New Settlement, New Perspective

New Cairo was a new attempt to get out of the Egyptian capital with all its troubles. In 1993, the nucleus of New Cairo was already existing to the east of Cairo: the first, the third and the fifth settlements. Simultaneously, these new spots were attracting lots of developers, investors and construction activities. Consequently, the government decided to increase the areas designated for these new urban settlements and to include them in one larger settlement that will hold the name of New Cairo. Thus, the remaining spaces between the first three settlements were divided and offered in the market to be sold for investment. Moreover, extra residential areas were added to the east of the first three settlements to enlarge, even more, the surface area of the new urban settlement of New Cairo (El Khorazaty, 2006).

Not only was New Cairo a new attempt to get out of the capital with all its troubles, but it was also a new vision of a city of all-inclusive urbanism. Basically, the intention was to address different social classes and the increasing divide between rich and poor; as well as to minimize the lack of affordable housing and to enhance the enforcement of urban laws. The way New Cairo developed was unfortunately the dichotomy of all-inclusive urbanism. It actually represents a setup for another process of social exclusion, due to several reasons: the appearance of walled gated communities, whether residential, business, educational or commercial, which eventually led to urban fragmentation. This shift in the urban planning intentions of New Cairo confronted us, thus constituting the object of this research.

1.3. Paper's Interests and Objectives

Today, the new settlement of New Cairo is tightly linked to the extensive existence of residential compounds. These compounds are simultaneously gated in order to control accessibility for security and cultural reasons. This phenomenon, that had started back in the mid-nineties and has been accelerating since, threatens, in our opinion, the social morphology of this new community. Especially that New Cairo was originally an attempt to integrate all social classes in one urban fabric.

Based on both theoretical and empirical research, this paper aims at demonstrating how the proliferation of this type of urbanization in a new settlement- originally designed to follow all-inclusive urbanism rules or thoughts- eventually promoted a social exclusion phenomenon. More explicitly, this research is an attempt to scrutinize the phenomenon of the sprawl of gated communities in a new society and its linkage to the turning point "in New Cairo's urban evolution" from all-inclusive urbanism to social exclusion

2. Research Outlines

2.1. Research Approach

The research approach is structured at different levels. Firstly, for us to be able to understand New Cairo's paradox, the research will be fed by a literature review that encompasses several urban sociological phenomena such as social exclusion *and ghettoïsation*, etc. Secondly, a field survey will be conducted in parallel with context appreciation to help us with relating different phenomena to the real urban environment. Finally, our research will be fed with interviews, especially with decision makers and planners, as well as cartographic and data analysis. By comparing the master plans of New Cairo, starting by its initial planning idea till today, we expect to elucidate the shift and the paradox in the urbanization process of this new settlement.

2.2. Literature review

New Cairo's Paradox requires the understanding of some urban sociology terms and phenomena. Despite the fact that New Cairo was originally planned according to all-inclusive urbanism concept, nowadays it is a living example of social exclusion, due to the uncontrolled sprawl of gated communities that will eventually lead to a *ghettoïsation* phenomenon.

All-inclusive Urbanism means an urbanism for all. The new concept of all-inclusive urbanism appeared recently to be applied in the urban design field. It is more about the need to create an urban environment that will accommodate a wide variety of social classes and include several activities (Eren, 2004). These all-inclusive urban environments should be able to subsist by avoiding marginalization. It can also be achieved through applying sensitive policies that allow all community individuals to grow economically as the physical urban environment evolves. This trend of planning takes into consideration the wide variety of abilities of each individual, it basically reinforces the involvement of each community member in the physical built environment. This active participation will encourage different individuals to reshape their built environment according to their needs.

Social Exclusion: the term of "social exclusion or marginalization" is used when a group of individuals or communities are systematically excluded or blocked from accessing certain services or practicing certain rights. The term "exclusion" embodies the opposite of "inclusion". This process of being deprived from certain opportunities or resources that are available to other individuals or groups of people might be connected to the individual's social class, economic status, skin colour or race. On the one hand, this process could happen naturally by the inability of some community members to access certain places or to benefit from certain services due to lack of money or social status. On the other hand, the same process could be reinforced physically by adding gates or barriers that cannot be crossed unless being a member or a part of that gated community.

Social exclusion of a group of individuals from a certain community eventually affects the social morphology of this community. As Emile Durkheim states, "Social life rests upon a substratum determinate in both size and form. It is made up of the mass of individuals, who constitute society, the manner in which they have settled upon the earth, the nature and configuration of those things of all kinds which affect collective relationships." (Durkheim, 1895:241). He also underlined the opposition between the two phenomena, social exclusion versus social cohesion and their consequences on the community. These two phenomena can either tie all the groups of a certain community together by blending them into a complex relationship or tearing this community apart with weak social bonds that will eventually affect the relationship between these society members and their nation (Durkheim, 1895). It will eventually lead to social segregation, inaccessibility to living resources and inequalities in living conditions (Wirth, 1938).

Gated communities are walled protected enclaves. Besides, they are privatized, monitored and secured spaces for residence, leisure, work, education, etc. (Caldera, 1996). The main justification of their existence is the feeling of insecurity, the fear of the other and of what he is capable of, the fear of violence! The necessity of belonging to a homogeneous community. It is the need of living without being criticized by others because of different social practices or habits, especially with the lack of liberty in a fake urban environment. An urban environment that welcomed long ago rural practices, the antithesis of city life. It is a whole new perspective of an urban environment that promoted social segregation to subsist. These walled communities are the secretion of an urban evolution that got out of control, the fight for the right to the city and the dream of "*le bien être*". They are the opposite of what we call an "urban process" as a collective social action. They represent another culture that abandons the wellbeing of a collective inclusive society for the welfare of individuals.

The expanding scale of gated communities, surrounded by high walls, whether residential or not, redefined the role and the image of essential constituents of the urban fabric. Streets, public spaces and squares take a whole new aspect where gated communities prevail. The spread of gated communities over the urban tissue, puts the remaining spaces in a critical framework. These remaining spaces will be automatically labelled as the residuals of that urban fabric. Thus, they will be treated and will be lived-in differently. Consequently, the type of activities practiced in these spaces will be limited or constrained as well as their identity. This will lead us to a contextual dichotomy between what happens inside versus outside the gates. Most of the urban maladies that people escape from, to find their perfect life inside the walls, will eventually and progressively be formed in the residual spaces outside the fences.

Especially, when it comes to high fences/walls as in the case of New Cairo. Gated communities illustrate the image of islands of wealth and wellbeing in oceans of poverty; it's relatively a continuous representation of social exclusion rather than lack of resources (Sardar, 2010).

Ghettoïsation is a French term used to describe the process of creating ghettos. A **ghetto** is a word used to describe a place in the city where a group of minority citizens live. Originally the term ghetto was first used in Venice, when back in 1527, the Jews were ordered by a decree to move to *Cannaregio* area in which the old cannon-melting process was carried out. This is how the word "***ghetto***" that means melting in Italian language was originally born to signify a part of the city where the minority of Jews were restricted and segregated to live.

Progressively the term surpassed its original use to signify any part of a city, where an excluded minority of individuals live together while forming a homogeneous community. At the beginning, this term was strongly related to exclude poor communities, where disadvantaged residential areas, usually troubled with high crime rates, struggle to subsist. Nowadays, this term has largely surpassed its original and trendy meaning to symbolize most of the socially-segregated or self-excluded groups of people in an enclave in the city, *vis-à-vis* the rest of population.

Hence, the ***Ghettoïsation*** is a process that promotes the creation of enclaves -sometimes walled which aggravates the process- in the urban fabric in order to shelter minorities of social groups for them to be able to form a homogeneous community. Thus, this process is actually a masked action of social segregation that will fragmentize eventually the urban tissue of a city.

3. Paradigm shift: Governmental Urban Politics vs. Private Sector's Interest

In order to understand the turning point in New Cairo's urban evolution from all-inclusive urbanism to social exclusion, we chose to analyse its master plan since 1993 till today (Fig.1). We will also scrutinize all the phases of its extension, as well as the deviations from the original master plan. These analyses, along with the context appreciation and the data we managed to obtain, will permit us to successfully understand the shift in New Cairo's urban evolution process

3.1. New Cairo as a Governmental Endeavour of All-inclusive Urbanism

3.1.1. Phase 1: 1993-1997 (Fig. 2&3)

The previous existence of the three settlements: 1st, 3rd and 5th, promoted the governmental vision of creating a new settlement based on all-inclusive urbanism ideas. These three new settlements enclosed different types of economic, low-income housing and were planned to contain neighborhoods with greenery and service centers Consequently, the settlement of New Cairo was planned with an approximate area of 115 km^2 (approximately 27,000 feddans) targeting a population of 1 million inhabitants (El Khorazaty, T., 2006).

Figure 1: Economic housing that existed in the 5th settlement since the start of New Cairo (Author, 2016)

Figure1 by the researcher

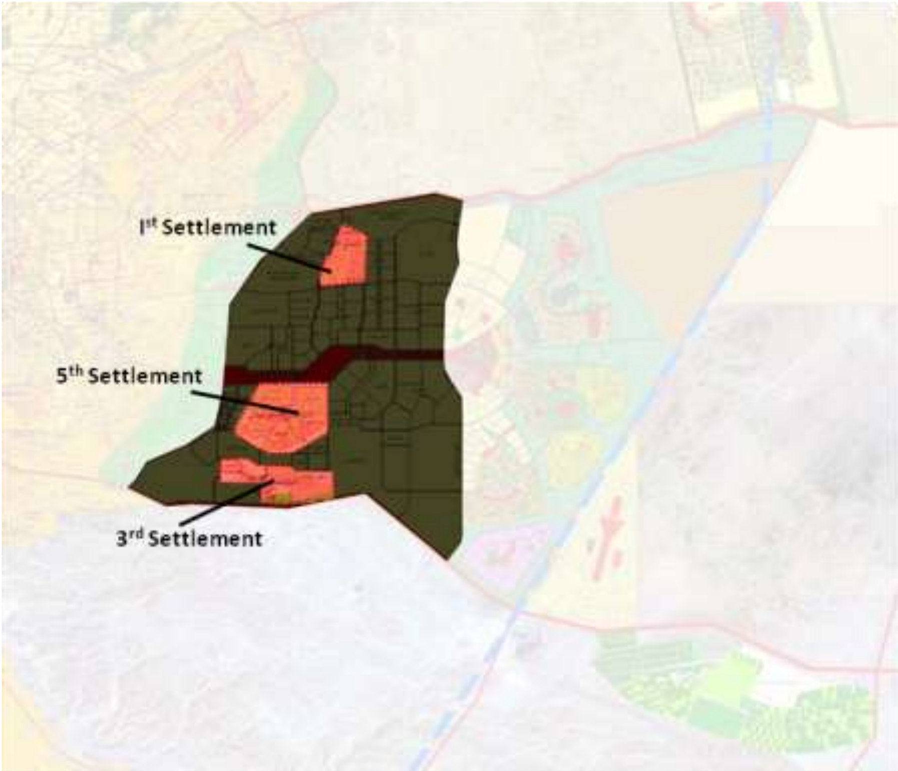

Figure 2: 1st, 5th and 3rd settlements included in New Cairo master plan 1993 (Oekoplan Engineering Consultations, (1997), New Cairo City Report)

3.1.2. Phase 2: 1997 (Fig. 4&5)

New Cairo City was initially created by developing and filling up the areas between the existing settlements with planned neighbourhoods, containing individual residential plots (each with an approximate area of 600 m^2 and building heights ranging from G+3 till G+5). Simultaneously, large-scale parcels have been offered to investors for development: the most prominent of which were Katameya Heights (350 feddans), Arabella (100 feddans), Mirage Golf City (400 feddans), and Al-Rehab (1500 feddans); in addition to other smaller scale parcels in the northern and southern investors' zones, with areas ranging from 15 to 100 feddans. It is worth pointing out that offering such parcels to investors to develop gated communities has been meant to facilitate their management and maintenance, which relieved the government greatly in this respect and was meant to accelerate the development of the city itself.

Figure 3: Katameya Heights, 5th Settlement Service Center, in addition to Neighbourhoods that existed back in 1997 (Author, 2016)

The linear city center with a length of approximately 13 km and a width ranging from 300 to 600m, linking New Cairo from the east to the west, has been planned to accommodate the general services of the city, in addition to mixed uses: retail, entertainment, offices, hotels and sports clubs, with building heights ranging from G+3 till G+7. Furthermore, the Police Academy acquired a land parcel along the ring road, covering an area of approximately 1500 feddans, and another significant governmental body acquired a land parcel of 400 feddans within the city.

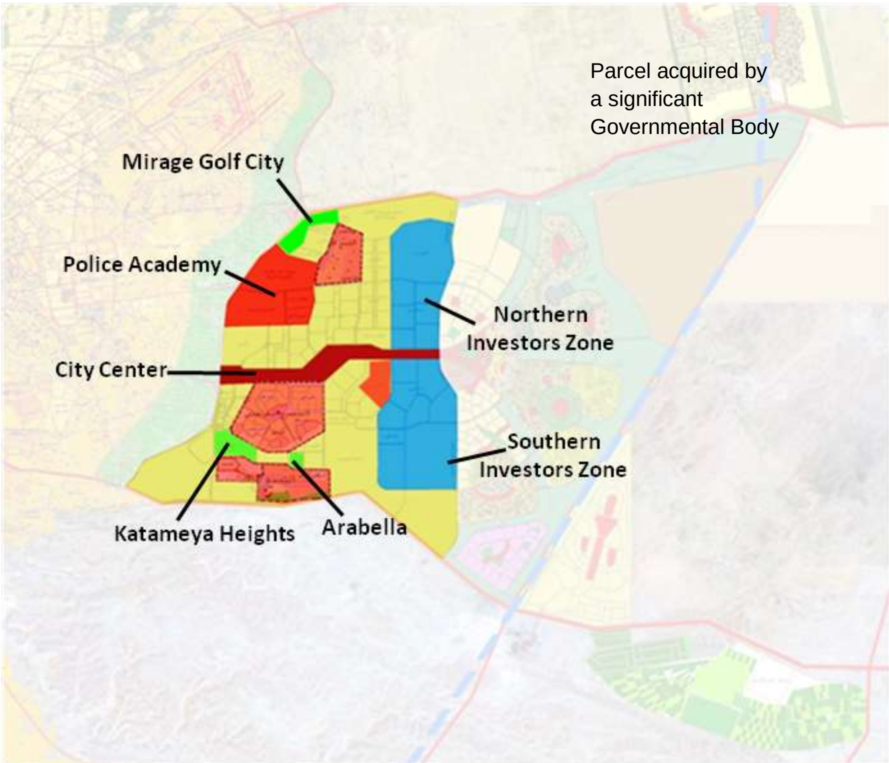

Figure 4: New Cairo City master plan in 1997 including the three settlements, first gated communities, the City Center, the Northern and the Southern Investors Zones (Oekoplan Engineering Consultations, (1997), New Cairo City Report)

Despite the fact that some gated communities had started to appear at the time, they were not totally separated from their surroundings due to the fact that the design of their fences was controlled by the law: a 40-cm brick base and a 160-cm metal fence, allowing for adequate visual integration with the city.

3.1.3. Phase 3: 1997-1999 (Fig. 6&7)

Figure 6 : Development of New Cairo: Al-Rehab City, Individual Housing and the 90 Street at the 5th Settlement that started to develop massively back in 1999. (Author, 2016)

Figure 5: The winning proposal for New Cairo's extension in 1997 (Oekoplan Engineering Consultations, (1997), New Cairo City Report)

At this time, the city had developed quickly, including the individual plots within the neighbourhoods, the neighbourhood and district services, the first gated communities, and the city center with some offices. Accordingly, the government announced a competition for the extension of New Cairo City to reach a total area of 45,000 feddans and to house 3 million inhabitants. The winning proposal had suggested the development of five oases, amid green, open spaces. Each oasis contained neighbourhoods and districts that were mainly planned to accommodate individual plots and very few gated communities to continue following the concept of all-inclusive urbanism. However, the winning proposal wasn't implemented, except for the main structure of the city extension and part of the land use: The city center had been extended and some large parcels for universities and other amenities had been designated. It is worth pointing out that the large-scale parcel in the north-eastern corner of the city shows that, at the time of the competition, there had already been ideas to offer mega-scale parcels to investors.

3.2. Private Residential Compounds, *Ghettoïsation* and Social Exclusion

3.2.1. Phase 4: 1999-2010 (Fig. 8&9)

The real shift in the urban environment had happened at this point in time: after abandoning the winning proposal for the extension and due to lack of governmental resources, the government had started offering even larger parcels to investors (more than 1000 feddans), especially after the success of Al-Rehab City, as a self-sufficient community.

This era is marked by massive investments in the real estate market promoted in the media and encouraged by the US Dollar unstable exchange rate. The master plan implemented between 1999 and 2010 (Fig.8) elucidates the difference between urban policies or targets in the original master plan and those of the extension. The yellow colour indicates the parcels sold to private investors, which imbalances the urban idea of all-inclusive urbanism intended previously in the original master plan. Nevertheless, the original master plan wasn't exempted either from the investors' invasion. In addition to the first gated communities of New Cairo (Mirage Golf City, Katameya Heights and Arabella) and the Northern and Southern Investors' zones (the majority developed into gated communities behind high walls), a part of the Police academy was sold and transformed into walled enclaves as well (Katameya Residence, Porto Cairo, Montagaa Al-Nakhiel and Swan Lake). By the end of this phase, living in private residential compounds started to symbolize everyone's ultimate dream. The promoted image of being different and socially high-ranked because of living in an isolated green compound within a homogenous community slipped overwhelmingly into Egyptians' heads.

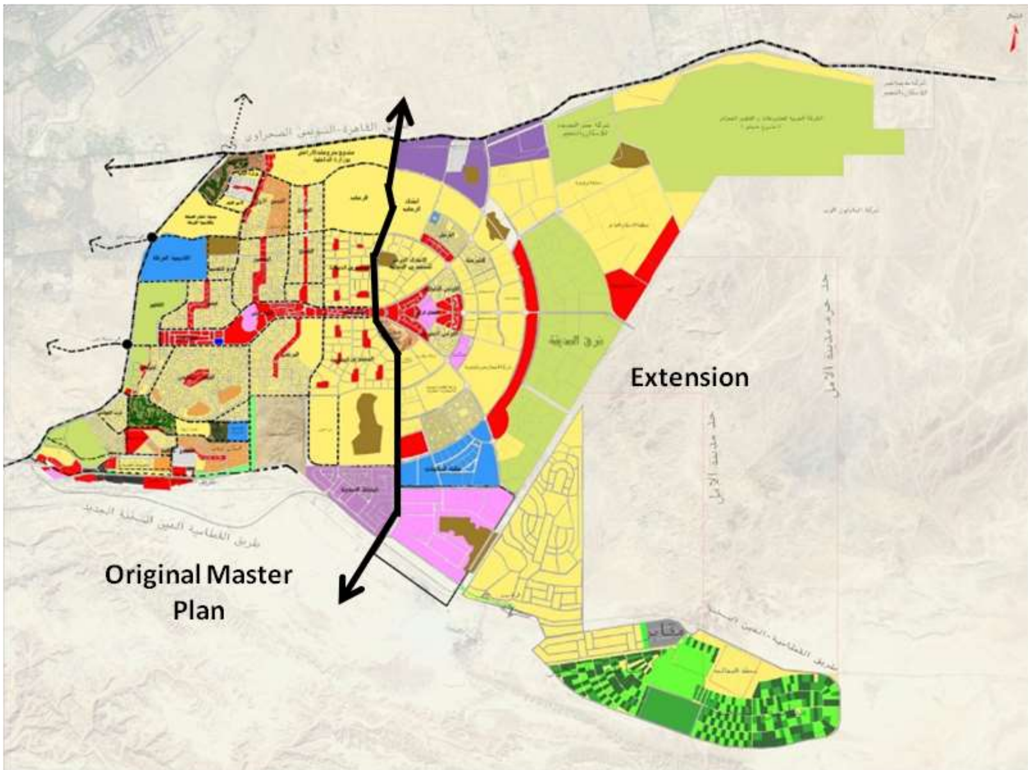

Figure 7: Master Plan of New Cairo between 1999 and 2010 (GOPP and NUCA, 2014; modified by Author)

Figure 8: Gated Communities in the Northern and Sothern Zones that started to outline a privileged social image since the year 2000. (Author, 2016)

3.2.2. Phase 5: 2010 to present (Fig. 10&11)

Figure 9: Different Gated Communities in New Cairo's extension. (Author, 2016)

This phase has been struck by the Egyptian revolution in 2011 and the instability of the economic situation in Egypt. The only market that kept its value was the real estate market. This alone was a catalyst for investing even more in that market. Consequently, the number of gated communities augmented to be able to face the demand. Nowadays the extended part of New Cairo consists mainly of gated communities, residential, educational, etc. (Fig.11), many of which are developed by large investment companies, developing large scale parcels, with areas more than 1000 feddans. Moreover, due to security and cultural needs, as well as the continuous media promotion for the social image of living in a gated community, some areas were walled to isolate houses from the rest of the settlement like in the case of The West of the Golf area adjacent to Katameya Heights, the housing of Public Security and the Ministry of Interior in Front of Mirage Golf City. The result is the appearance of a ***Ghettoïsation*** phenomenon that will lead in our opinion to a certain social exclusion.

Figure 10: Latest Master Plan of New Cairo with its extensions, in which the investors' yellow colour prevails. (GOPP &

3.3. Outcomes and Remarks

New Cairo's urban paradox is incredibly noticeable when the original master plan- *with all-inclusive intentions-* and the implemented extension plan- *in which investors' parcels outnumber the remaining uses-* are compared. This paradox is clearly legible through the widely spread high-walled enclaves in the city, especially in the newly-developed eastern part. The existence of gated communities at this rate will residualize road networks and un-gated public spaces; thus all the remaining parts of the urban fabric will be looked at or treated as left-over areas. This marginalization is very well perceived if we compare the same brands of outdoor retail, existing, for example, in Downtown commercial center and CFC (Cairo Festival City). Before the inauguration of CFC different social classes used to go to Downtown, while after The Village opening in CFC (open-air area with a huge food court and dancing fountains), the same social classes now prefer to go there because they feel more secure and unseen in a gated area. Moreover, "exacerbation of social cleavages existing already is promoted by the proliferation of gated communities" (Blakely and Snyder, 1997). The need to be or to live in a gated area will eventually lead to social exclusion and a ***Ghettoïsation*** phenomenon, because at the end of the day, these gated communities will only be reserved for certain social classes, where the rest of the population will be prohibited. Moreover, there is also that social hierarchy between different residential compounds. Furthermore, within the same compound there is a competition between different residences; and due to cultural beliefs and lack of the sense of security, houses are also gated inside the gated communities.

4. CONCLUSIONS

The world-wide proliferation of Gated Communities over the past twenty years is a clear manifestation of the need for self-segregation. It represents the individuals' dreams of living "*la belle vie*", of being secured and protected in a self-made cocoon. There is also the marketed vision of living in a bubble, escaping from all city problems: traffic, garbage and sexual harassment (Cairo Observer, 2013). As Le Goix pointed in his research gated communities are considered "as symptoms of urban pathologies, among them social exclusion is considered to be preeminent." (Le Goix, 2005).

New Cairo was a new attempt of all-inclusive urbanism that ended up with a ***Ghettoïsation*** phenomenon and social exclusion due to several factors. Firstly, for a settlement to be socially sustainable, marginalization and segregation should be avoided among its population (Bagaeen & Uduku, 2010). However, from the very beginning, there were seeds of social segregation represented by the very first lavish gated communities as Katameya heights, Mirage Golf City and Arabella. These communities were the igniters of an imbalanced urbanization process. They have set certain models of housing types, lifestyles and qualities that most of the middle to upper social classes were eager *or* dreaming to have. Secondly, this paradoxical urbanization process was also promoted by the instability of the Egyptian economic situation, as well as the Egyptian pound inflation over the past few years that made the real estate market *appear* to be the most stable to invest in. Finally, the withdrawal of governmental intentions in creating an all-inclusive urbanism settlement for the benefit of the private sector, which greatly helped the government with developing and managing large parcels in the city, thus alleviating a lot of the pressure off its shoulders, and consequently facilitating the continuity and the aggravation of the process of building gated communities behind *"uncontrolled"* high walls. Consequently, the heterogeneous sprawl of gated communities in New Cairo will eventually result in social exclusion, *Ghettoïsation* and lack of public spaces. City streets will be treated as leftover areas that take the user from point A to point B without any urban interaction; for that reason walking in the city street will be alienated from urban activities, especially at night, streets will be deserted.

New Cairo's urban paradoxical process will redefine city components in urban studies, thus it needs to be scrutinized to be aware of its causes, catalysts and origins. As a living example of urban paradox, its analysis might help prevent similar actions in further urban developments.

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Informal Settlements in Cairo

Understanding Sustainable Development through the Existing Comfort levels in South-West Cairo

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Abstract: *The city of Cairo has witnessed unprecedented transformation since the introduction of informal settlements in the 1960's. The creation of public housing schemes in desert areas was a solution created by Government housing agencies to house informal settlement inhabitants and allow for the transformation of the city as a whole into a formal utopia. However, informal settlement areas are still present today and demonstrate what housing needs are truly about. In many ways they have succeeded in imposing an entirely organized city without economical, social or constructional surveillance from formal institutes. Despite these successful functioning areas they receive much negativity for their existence as being centres of disruption, energy consumption and environmental degradation due to their transformation of agricultural land to building plots and unmetered amenities in many households. Currently, there is a gap in the understanding of the level of sustainable efficiency informal settlements present in terms of the comfort levels they provide within their built environments. As a result, the collective examination of the quantitative results obtained from the building performance simulation analysis of existing informal and public settlements models along with the qualitative data collection from residents and professionals provided an understanding of the level of sustainable development present through the obtained comfort levels. The results showed fluxes in each comfort level section depicting the existing high and low levels of sustainable development in informal settlements and also the need for further sampling and testing.*

Keywords: comfort levels, informal settlements, sustainable development.

1. INTRODUCTION

Informal settlements are defined as housing built on prohibited land, where they are in violation of the law and are usually refused provision of services by the Government. Residents of informal settlements are likely to experience poverty and disease due to the effects of quickly deteriorating housing and lack of infrastructure (Afify, 2004) There appearance initiated when the private sector was still set for the elite and the Government did not provide sufficient or affordable housing alternatives to the illicit construction of agricultural lands, a large portion of the Egyptian expatriates thus invested their capital into informal housing which also led to their development and growth in the-once agricultural-informal areas (Sims ,2010). Figure 1.1 shows the development of informal settlements in Cairo over the late 20th century and in which locations exactly did they prosper.

The estimated growth of Cairo in the last couple of decades of the 20th century has been reported to be 26.8% from 7158 persons/km2 to 9074 persons/km2 according to research conducted by Yin et al., (2005) using satellite images. These urban densification changes occurred due to the conversion of valuable agricultural land plots around the Nile Delta which was a process that started in the 1960's (Al-Malky, 2009, cited in Khalifa, 2011). However, most population increase in built-up areas took place in smaller peri urban areas and to the south of Cairo which appeared as a result of the Government's delayed inauguration of housing projects construction which were introduced to solve the urban densification problem (UN, 2011). This short demographic clarification reflects the growing need of housing and the results of the unsuccessful Governmental housing trials which were partially responsible for the urbanization of fertile land by the population in the South-West Cairo area (O'Donnell, 2010). According to Vaughan (2007) it is possible to simplify the reason for the flourishing of informal settlements into two main reasons which are :

- How they respond to the public space transformation process
- Residential space formations and vaiations

Yet despite the settlements' success in their self-provision for housing, economic development and economic support for the formal sector, they are regarded as areas which do not promote a modern state approach to authority in terms of economic transactions monitoring, census counts or the establishment of well-functioning civil forces (Durand-Lasserve, 2006). The aim of this research is to provide an understanding of the existing levels of sustainability in informal settlements (especially Southwest Cairo) by examining the existing comfort levels they provide as opposed to the public housing typology substitute.

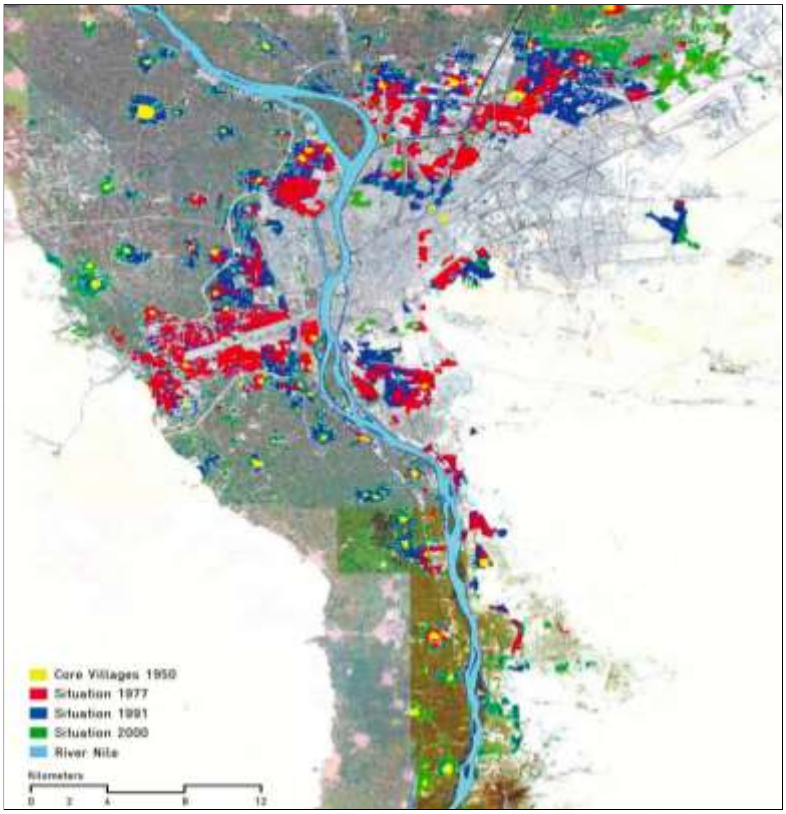


Figure 1.1: The figure demonstrates the development of informal settlements which took place in the late 20th century. It is clear that southwest Cairo went through strong densification of agricultural urban centres in the late 70's, less in the 80's but is still ongoing in the 21st century. These urban developments mostly affected the land plots on the fringes of formal areas, the peri-urban centres and the agricultural lands in between (Kipper, Howeidy and Wiens, 2009).

2. Informal settlements in context

2.1. Sustainability issues within Informal settlement

The understanding of informal settlements using institutional terminologies has changed significantly to be defined recently by the ISDF (Informal Settlements Development Fund) into two categories, "Unplanned Areas" and Unsafe Areas" (Abouelmagd and Sakr, 2013). Further distinction by the ISDF has distinguished unsafe areas from unplanned areas as having 50% or more of their housing structures with one or more threats to the residents' life, health, tenure and housing appropriateness while unplanned areas are characterized with better housing conditions despite their informal initiation which was unmonitored by municipalities (UNICEF & ISDF, 2016). These risks might have developed due to severe deterioration, the inhabitation of hazardous sites, the absence of sanitation and deprivation of clean water (MTI & GOGPO, 2009a, cited in Khalifa, 2011). This method in which informal settlements have been classified by the ISDF under represent the many social and economic functions that these informal settlements present despite their shortcomings. Not only do informal settlements provide housing amongst the poor, they also provide a wide range of housing options and solutions for various budgets and social circles living amongst the population spectrum (El-Batran and Arandel, 1998). However, this does not refute that there are still many factors to consider for housing in informal settlements which were mentioned by the ISDF whilst selecting the suitable housing unit such as infrastructure, social services and environmental conditions.

2.1.1. The socio-economic complications in Informal settlements

Informal settlements and ill-health

Informal settlements not only experience infrastructure complexations and unlawful tenure-ship, but also fundamental safety problems in specific areas caused by poorly maintained buildings, damaged sewers systems and alleyways as wide as an arms stretch (Ahmed, 2013). According to Shehayeb (2009), health issues thrive rapidly by virtue of law regulations, such as the stagnation of rent increase in the 1980s, which caused landlords to neglect building maintenance. The results of these regulations were water and sewage leaks, building structure depletion, inadequate lighting, the appearance of makeshift materials and overall poor maintenance leading to health hazards.

Shortages in supply and self-help schemes

According to Abdel Halim et al., (2014), informal area residents always find quick and feasible solutions for shortages in resources and infrastructure impairments without referring to the Government for financial support. To further fortify this statement, an informal area on the peripherals of the Giza district named "Saft Elaaban" is used as an example where water supply was cut for a 1 month in 2013, the residents demonstrated the ability to cope with the shortage despite the Government's shortcomings by referring to solutions such as residents walking to neighbouring settlements carrying water buckets back to the area for cooking, cleaning and showering. Other solutions such as the installation of water hand pumps and pressure pumps providing water deep from the ground were referred to, since these settlements were once agricultural lands. The costs were covered by community shared payments. The local Government provided water trucks, which had unclean and rusty tanks and were deficient in terms of the supplied volumes to the needed supply (Ahram Online, 2012). These kinds of self-reliant methodologies are repeated as result of authoritative inconsistencies. The lack of correlation between the residents and the municipalities causes informal settlement residents to develop infrastructure themselves when needed and rely on these solutions for emergency situations. For example, despite the Government providing legitimate water supply infrastructure to “Ezbet El Haggana”, a settlement in East Cairo, after decades of illicit water connections use, the old water supply system continues as a secondary means for water provision due to the overpricing by authorities for past un-calculated payments and also due to sudden deprivation of water supply during summer peak hours which occur mainly to maintain water supply for golf courses in gated communities near by (Bremer and Bhuiyan, 2014).

2.1.2. The existing sustainable approaches in informal settlements

Monqid and Barthel (2012) discuss that most of the global definitions of sustainability are relevant to the West, with its unique social, economic, political and cultural realities which differ from those in the Middle East, particularly in Egypt. As stressed by Sims (2010, cited in Monqid and Barthel, 2012), Cairo is a success of a city that has avoided chaos by means of the informal residents’ development of effective mechanisms despite the authoritarian state rejecting informal developments and their immobilization using ban laws for further infrastructure development, installation and services provision. This statement is fortified by the explanation made by the UNFPA (2012) stating that the sustainability shift that should be implemented in Cairo is one that develops urban strategies as systems of successful production and consumption through population dynamics, focusing on human-centred and rights-based policies developing health care, civil rights, education, participation and empowerment in developing urban and rural strategies.

Smart Locations, linkages and transit facilities

The issue of “smart location and linkages” in informal settlements is addressed by Shehayeb (2009), who states that self-sufficiency is spread amongst these settlements through affordable markets, shops and workshops which are valuable income sources. The manifestation of close proximity overrides nuisances such as noise from workshops. The pedestrian and vehicular commercial patterns are the guidelines for the geographical establishment of these economic nucleuses which are mainly situated on main streets and rarely reach the narrow residential streets, concealing them from outsiders and making them social abridgements to residential units (Loo and Tsui, 2007). Informal settlements are connected communities with walkable streets and compact urban formations which are demonstrated through the predominating walkability feature due to close home-work proximity (Eldefrawi, 2015). This is certainly true in the case of the informal settlement area of Boulaq al-Dakrour, which demonstrated 60% of its residents as pedestrians causing the fulfilment of activities and various errands along the pathway to work saving time, money and effort at an individual level, also reducing the overall fuel consumption and carbon emissions (UNDP, 2010).
It is important to note that informal settlements have shown high percentages of public transportation use to transfer themselves from one district to another and from their settlements to the city centre where services and jobs are located. This is in stark comparison with public housing projects which require much more transportation costs, time, infrastructure and effort to run. However, transportation is still costly for informal settlement dwellers since they are not officially included by authoritative plans in public transportation

routes and therefore rely on private microbuses and rickshaws, the residents also change to more than 1 bus or microbus to get to their destination (Sabry, 2009). Furthermore, Cairo holds one of the highest non-motorized transportation estimates. In 2001, pedestrian and cycling in Cairo was estimated at 32% of all trips. Depending on the size of the district or region, the smaller the region the higher the estimate. In some cases the percentage may increase from 31% to 52% (UNDP, 2008, cited in El-Geneidy et al., 2013).

Renewable energy methods and infrastructure

Informal settlements have demonstrated high levels of waste regeneration, mediocre levels of air quality improvement and overall environmental development through community participation and resources consumption reduction. Yet the levels of these environmental improvements vary from one district to the other. In the past, research by Thomas Culhane, an urban planner and the founder of Solar CITIES, was mainly concerned with informal settlements and providing them with self-build knowledge for renewable energy strategies (AFPTV, 2009). He has trained informal settlement inhabitants to install around 100 solar tanks and organic kitchen waste to biogas systems on building rooftops using recycled and economic materials providing hot water and ethanol gas for washing and cooking (Anon, 2015). Despite the absence of projects which continue and develop these pilot prototypes, these experiments confirm the informal settlement resident's potential for change within their budgets and without interfering with their way of life (Figure 2.1). Whilst Thomas Culhane's focus on renewable energy pivots around single household scales, the Zabbaleen city dwellers (garbage collectors city), formally named Manshiet Nasser, are specialized at waste regeneration on a city scale. With a population of 70,000, they have an infamous reputation and job description of hand picking and recycling for the city of 12 million. They have created one of the world's greenest waste-management systems costing the Government almost nothing at all (El Wardany, 2015) (Figure 2.1).

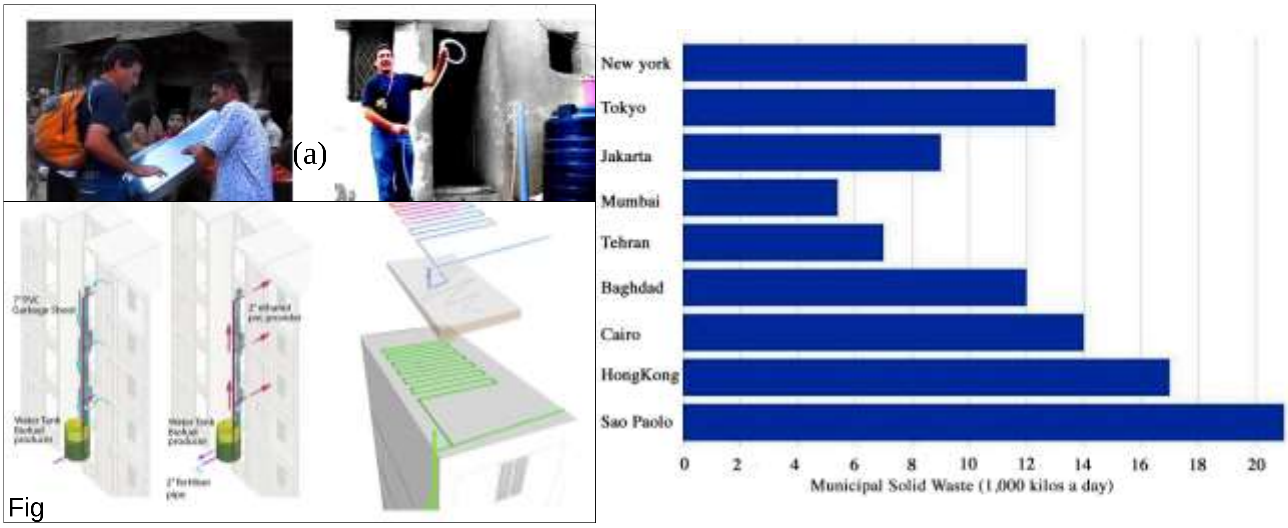


Figure 2.1: (a) The figure demonstrates the participation of Thomas Culhane with the informal settlement dwellers whilst purchasing affordable and recycled materials, installing and testing the system (AFPTV, 2009). **(b)** The graphical images portray the production of ethanol using waste food products and water tanks, they also present the passive water heating system which uses zig-zag pipe patterns on roof tops for prolonged solar heat exposure along with a reflective surface of recycled aluminum (Yasser et.al,2015). **(c)** The graph demonstrates Cairo as having the third highest value for municipal waste collection per day at 14,000 kilos of waste collection a day. Sao Paolo and Hong Kong ranking at first and second place collecting 20,500 and 17,000 kilograms respectively on a daily basis (El Wardany, 2015).

2.2. Perspectives on the potential for sustainable development in informal settlements

The estimated quantitative data of Cairo's consumption rates compared to global averages under various categories are listed in table 2.1. This information coupled with past research, demonstrates that Cairo as a whole shows inadequate levels of energy efficiency. While informal settlements are not specifically responsible for these figures, the current level of sustainable development that informal settlements are at may be the cause why these numbers are at such current poor ranges, however they also might be the reason why the ranges are not even more defective. For instance, gated communities contribute to huge amounts of water consumption for facilities with large land plots such as golf courses, parks and sports fields in Cairo's hot and arid climate, they alone might be the primary reason for the poor water consumption rates of Cairo. These communities are located in the three major new desert cities forming 46% of the extensions to Cairo (Ghonimi et al., 2011) (See figure 2.2).

Table 2.1: Cairo's consumption rates compared to the global averages.

Category	Indicator	Average	Cairo	Year*	Source
ENERGY and CO_2	Proportion of households with access to electricity (%)	84.2	**99.7**[e]	2005	UN Habitat
	Electricity consumption per capita (GJ/inhabitant)	6.4	**8.0**	2006	Egypt Information Portal
	CO_2 emissions from electricity consumption per person (kg/person)	983.9	**477.0**[1e]	2007	Egypt Information Portal
LAND USE	Population density (persons/km²)	4,578.1	**19,083.5**	2010	EIU calculation
	Population living in informal settlements (%)	38.0	**31.3**[e]	2005	IDSC Egypt Information and Decision Support Centre
	Green spaces per person (m²/person)	73.6	**0.8**[e]	2007	CAPMAS
TRANSPORT	Length of mass transport network (km/km²)	2.7	**7.3**[2]	2008	CAPMAS
	Superior public transport network (km/km²)	0.07	**0.24**[2,3]	2008	CAPMAS
WASTE	Waste generated per person (kg/person/year)	407.8	**456.9**[e]	2007	Egyptian Environmental Affairs Agency
WATER	Population with access to potable water (%)	91.2	**99.6**[e]	2005	UN Habitat
	Water consumption per person (litres per person per day)	187.2	**237.0**[2]	2009	OECD
	Water system leakages (%)	30.5	**35.0**[2e]	2007	Egyptian Holding Company for Water and Wastewater
SANITATION	Population with access to sanitation (%)	84.1	**98.2**[e]	2006	Egypt Information Portal

All data applies to Cairo unless stated otherwise below. * Where data from different years were used only the year of the main indicator is listed. e = EIU Estimate. 1) National electricity generation mix used to estimate city level CO_2 data. 2) Greater Cairo area. 3) There are no light rail or BRT lines

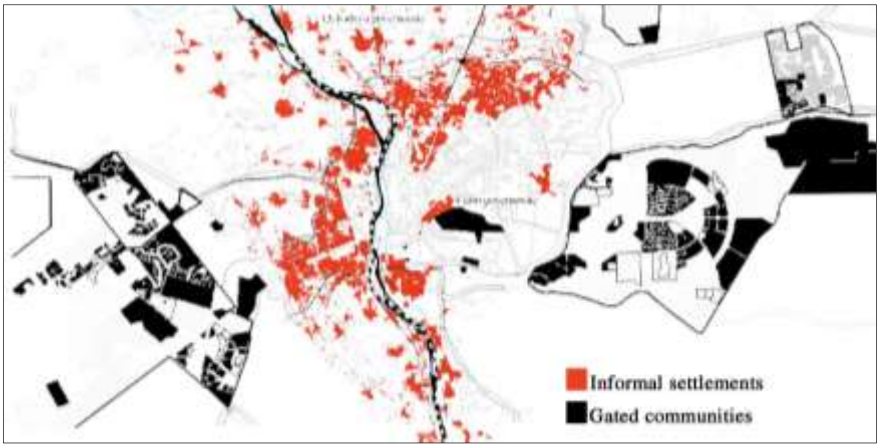
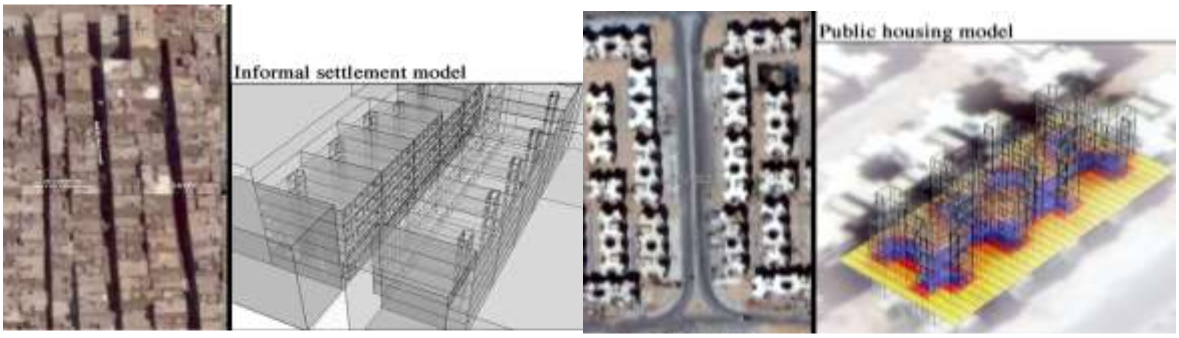


Figure 2.2: The figure demonstrates the ratio of informal settlements compared to that of gated communities, in red and black respectively. The settlement zoning vividly portrays how the vast green areas of gated communities may even double the built environment areas of informal settlements thus consuming much more amounts of water and having an effect on the global energy averages represented in table 2.1. The figure is an edited combination by the author of diagrams from Sejourne (2005, cited in USAID, 2006) and (Ghonimi et al., 2011).

3. METHODOLOGY AND ANALYSIS

Since the objective needed both quantitative and qualitative data to be fulfilled, positivist and interpretive approaches were utilized. The positivist approach presented results as fixed truths and objective facts (Crotty, 1998, cited in Gray, 2004), this data was shown in the large amounts of quantitative data that was collected from the building performance simulation analysis which allowed for a clearer understanding of the existing comfort levels. Ecotect was the environmental analysis software used to create an accurate informal settlement model and a public housing settlement model which already exist in South-West Cairo. This first methodology technique was used to accurately understand the comfort levels that exist within the 2 types of settlements and the differences between them.

The simulation data was coupled with qualitative data which is where the interpretive approach was used to study the informal settlement residents and professionals by means of interviews. Both sample groups have had experience with informal settlements and also public housing settlements. They were interviewed using semi-structured interviews. This allowed for new dimensions and explanations for both the literature and models results. Since random sampling, the most common, determines the nature of the population to be defined and provides an equal chance of selection for all members (Marshall, 1996), it was used to determine the resident sample range which did not focus on the significance of the number selected but rather on the variety of respondent backgrounds within the cluster selected. The qualitative data that was collected was from two respondent groups, all of which responded. The first group that was interviewed had ten respondents which were residents of informal settlements. They all had experience with public housing schemes by having relatives and friends living there which they visit regularly. The respondents were of different social and educational backgrounds, age groups, professions, income levels and genders. Semi-structured interviews were preferred since they provide a clear set of instructions for interviewers allowing for reliable, comparable qualitative data through a mixed method of closed and mostly open-ended questions. Attitudes and subjective norms regarding comfort levels were measured by providing normative statements, requiring the residents to respond on a five point Likert-type scale ranging from “very good” to “very poor” and “very satisfactory” to “very unsatisfactory”. The second group of respondents were six professionals from different professional backgrounds which have worked on projects involving informal settlements and have been involved in developing and monitoring their progress. This provided significant explanations for many topics that could not have been entirely explicated solely using the qualitative data from resident responses and the quantitative data from the simulation models



(b)) (d)

Figure 3.1: (a) The first image in the figure represents the satellite image of the selected informal settlement in South-West Cairo (Google Earth, 2015). **(b)** The second image represents the informal settlement Ecotect model (Author , 2015).**(c)** The third image in the figure represents the satellite image of the selected public housing settlement in South-West Cairo (Google Earth, 2015). **(d)** The fourth image represents the public housing Ecotect model (Author , 2015).

Both of the samples selected had the main street between the buildings directed towards the North orientation. The length of the street sampled was 50 meters in both models. The informal settlement model had blocks adhering to the simulated buildings, these blocks where not rendered but only acted as solid blocks adhering to the targeted informal building structures so as to provide accurate data on the comfort levels they provide since these blocks have an effect on all of the outcomes but cannot be added to the total values obtained. The openings were designed based on an on-site visit of the sample areas. After the completion of the models, the software analysis provided data with the existing fabric gains, solar gains, ventilation parameters and discomfort hours. The mentioned results were analyzed and dissected showing clearer figures of the obtained data results.

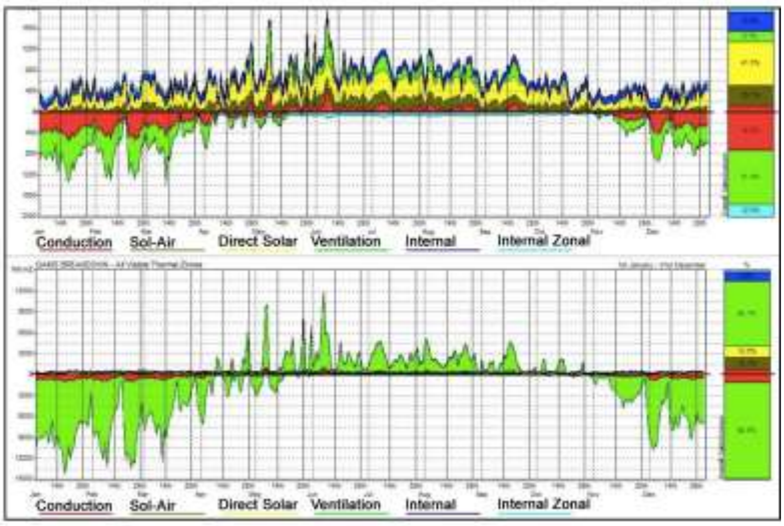


Figure 3.2: Shows the outcome of all comfort level data in one graph as rendered by Ecotect for both models (Informal settlement model at the top, public housing model at the bottom).

3.1. Fabric gains and Sol-Air gains

The Fabric gains shown in Figure 3.3 (a) portray the heat transfer through the building fabric. This helps determine the heating/cooling loads and internal temperature variations of a building (Barry, 2010). The informal settlement Fabric gains, which were 5.60%, were almost at odds with the public housing's fabric gains of 4.80%. Unsurprisingly though, the losses in the informal model were of a much higher percentage, 36.5% compared to 7.20% in the public housing model. This brings the total losses of the building fabric to 30.90% and 2.40% respectively.
Sol-Air figures shown in Figure 3.3 (b) are temperature gains produced by indirect solar exposure of the building’s exterior surfaces when exposed to solar radiation (Lin, 2007). The gains found were almost the double in informal settlements than those in public housing with percentages of 20.10% and 12.10% respectively.

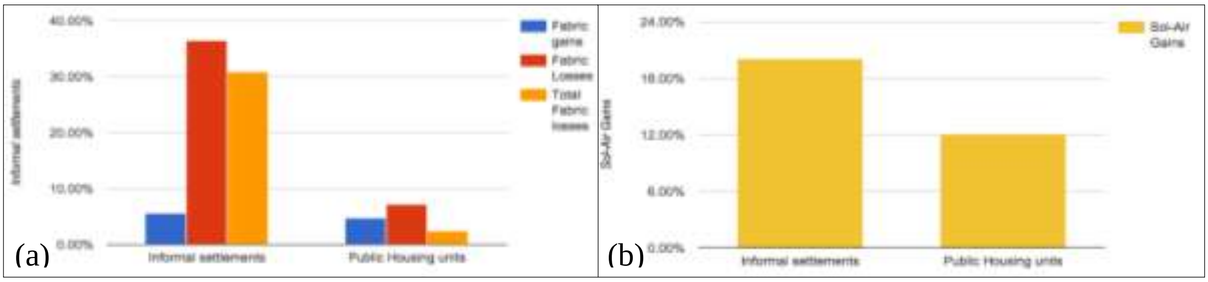


Figure 3.3: The figure describes the Fabric gains and Sol-Air gains results obtained from the ecotect simulation for both the informal settlement and public housing models.

The literature did not mention the level of comfort within informal settlements in terms of the fabric gains which take place, however the low fabric gain values retrieved maybe due to the close proximity of buildings and narrow corridors in between them (Shehayeb, 2009). The residents that were interviewed on the other hand did not complain of the temperature of informal settlements and explained that their areas of residence had shops using water constantly bring sprinkled in the streets in front of stores and building entrances thrice on a daily basis to cool the air temperature. Also, the constant shading effect due to the narrow street widths causes the air to be very cool and humid in informal settlements. This was confirmed by both the residents and professionals. Moreover , the heat losses in the informal settlement model were much higher than the public housing model, this could be due to the mentioned high temperature difference between the alleyway and the buildings themselves as a result of the high humidity levels and shading degrees but also due to the adhering structures next to the street sample buildings which absorb heat through conduction. Furthermore, public housing projects are characterized as areas of high temperatures, wide streets and large spaces between buildings which would make the trends used in informal settlements unproductive methods for heat loss and cooling effects such as street water sprinkling and shading devices (Sham, Lo and Memon, 2012).
The results showing lower sol-air gains in public housing denies the fact stated by Sayed H. et al.(2012) that these prototypes are designed without any regard to the comfort needs of their residents from the selected design form perspective. It also challenges the statement made that public housing structures provide feeble thermal comfort levels (Khalil, Hassan and Saleh, 2014). The respondents’ answers reaffirmed the simulation’s data outcome stating that they face extreme heat in informal settlements especially during the day in the summer. However, they did not mention heat as a drawback of the apartments in public housing. These results suggest that the single flat elevation of buildings in informal settlements may be the cause of more heat induction despite less exposure to the sun which are in contrast to the design of multiple elevations and outer wall protrusions being exposed

to the sun in public housing prototypes making them the main reason for the prevention of much direct sun radiation incidence despite their multiple surface exposure.

3.2. Ventilation Heat Gains / Losses and Monthly discomfort loads:

Ventilation heat gains are the ventilation gains and losses which take place through windows, doors as well as cracks and vents in the building structure (Taylor, 2002). The total ventilation heat losses were higher in the informal settlement model compared to the public housing model with values of 41.70% and 29.90% respectively (Figure 3.4)(a). The following figure demonstrates the total over heating and cooling for each zone in the form of Kdeg per hour within the building throughout the year which would in turn has an effect on the cooling and heating loads (Young, 2015). The highest heat discomfort hours values in the informal settlement and public housing model were almost equal at a value of 0.9 kDeg/Hr and 1.0 kDeg/Hr in June respectively. The highest cooling discomfort hours were 2.1 k Deg/Hr and 3.0 kDeg/Hr in January respectively. The monthly heat discomfort hours were almost the same in both models throughout the year yet slightly higher in the informal settlement model with a slight monthly difference ranging between 0.05 to 0.1 kDeg/Hr (Figure 3.4)(b).

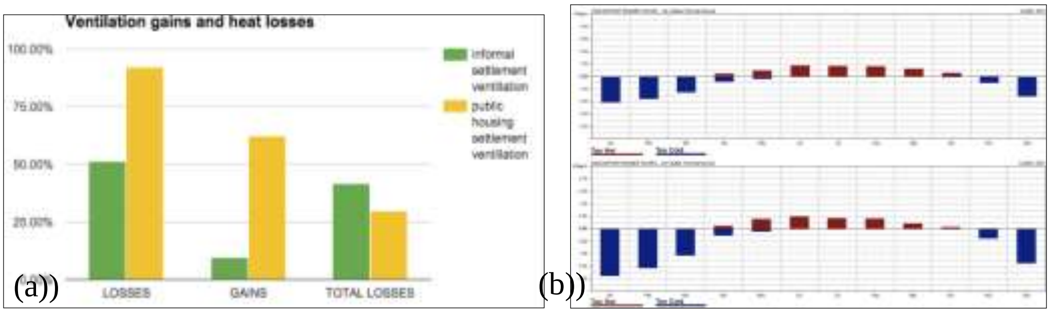


Figure 3.4: (a) The figure represents the ventilation heat gains and losses in both of the models. **(b)** The Monthly heating and cooling discomfort hours of both models, informal settlemtent model at the top and the public housing model on the bottom (Note: the Ecotect software rendered the 2 graphs with different values on the y-axis, this was taken into consideration during the analysis by using the accurate values presented on the spreadsheet file exported from Ecotect)

These observed values justify the literature where Rehan (2014) suggests that Cairo's new building prototypes need building design development strategies to enhance the applications of passive design functions such as ventilation to reduce the dependence on air conditioning amongst the many other design guidelines she proposed. The respondents authenticated that the level of ventilation in informal settlements as either good or neutral in the past, although they rated it as poor for the current situation especially after the increase of average building heights which took place after the revolution of January 2015 in the absence of Governmental surveillance. The respondents also claimed abundant ventilation in public housing blocks open areas due to the large spaces in front of the buildings, however no claims of cooler temperatures in public housing were made. A possible explanation for these results may be the lack of service courts in public housing settlements which act as a main reason for adequate total heat loss through cross ventilation in informal settlements. The absence of courts coupled with the single sided orientation of flats in public housing blocks further prevents adequate ventilation for heat loss to occur.
The similarity between the heat degree hours in the informal settlement model and the public housing model fortifies the research by Sayed H. et al.(2012) that heat gain and thermal discomfort in public housing is a result of the Government's lack of adequate design tools in the construction of new communities as was reaffirmed by the Phd candidate specializing in historic slum areas sustainable development whom stated that, “Public housing projects are fixed prototype housing projects that are built all repetitively regardless of the climatic conditions specific to each site”. Four of the interviewed residents mentioned that their apartments were extremely hot and that numerous fans were needed to cool the

temperature. On the other hand, nothing was mentioned concerning public housing settlement flats other than respondent 8 stating from a health well being perspective that, “The strong airflow and heat of the sites where public housing projects are located are beneficial as they purify the air and any contaminations that may take place in streets and apartments”. The Public housing researcher however made clear that the overheating-and in some cases-over cooling of apartments is a result of the inadequacy of the building orientation in public housing blocks. Her research findings portray many housing projects as cookie-cut urban plans which are repeated constantly without consideration to the site’s orientation or location. These results from residents comparisons of public housing and informal settlement temperature difference descriptions added a new dimension to the results , which is that just as public housing blocks may simply be cookie cut projects therefore causing all of these solar gains, informal settlements were once land plots and then transformed in to building plots for construction regardless of the adequacy or inadequacy of the orientation at hand.

These results of slightly higher heat discomfort hours in informal settlements and higher cooling discomfort hours in public housing blocks during the winter might partly be explained by the previous findings that the overshadowing elevations of the public housing units allow for less direct heat gain resulting in less overall heat discomfort hours. However, them being in the desert regions of Cairo where the temperature is relatively lower than in the city of Cairo itself or its fringes, causes much higher levels of radiant heat loss and in turn more cooling discomfort hours (Mohamed, 2010). Moreover, the public housing units being exposed to the outdoors from all 4 sides causes much more heat loss through convection, this could explain the much higher overall cooling discomfort hours in the public housing model (Ministry of New and Renewable Energy, 2015).

4. CONCLUSIONS

This paper focused on the level of sustainability of informal settlements through studying the comfort levels of informal settlements with mention of their counter product public housing blocks. The Ecotect environmental analysis software has proved informal settlements to be almost evenly balanced with public housing units in the level of thermal gains and losses. It's characterized with much higher direct and indirect solar thermal gains and better overall ventilation and fabric losses than public housing projects. The direct and indirect solar gains were extremely high in informal settlements almost doubling the public housing solar gains values. The final ventilation and fabric losses after deducting the initial gains were higher in informal settlements despite the higher initial ventilation losses in public housing due to heat loss through convection as mentioned earlier. This provides the informal settlement housing units with a certain degree of sustainable efficiency through comfort levels despite the absence of professionals to design and construct these settlements. They have proven to be successful in terms of heat losses due to their intertwined clustering and narrow streets, although this does not exclude them of having strong heat gains due to their construction method which is oblivious to the effects of sun rays on the elevations and also disregards the use and design of appropriate solar exposure reduction techniques such as louvers and accurate protrusions.

The results also raise the question of why aren't public housing units much more efficient in terms of comfort levels despite their surveillance by the Government? Although informal settlements may be at a disadvantage of its residents not being able to specify the needed orientation for buildings (as they were predefined agricultural land plots), or afford the needed materials for less fabric gains, or collaborate with professional engineers for effective architectural designs does not deny the fact that they are at heads with the governmental public housing which had the advantage of conducting proper urban and architectural design prior to construction and the means for proper material use. What makes them even more efficient than public housing blocks, aside of the comfort levels, are the social and economic lifestyle benefits they provide which are absent in government housing blocks. The

interviews results state that the Government's public housing schemes are much dreaded mainly for their outdoor spaces, clean environments, quality elevations and well prepared services as they do not offer the targeted informal residents the desired economic or social lifestyles they need and are accustomed to. Many professionals and residents realize potential in informal settlements, although still view the relocation of informal settlement residents to public housing projects as the ideal solution, for those who can afford it, only for better environmental conditions. The only comfort level advantages in public housing blocks over informal settlements is them being clear of over humid, damp and shaded streets and instead are characterized with sufficient direct sun exposure through the wide spaces between the buildings preventing the strong probability of disease and providing for sufficient heat loss in the summer nights through the many exposed elevations.
Additional research with more cross locational studies with various street orientations and similar building samples would provide greater details in the quantitative values obtained through the software rendering. Also determining the average typical plan of the apartments in both settlement types would enable the rendering outputs to be more accurate once the inner zone partitions are modelled.

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Developing a Methodology to Cluster Commercial Transport Services in Urban Areas

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Abstract *Vehicles performing commercial services in urban areas have been largely neglected by transport researchers and policy makers. The main focus has been on long distance freight transport rather than transport of light goods and services in urban areas. Commercial service vehicle trips contribute significantly to urban traffic. Consequently, they are held responsible for many of the problems that urban areas encounter nowadays such as: congestion and pollution. Therefore, analysing travel patterns and behaviour of services in the city is an essential task that should be given more attention in terms of research and investigation. This paper addresses the problem, as an attempt to fill the gap of understanding the different tour patterns that companies in urban areas perform. A fuzzy clustering technique is applied on tours of four health nursing companies in Germany. The work presented in this paper was part of a project proposed by these companies, to explore whether electric vehicles can be part of urban commercial transport patterns. Company fleet was tracked using GPS (Global Positioning System) trackers for a period of approximately 3 weeks. Fuzzy clustering results showed three main tour types (clusters) for the four companies. Clusters indicate the most common tour patterns performed by this service. The output of the cluster analysis is then used to examine the applicability of electric cars to the tours performed. The use of electric cars as a substitute to conventional cars decreases the negative impacts of this service on the environment, and its dependency on fuel consumption. Tour types also provide indicators that assist companies in decision making and updating policies. Transport modellers also can also benefit from such studies by incorporating their results to larger tour-based models that represent the real world.*

Keywords: Commercial vehicle tours, electro-mobility, Fuzzy clustering, Travel patterns of commercial vehicles.

1. Introduction

Commercial vehicles responsible for transport of services or light goods contribute significantly to the percentage of vehicles kilometres travelled (VKT) in urban areas, due to the variety of activities they perform (Allen & Browne, 2008). Methods to collect Real-world traffic flow information have recently developed and become very important to researchers in many fields, since they have a great influence in the analysis of traffic systems. Accordingly, several studies have been conducted to examine mobility patterns, using new technologies such as: GPS (Global Positioning System) tracking devices (Liu & Ban, 2013). Analysing commercial vehicle travel patterns in urban areas using new advanced techniques is very important to provide insight into the tour patterns these vehicles perform. Transportation research is in need for innovative models that utilize modern technologies, to face the challenges of urban transport such as congestion and pollution; providing safe, reliable and efficient systems (Hensher & Figliozzi, 2007). By identifying travel patterns and behaviour, it is possible to model and predict future travel demands. This can influence key factors related to the environment, policy making, economy and quality of life. Research focusing on travel behaviour can also significantly affect sustainability and efficiency of transport systems. Moreover, the study of service activities provides in depth knowledge of how different business sectors function in urban areas (Ambrosini, et al., 2010) and how they affect the transport system. Despite the impact of commercial services on the network, yet very little attention is given to model such services. Even though attempts have been made to cover as many aspects as possible in the transport of freight in urban areas, however, more research is a necessity (Hensher & Figliozzi, 2007). Especially that the characteristics associated with urban freight transport validate considering it a separate field of research.

In response to filling the gap of understanding the behaviour of commercial transport services in urban areas, this paper uses a fuzzy clustering technique. This is to provide more insight on how the tours performed by commercial services in urban areas can be characterized. The companies in this paper offer health nursing services for seniors in Germany. Suitable electro-mobility for commercial transport (SELECT) is a project supported by the European Union as well as national funding authorities in Austria, Denmark and Germany and brings together partners from business and science (DLRBerlinportal, 2012). The aim of the project is to explore how electric vehicles can be part of urban commercial transport patterns, in order to reduce noise and negative effects of conventional cars used in commercial trips on the environment. By developing an understanding of the types of tours performed by these companies, it is possible to apply fuzzy clustering technique to the datasets of other companies offering services with similar tour characteristics.

The objective of this paper is to investigate travel patterns made by commercial service vehicles that deliver the service directly to households. By conducting a tour-based analysis on the GPS dataset at hand, it is possible to identify the patterns of commercial services movement in urban areas. By doing so, transport planners and modellers can extract information from such studies for further utilization. Also, companies that offer similar services can use this as a tool to improve and benchmark operations. In addition, the paper aims to estimate the percentage of tours that could be performed using electric cars instead of conventional cars. This is to minimize the negative impacts of commercial services on the environment, and create indicators for the companies in this study. This way it is possible to decide whether or not substitution is applicable based on the technical and economic constraints of electrifying a company fleet, which can be carried out in future research.

2. Literature review

Efforts have been made by researchers and transport planners, to produce models that help in understanding commercial services and goods movement in urban areas. In this context, Figliozzi (2007) studied the productivity of commercial vehicle tours and the impact of stop frequency, total duration of tour and time constraints on vehicle- kilometres travelled (VKT). Allen & Browne (2008) have also made progress in reviewing light goods vehicles and services operating in urban areas which can be considered as a firm platform to propose a typology for tours and a new model describing services in areas with higher traffic density.

Distinguishing tour types based on a certain criteria proved to be very helpful when attempting to analyse travel data. Several typologies were proposed in the literature with the aim of understanding the mobility patterns of commercial trucks and vehicles in urban areas. Figliozzi, et al., (2007) classified truck tours in urban areas into four classes according to distance travelled, number of stops, speed, tour duration, distance per stop and percentage of time driving. Another typology was proposed by Krizek (2003) based on travel purposes such as: work, recreation, shopping health.

Proposing new typologies facilitates handling of large travel data such as travel logs, surveys and GPS raw data. The pros and cons of using GPS tracking techniques are further explained in Greaves & Figliozzi (2008), in a study carried out in the metropolitan area of Melbourne, Australia, using GPS survey of commercial vehicles. Another study by Pluvinet, Gonzalez-Feliu, & Ambrosini (2012) discusses the potential of GPS technique in collecting commercial vehicle travel data in urban areas. With larger datasets, the need for new algorithms to analyse this data increases. Fuzzy algorithms were found to be one of the most convenient techniques in transportation research. An interesting study by Cirovic et al. (2014) presents a model for the routing of light delivery vehicles by logistics operators using a neuro-fuzzy approach. Hence the applications of fuzzy clustering vary in the field of transportation, and can solve several problems. According to the author’s knowledge no research has combined all the aspects in this paper, moreover fuzzy clustering has not yet been applied on GPS data of commercial services tours in urban areas taking into consideration the parameters of each tour performed by the service.

3. Methodology

3.1. Data collection

The sample in this study consists of four companies located in the south of Germany that were tracked using Global Positioning Systems (GPS) for approximately 3 weeks. The four companies resulted from a survey which was conducted during the SELECT project. The companies were contacted by phone after the survey and they agreed on participating the GPS logging. Company (01) is located in a dense urban area while the other three companies are located in less dense areas. Each company operated in a different sized area. Table (1) represents a summary of the data collected.

Table 1: Summary of the data collected

Company	(01)	(02)	(03)	(04)
Vehicles	15	8	8	22
Collection period (Days)	22	24	23	18
Total number of trips	1612	2230	1626	3190
Total number of tours	190	159	150	245

3.2. Data preparation

Preparing the data for analysis is a very important phase in the research. In this step logic errors were omitted to ensure that clusters fairly represent the dataset. Therefore, any tracked day or tour in this dataset where no number of stops was observed (stop count = zero) is neglected in this analysis. In addition, data was normalized on a scale from 0 to 1. This is to guarantee that all attributes have the same weight, since each attribute has a different unit of measurement (distance in km, average stop duration in minutes and stop counts). By normalizing the data large numerical sets are reduced to smaller scales, to provide better understanding and a logic comparison.

3.3. Choice of attributes

The choice of attributes affects the cluster output greatly therefore it is essential to highlight the motive behind choosing the attributes which this study is based on. Distance is an important factor in the analysis of commercial tours, since it influences a number of key factors such as: fuel consumption and maximum number of customers served per day. The number of stops per tour is also one of the key attributes; as it gives an estimation of how many (delivery or collection) trips are made in each tour. Average stop duration was also chosen since it indicates the average amount of time spent in serving a customer per tour.

3.4. Fuzzy clustering procedure

The dataset in this cluster analysis consists of the tours performed by the four companies; these tours are clustered according to the attributes previously mentioned. First, fuzzy c-means algorithm was implemented in R on the data collected from all the companies together. Based on the predetermined number of clusters which according to the majority rule was 3 clusters, fuzzy c-means algorithm was carried out on 709 tours a number of times ensuring that the algorithm yields the same results every time, with the maximum number of iterations set to 100. In this paper fuzzy c-means (FCM) was chosen, due to the simplicity and applicability of this specific technique (Klawonn & Hoppner, 2003). In fuzzy clustering the main goal is to minimize the following objective function (1) ((Bedzek, Dave, & Cannon, 1986):

$$\sum_{k=1}^{n} \sum_{i=1}^{c} (u_{ik})^m \ (d_{ik})^2 \tag{1}$$

In equation (1) n is the number of data points in the data set and c is the number of clusters. U_{ik} is the membership degree of object i to cluster k, and m is a fuzzifier. The parameter m is describes as a real number in the interval $[1, \infty]$ introduced to the equation to indicate the extent of fuzziness in the clusters formed, to be able to control the level of overlapping (Klawonn & Hoppner, 2003). The d in the formula indicated the proximity (similarity) measure which is normally the squared Euclidean distance measure between any element n_k in the dataset and any cluster c_i.

The 709 tours were divided among 3 clusters, after 23 iterations, according to the Euclidean distance from each point to the cluster centre, assuming the fuzzifier m = 2, since the precise value of m is very hard to determine. This was chosen based on general empirical guidelines similar to previous studies using fuzzy clustering techniques. To visualize the results, R was also used to draw a 3D scatterplot of the output clusters. After the fuzzy c-means was applied on the total number of tours tracked, the membership function for each variable was extracted and analysed. By analysing the membership function of each variable it is possible to determine its limits and characterize the tours accordingly. The optimum number of clusters according to the majority rule was applied to each company separately and indices resulted in 3 clusters for two of the companies while the other two companies were divided among 4 and 2 clusters. The minimum and maximum numbers of iterations were 100 and 18 respectively.

4. Applicability of electric vehicles

A separate analysis was made for evaluation of the percentage of tours that have the potential of being performed by electric cars as a substitute for conventional cars, to decrease exhaust emissions and create indicators for company managers to determine whether or not fleet electrification would be the best choice from an economical and technical point of view.

Two major concerns were found when examining the applicability of electric cars for a company. The first concern is “the maximum range per charge” and the second is “the charging time”. The maximum range an electric car can travel is influenced by the actual distance travelled by the car and the driving style. The issue of charging time taken for an electric vehicle to reach full charge depends on the average stop duration of the vehicle.

However, for companies that offer services that only operate by daytime, charging time is not a major concern. In this case, the main factors affecting the applicability are the maximum car range (distance travelled per charge), the number of stops and the overall cost of operating an electric car. Accordingly, the attributes chosen to carry out this analysis are total tour distance and number of stops per tour.

Since most electric cars in the market are distinct by the range per charge. Therefore, it is critical to put the total tour distance into consideration when evaluating the potential of electrification. In this case the economic part of the decision is partially made. According to Hacker et al. (2015) the average daily mileage must exceed 60km to be able to redeem the extra costs of purchasing an electric car. This calculation is based on the current market prices and rates of conventional and electric cars, in addition to current Diesel/Petrol (at gas stations) prices and the current prices for electricity (charging). The “60 km” per day benchmark is obtained from an estimated annual mileage of 22,500 km/year. Another criterion that can be considered rather a technological one, also based on Hacker et al. (2015) is that the average daily mileage mustn’t exceed 140 km/day. Even though there electric cars have the ability to drive this range per charge and even longer ranges, however, their purchasing cost is relatively high, which would not be recommended for small services such as health nursing services. However, it must be noted that the analysis is strictly tour-based and only considers tour characteristics when clustering tours among categories which indicate whether or not the type they belong to should be electrified or not.

5. Discussion of Results

Fuzzy clustering results show that data points were scattered mainly around three types of tours (clusters). Therefore it is possible to say that the tour characteristics of these four nursery services are divided between tour type (1), (2) and (3), as they represent the most common travel patterns performed by this service. The percentages of three tour types show that there is no significantly dominant pattern. 40% of the tours belong to tour type (1), making it the most occurring tour pattern. Tour type(1) is characterized by a relatively short distance travelled, and based on the medium number of stops in this type of tour it is possible that customers served in this tour are closer to the company depot. However, the duration of service of each customer is approximately 30 minutes. While 21% were tour type(2), which is the least detected tour type, characterized by long distance travelled many stops, therefore a large number of customers are served in this tour and also the duration of service was found to be approximately 30 minutes per customer. And 39% of the tracked data belonged to tour type(3), which occurs nearly as much as tour type(1), having short distance and very low stop count, therefore not many customers are served and longer time is spent serving each customer exceeding one hour. However, the second and third tour type, indicate that when there is increase in the total tour distance, the number of stops also increases, consequently, decreasing the average stop duration and vice versa. Thus, it is deduced that in tours where many customers are served (many stops), the time of the service performed does not exceed 30 minutes. However, the purpose of the stops were not taken into account in this study therefore, it is assumed that all stops are for services. The types of tours found in this cluster analysis are shown in table (2). It is important to point out that the values in table (2) correspond to the real values; however, the values used in the cluster analysis were normalized as well as the values used in the scatterplot to better represent the cluster space.

Table 2: summary of fuzzy clustering results for all companies

All Companies	Distance	stop count	average stop duration	cluster Size	Percentage
Tour Type (1)	50	12	30	281	40
Tour Type (2)	104	22	30	153	21
Tour Type (3)	23	4	75	275	39
				709	100

To visualize the results, figure (1) also shows the distribution of data points in a 3D space around their clusters based on the three attributes chosen for the selection criteria.

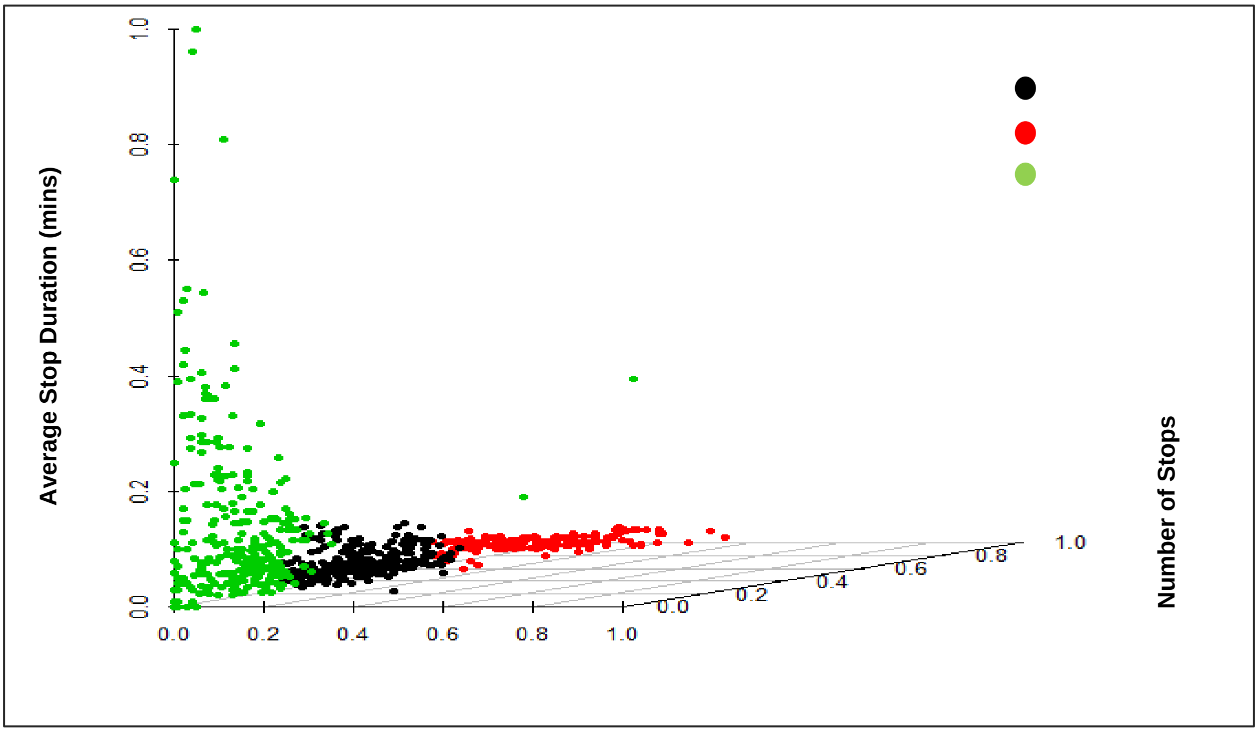

Figure 1: 3D scatterplot of clustered tours

As for the possibility of replacing the company fleet with electric cars findings indicated that out of the 709 tracked tours only 194 had a total distance within the required range. Since all the tours included in this analysis fit the basic criteria of being performed by electric vehicles, another attribute is put into consideration in addition to total distance of each tour. This attribute is the number of stops, since the increase in the number of stops, increases the amount of emissions, due to increase in the amount of fuel burnt to start the car each time. Therefore, putting the number of stops into consideration allows a better estimation of the tours that are perfect candidates for being carried out by electric vehicles, optimizing the selection process. Based on the mentioned attributes tours were divided into three categories according to tour potential to be performed by electric car and the extent to which each tour matches the criteria. The three categories distinguish tours with high potential of being performed by electric cars from tours with good and satisfactory potential. The findings shown in table (8) indicate that out of the 196 tours chosen for this analysis 27.31% have high potential, and are regarded as the best candidates for vehicle electrification with a total number of stops exceeding 22. Tours considered with good potential to be carried out by electric cars form 58.24% of the tracked tours having a total number of stops between 12 and 22, while only 14.45% are considered satisfactory candidates with the least potential having a total number of stops of 12 or less. The potential for electrification was colour coded in orange, blue and green points in the plot to represent tours with high, good and satisfactory potential respectively. This is shown in figure (2).

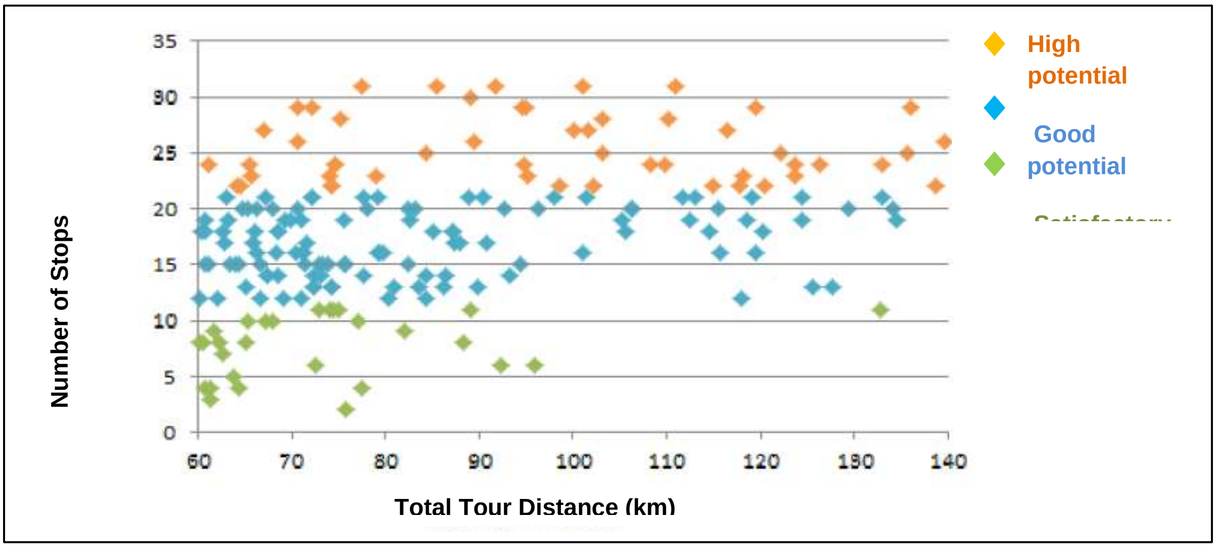

Figure 2: Potential tours to be performed by electric cars

When analysing the applicability of electric cars in each company separately, findings indicated that the company with highest electrification potential is company (02), since 48.4% of its tours can be carried out by electric vehicles. On the other hand, in company (01) only 12.3% of tours are suitable for electrification. And company (03) and (04) had the same percentage of 26.1%.

6. Conclusion

Modelling and understanding the travel behaviour of freight transport in urban areas is a challenging task due to its complex nature and the involvement of several parties in this activity. This paper contributes to the field by analysing travel patterns of commercial services in urban areas. There are multiple techniques to detect patterns in datasets; however, in this paper a fuzzy cluster analysis approach was adopted. The aim of the paper was to describe the travel behaviour of commercial services in urban area, by using fuzzy c-means technique to analyse data collected for health nursing companies for seniors in Germany using GPS technology to get the tours performed.

By applying c-means algorithm on the data collected from all companies, it was possible to cluster the tracked tours into three types; afterwards the same algorithm was applied on each company separately to discover clusters found within each company, to get more insight on the most dominant type of tour performed in each company. This resulted in different clusters of different attribute magnitude, showing how travel patterns could differ even though companies in the study offer the same service.

The possibility of replacing company fleet with electric cars was also examined. It was possible to determine which tours best fit to be performed by electric cars as a substitute to conventional. The choice of tours was based on an economical and technical criterion that allowed the identification of the best tracked tours, thus, creating indicators for the companies, so they can determine whether or not electrification would be a wise choice according types of tours performed, and the percentage of tours that best fit the criteria.

The results of this paper could be further analysed through spatial analysis to capture the variability of tour patterns spatially. This information can be further utilized to alternate company fleet strategies, in addition to optimizing routing and scheduling strategies for companies. As for transport planners, spatial information can help in making future forecasts and predictions for developing the road network. Further analysis could also be made to study stop purposes. By analysing stop duration separately, parking studies for commercial service vehicles in urban areas can take place based on estimating the percentage of each stop class and getting more insight on how much "out of service time" is spent on the road and how commercial services can influence traffic flow and congestion. This could also be integrated to spatial analysis of the data to produce more accurate parking studies.

Companies willing to alternate their fleet and support clean energy solutions can also apply the same algorithm on the tours. According to the tour typology it is possible to decide whether or not the decision will benefit the company. Being aware of tour characteristics and patterns can have a great impact on the economy, the environment and the quality of services offered. Moreover, If a large number of companies are willing to engage in a similar study, then such information could be utilized to assist in traffic control and network optimization.

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A Traffic Datacenter Based on Available GPS Data

A Case Study for Egypt

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Abstract: *Probe data are very promising sources of traffic data especially at the absence of any other traffic surveillance equipment; as in Egypt's case. Probes use GPS equipment to continuously collect spatiotemporal data; while travel and stop. These data are required for real-time tracking by the fleet management companies or by the vehicles' owners such as: private cars, commercial vehicles, school buses, taxis, trucks … etc. Tracking data are kept for a long duration of time and can be accessed from the archives. Huge amounts of data are lost with no further processing. Simultaneously, the collection of probe data for traffic studies is very costly.*

This paper presents the architecture of a GPS based traffic datacenter. Vehicles with GPS aboard are envisioned as anonymous passive probe vehicles that well represents the traffic stream. The datacenter collects GPS data from tracking agencies anonymously to preserve the privacy of the vehicles and trips. The vehicle traces represent realistic trips undertaken in the traffic network; thus saving both efforts and budgets. Moreover, the suitability and applicability of the datacenter is tested by measuring the spatiotemporal coverage of the GPS data. Data are provided by an organization in Egypt for March 2014. The data coverage is evaluated on four roads namely: the Ring Road, EL-Suez Road, El-Shaheed Corridor and El-Mosheer Tantawy Road. The developed GIS based tool had successfully and accurately extracted the GPS traces and the data coverage was 100% except for the Ring Road which had coverage of 70.1±10.3%. Finally, the monetary value of the total daily traces of 10,028 VKT was estimated to about 4.22 M LE per year. Thus, collecting the GPS traces from the GPS agencies not only proved to have a good coverage but also saves huge amounts if the traces would be collected by dedicated probes.

Keywords: GPS, Spatiotemporal data, GIS

1. INTRODUCTION

Transportation projects should be designed and implemented to support the concepts of:1- Sustainability, 2- Safe growth, and 3- Livability. A sustainable transportation system is designed to meet both mobility and access needs in a way that doesn't affect the quality of life of future generations. Smart growth focuses on studying the growth in existing communities to expand the transportation network but also to avoid sprawl. Livability in

Transportation requires better planning and design to maximize and expand new technologies such as intelligent transportation systems (ITS) and quiet pavements, and uses travel demand management (TDM) approaches in system planning and operations to provide road safety with a sufficient capacity. The six livability principles are to: 1- Provide more transportation choices, 2- Promote equitable, affordable housing, 3- Enhance economic competitiveness, 4- Support existing communities, 5- Coordinate policies and leverage investment, and 6- Value communities and neighborhoods. Traffic Control Systems and Traffic Calming Measures are from the applications that consider livability principles. Different transportation policies are followed to consider such concepts in transportation projects design and implementation, as well. The results of the selected polices are integrated into travel demand forecasts and traffic impact studies. As such, road expansion and congestion management objectives can be prioritized (Rue, et al., 2010).

Travel demand models are used to forecast traffic patterns. Moreover, traffic calming approaches require the identification of the congested locations. Both applications require the availability of data about the current traffic conditions. One of the very promising and most recognized techniques for traffic speed data collection is probes. Probes are vehicles with GPS equipment that continuously collect spatiotemporal data of the vehicle as it travels returning the updated location (latitude ϕ & longitude λ) and timestamp in addition to other types of data. These types of data are known as Floating Car Data (FCD). Otherwise, if all types of vehicles are measured -including buses and trucks- data are known as Probe Vehicle Data (PVD) (Felici, Wilmink & Noordegraaf 2015).

Currently, Egypt has about seven GPS tracking agencies. One of the main companies serve about 20-30’000 devices with an operation rate is about 78%. GPS tracking agencies provide live tracking for operational and vehicle security purposes, online fleet management systems, and reporting to help decision makers in fleet management processes. The reporting and any further historical data is extracted from processed data. Yet, the raw GPS tracking files are deleted after about three months from the GPS tracking agency but can be kept by the customer – if requested. But in all cases, the data are not further utilized for any traffic information or analysis. Unlike other tracking agencies worldwide as TomTom, INRIX, and Here that are currently providing traffic data in the areas they cover as service.

Meanwhile in Egypt, the country has a population of over 90 M and a highly dense area of Greater Cairo Metropolitan Area (GCMA) of over 20 M capita; has no traffic information sources nor traffic surveillance systems. The road density in Egypt is very low (0.045 km/km^2) compared to the worldwide average of 0.2 km/km^2. Passenger Cars Units (PCU) of 1,210,000 travelled GCMA during peak hours in 2010 with a high dependency on private cars (only 23% of daily trips were by public transport). The annual economic congestion cost was estimated as 47 billion LE and is expected to reach 105 billion LE by 2030. The congestion cost causes a loss of 3.6% of Egypt’s total GDP and 15% of GCMA GDP per capita. The very high congestion rates were caused by: travel time delay, unreliability, recurrent and non-recurrent congestion & excess fuel cost and CO_2 emissions. The share of each congestion cause was 36%, 25%, 37% and 2% respectively. (Cairo Traffic Congestion Study 2014).

The Egyptian market is very eager to accept new sources and solutions that provide traffic information to travellers. Application based on users' feedback and evaluation has been introduced such as: "Bey2olk", "Wassalny", and "Elzahma" that started by covering Greater Cairo and Alexandria. The applications provide actual updated information received from current active users' feedback only. The feedback is based on the users' qualitative evaluation of the road condition. Elzahma application also supports tracing of GPS assisted (A-GPS) mobile phones with a map-based interface and presents aggregated travel speed distributions of roads by day and time of day. However, the applications' reliability is not guaranteed nor yet validated; but, as the only source of traffic information, they have gained an increasing credibility by the travellers in Egypt. In early 2016, Google Traffic was enabled upon Google Maps in Egypt; the data is obtained from road users with A-GPS phones.

In this paper, a procedure is developed using ArcGIS 10 ModelBuilder to extract trips from raw GPS batch files. The procedure is based on linear referencing of spatiotemporal data of vehicles using Linear Referencing tool in GIS. Possible routes of trips conducted by vehicles are predefined. Each trip is filtered out from raw GPS files by defining spatiotemporal criteria. The developed procedure is also compared to GPX importer; a new module provided by PTV Visum-15 macro-simulation software. The coverage of the GPS data is estimated and the monetary value of the GPS traces is also computed.

2. LITERATURE REVIEW

The trajectories constructed by the PVD represent the traffic conditions along the stream (Figure 11). Moreover, travellers' vehicles represent the actual travel conditions with real driving behaviour very realistically. However, if PVD are obtained from anonymous vehicles to preserve the privacy of the travellers, several pre-processing steps are necessary to identify the trips as: the trip start time and routes are not known to the data warehouse. PVD is very similar to FCD but show some slight differences and travel behaviour. Buses stop at bus stops; taxis operate differently if occupied than if not occupied due to the loading and loading operations. Heavy vehicles have slower acceleration and deceleration rates. Commercial vehicles operate between service areas and mostly along fixed routes (Pu, Lin & Long 2009).

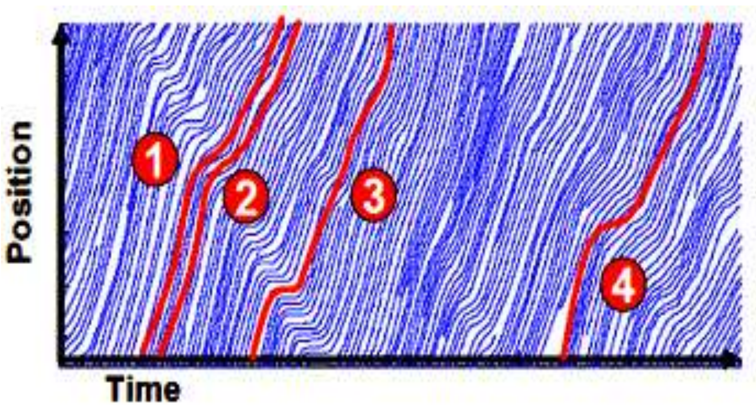

Figure 11: Vehicles' trajectories in a traffic stream. Trajectories 1-4 are measured with GPS

Speed estimates from GPS traces have very limited errors from GPS points to that from loop detectors (Patire et al. 2015). Nonetheless, the accuracy of the speed estimates is influenced by the accuracy of the GPS points that depends on the coordinate error and the communication error, which may cause missing records. The GPS coordinate error increases as the density of links in the zone increases. The GPS coordinate error is the difference between the recorded location and the map–matched location. Potential errors may be returned particularly in urban areas with high-rise buildings, where signals from the satellite can be blocked. GPS measurement errors occur due to: 1- multipath issues, (a place may receive multiple GPS positioning information), 2- few visible satellites, 3- possible missing data. Moreover, some areas cannot have any GPS measurements such as through tunnels (Zhang et al. December 2011).

At low speed (lower than 5.4 kph) positional jumps occur and appear as outliers in a trajectory (Bandyopadhyay & Singh 2014). GPS communication can be either based on analogue (coordinate error 30 m at 90% confidence) or digital Multi Channel Access (MCA) (much better than analogue GPS for data transfer). In analogue GPS data are easily lost when vehicles move into the shadows of buildings which is important in city centers. GPS based on General Packet Radio Service (GPRS) Global System for Mobile communications (GSM) networks are more accurate (coordinate error 15m at 90% confidence) (Liu, Yamamoto & Morikawa 2009).

GPS data are collected at intervals either with pre-set distance (50 m) or pre-set time (5-50 sec). Data transmitted at pre-set time is better than pre-set distance to prevent any channel congestion; data are rarely lost. Data sent at intervals of about 5 sec/50 m have no error. As the distance between two locations' updates increases, the error decreases.

However, at long distance intervals as 2 km, data cannot be used to determine real-time traffic conditions. A distance interval of 300 m or time interval of 50 sec has superior results. Nonetheless, the selection of longer road segments helps in greatly reducing traffic surveillance errors (greater than the location error so doesn't affect map-matching). No communication errors occur at interval distance/time between two adjacent records is less than 1.4 times the pre-set time interval or 1.2 times the pre-set distance interval. By complying with this rule error was decreased by more than 2-6 times (Liu, Yamamoto & Morikawa 2009).

Map matching has a common disadvantage as the determination of a point is depends on its prior point. Topological Map matching procedures are faster and are more accurate than Geometric procedures as the projection of GPS points takes into consideration the sequence or history of GPS points. In advanced approaches, points are determined by taking into consideration other factors as error or confidence regions around the GPS points or by shortest path algorithms besides the whole sequence of GPS points and the network topology (Schuessler & Axhausen 2009). Map matching can be implemented in ArcGIS through buffer & near tools in ArcGIS Proximity analysis (Bandyopadhyay & Singh 2014).

Linear referencing is a method to express the position of a point along a route or highway stretch in postmile instead of the conventional geographical representation (ϕ, λ) or (X, Y). Each point is defined by a distance along the line and the orthogonal distance to the line. The Linear Referencing technique simplifies the representation and computation of the speed (V) and acceleration (a), as well, to be in the direction of travel only. Otherwise (V & a) must be decomposed into (V_x & V_y) and (a_x & a_y), respectively. Linear referencing is performed in ArcMap by using the Linear Referencing Toolbox (Linear Referencing in ArcGIS n.d.; Tong, Merry & Coifman 2005).

World-wide GPS tracking companies started to procure traffic data from FCD such as: vehicle counts, travel times, spot speeds, origin-destination data, and incident detection. GPS pioneer companies such as TomTom, INRIX and Here covers thousands of kilometers with FCD in many countries. Moreover, in Netherlands, the National Data Warehouse (NDW) provides processed traffic data to road authorities. NDW procures traffic data from various sources that includes PVD. The NDW obtains data from 14 companies: ARS T&TT, Be-mobile, Cellint, Connection Systems, Goudappel Coffeng, HERE, HIG, Dynniq (Imetch), Swarco, Technolution, TomTom, Traffic ITS (INRIX reseller), Vialis, and VID.

The possible uses of PVD are extended to traffic management operations such as: lane closures and queue warnings on VMS, for instance. However, the suitability of the PVD at very low traffic volumes and in urban areas is also questionable (Felici, Wilmink & Noordegraaf 2015). However, the GPS data might be needed to process in-house for use in research, or for special applications, or because processed data are not so readily available in your part of the world.

3. METHODOLOGY

The datacenter was designed by the layered approach and consists of three layers: the Core Layer, the Aggregation Layer, and the Access Layer as shown in Figure 12 below. The layered approach is the basic foundation of the data center design that seeks to improve scalability, performance, flexibility, resiliency, and maintenance.

Data are compiled from different fleet companies. Each company has a different fleet size and operates to serve different categories. By collecting the raw GPS traces from the tracking company backend to preserve the travellers' identities and privacies, as well as, to preserve each company's analytics and methodologies. Nonetheless, this standardizes the methodology of the approaches adopted to extract useful travel speed and travel time data. The companies are classified into three categories based on the fleet size. Category A, category B and category C according to the operating fleet size defined as large, medium, and small sized companies respectively, as depicted in the Data Center Architecture shown in Figure 12 below. Data is obtained anonymously to preserve the privacy of the users; thus the data is from PVD. First, the suitability of using GPX importer from PTV Visum will be investigated to extract the traffic data.

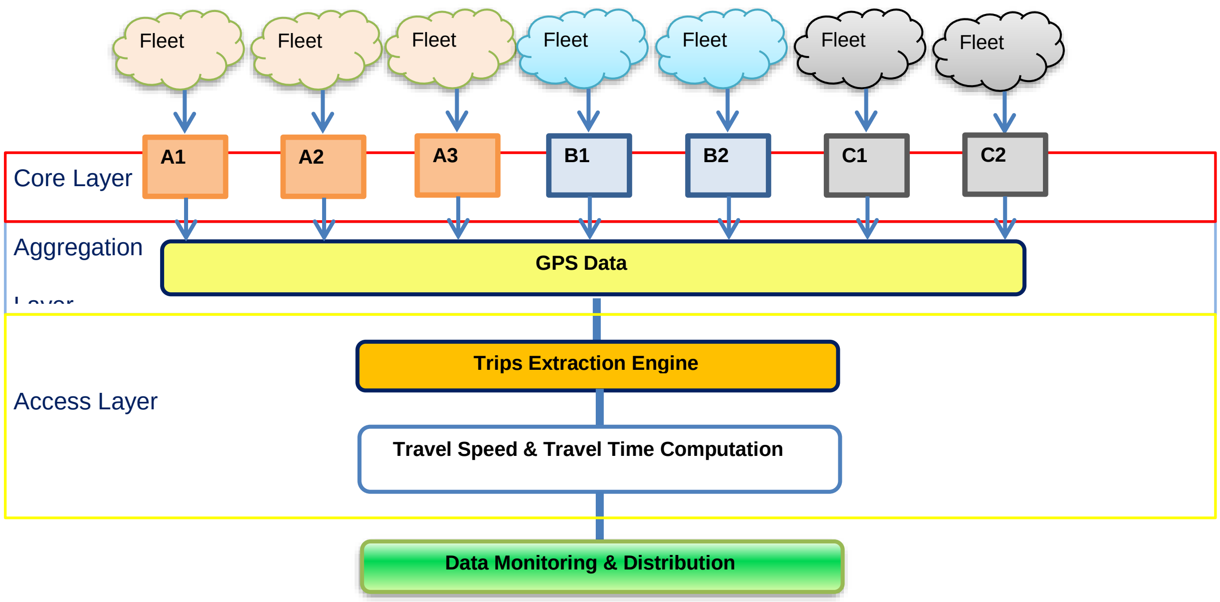

Figure 12: Architecture of the proposed Datacenter

3.1. PTV-GPX Importer

GPX Importer of PTV Visum 15 imports GPX format GPS data in WGS84 system. The imported GPS data are typically used to estimate information of the speed of travel and time losses on links. GPS data are also used to calibrate journey times in transportation models. Nonetheless, the data can be exported to an excel report for further analysis. Thus the GPX importer is a very promising method to extract speed data projected to links from GPS measurements. The data are imported either as a path or like points of interests (POI). The POI method combines all track points to a single POI. And data are imported as Tracks or Track segments with the relevant track attributes as line POIs. Time information of the point is assigned information of the nearest track point for the path. The path import depends on a shortest path search and a map matching algorithm and the time information is assigned nearest track point of the path. The search of the shortest path is based on: routing properties for links & turns, links cost attribute, turns cost attribute, condition to discard the shortest path search (based on the track length). Whereas, the map matching is based on selecting the track points within a defined snap radius considering a standard deviation, the maximum numbers of candidates for each track point, and the transport system of the links (Car, Bus, or Walk).

By examining PTV Visum GPX importer, it was found that; unless all track points have a link to be assigned to, the whole track is not imported. And for the path solution, the path will include links that have been completely traversed by the probe, only. The results of importing a GPS track by PTV Visum based on the linear Points of interests (POI) method are depicted in Figure 13 below (on the right). The resulted errors are caused by GPS points that had no tracks. Thus, to use the GPX importer the network should cover all possible links the PVD may refer to.

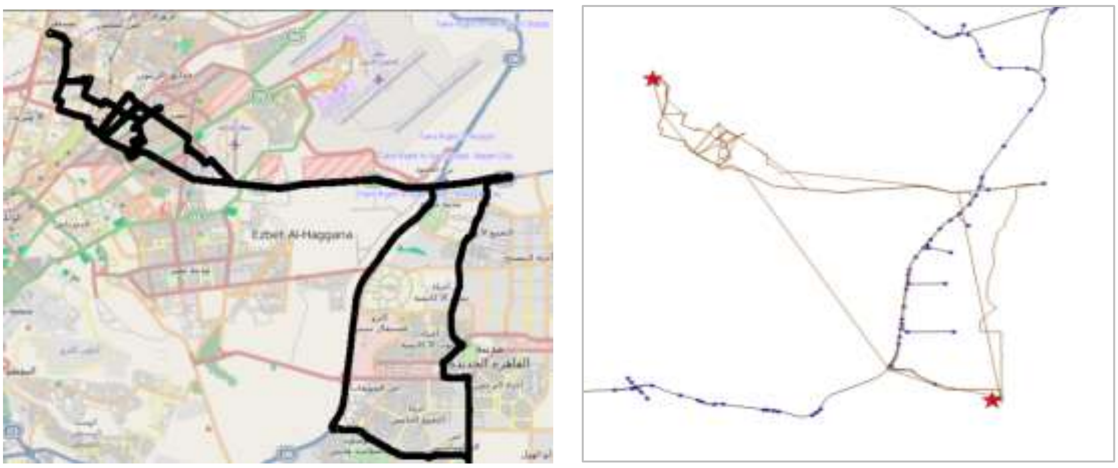

Figure 13: Projection of GPS data: on left in ArcGIS & on right in Visum 15

Two methods were feasible to import the GPS files other than PTV GPX; either by using MATLAB or ArcMap. Both programs enable the geospatial calculations. However, ArcGIS has various readily built-in powerful geospatial analysis tools that can be used on a set of data individually or in sequence. Nonetheless, the spatial representation on maps and accurate methods for geospatial data projection and analysis is very suitable for the data extraction application. Thus, our method was developed by ArcGIS that will export the GPS extracted data to ASCII files to be imported in MATLAB for further computations.

3.2. GIS Based Model Development

Given the limitations of the GPX importer, a GIS based method was developed using ArcGIS 10 ModelBuilder to extract trips from raw GPS batch files. The procedure is based on spatial referencing of the GPS points using Linear Referencing tool. The ArcGIS ModelBuilder is a visual programming language for building workflows in ArcGIS that perform a sequence of geoprocessing tools in the form of a block diagram to perform a model designed by the user. The output of one tool is the input of the following tool. The model can be saved as a new tool and can run on a number of files consecutively; which is very suitable for big data sets and minimizes the time of analysing. The ModelBuilder can be used either by a graphical interface or by scripting using Python open source dynamic programming language. The graphical based models can be also exported to Python. The scripts by Python are widely used by several transportation software packages such as; Paramics, Visum, VISSIM, Aimsun, Cube … etc.

The model developed to extract GPS data from raw data files is named the GPS Linear Referencing (GPS-LR) Tool. The required data is filtered by spatiotemporal selection criteria to define the routes of travel and the time window of the data collected. GPS-LR runs seven GIS tools in sequence on batch geo-database tables. The six tools are: 1-Make XY Event Layer, 2- Select Layer by Attribute (Time), 3- Select Layer by Location (Route), 4- Locate Features Along Routes, 5- Make Route Event Layer, and 6- Export Feature Attribute to ASCII. The developed model is presented in Figure 14 below. Further post-analysis can be performed on the extracted trajectories such as: trip identification in spatial areas, zones, or origin-destination (OD) analysis. In addition to traffic analysis for travel time, travel speed, incident detection … etc.

Figure 14: The GPS-LR tool workflow developed in ArcGIS ModelBuilder

3.3. PVD Evaluation

The PVD will be evaluated on a number of pre-defined main roads. The roads are distant and thus the map matching problems are eliminated. Moreover, the GPS errors are minimized as the main roads are not in dense urban areas. The coverage percentage on a certain link can be estimated by Equation 1. The speed on a certain link is computed as the average speed of the GPS trajectories of that link Equation 2. The speed data on a link is considered to have a good coverage if about 75% of the link length is covered (Bandyopadhyay & Singh 2014).

$$\text{Coverage Percentage}_i = \frac{1}{\text{length}_i} \left(\sum_{i=1}^{n} d\left(\text{GPS}_j, \text{GPS}_{j+1}\right) \right) \times 100$$

Equation 1

$$\text{avg Speed}_i = \frac{1}{n} \sum_{j=1}^{n} \text{GPS}_j \ \text{Speed}_i$$

Equation 2

4. Case Study

The proposed method is tested on PVD obtained from an organization located in New Cairo, Egypt. The organization has a fleet of 80 vehicles that serves commuters and operates based on a near fixed schedule. The suitability of the probes to provide traffic data continuously and with good coverage is primarily evaluated by estimating the total historic kilometrage of each probe for two years dataset obtained (March 2013–March 2015). The dataset was large and had 174,578 raw GPS TXT files (75.7 GB) for anonymous vehicles that perform several trips a day to different locations and at different start times on different routes. The GPS files only contains: latitude, longitude, time, and instantaneous speed. The GPS equipment return data every second, and each file has about 80,000 records a day.

It was found that 85% of the fleet had 40-60 thousand Vehicle Kilometres Travelled (VKT); giving an approximate of 60-100 VKT per day. About 71 vehicles operate on a daily basis producing a daily VKT of 10,028 during a total driving time of 295:06:46 hrs. The overall total average travelling speed is 33.99 kph. The preliminary tests of the quality of data showed that the speed is much smoothed -with an unknown smoothing technique- and the data had great spikes as depicted in Figure 15 below. Thus, the speed will be computed from the raw data (location & time) based on the Space Mean Speed (SMS).

On the other hand, Figure 16 depicts the space-time diagram of a vehicle travelling throughout using the data imported from a TXT file of one day. From the constructed trajectory, it is quite obvious that the vehicle performed two trips only. On the other hand, the GPS data showed a very good coverage throughout the main roads of GCMA as depicted in Figure 17 below.

The coverage of the PVD was visually tested on the Ring Road per hour from hour 6:00 to 8:00 and from hour 14:00 to 19:00 as shown in Figure 8. Hours 16:00, 17:00, and 18:00 are very similar. The test hour was selected to be 16:00.

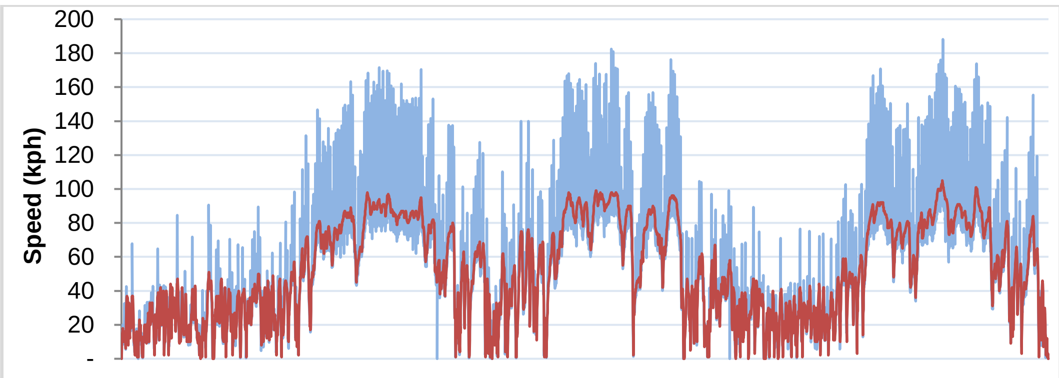

Figure 15: Speed trace for a vehicle throughout a day – raw speed vs. smooth estimated speed

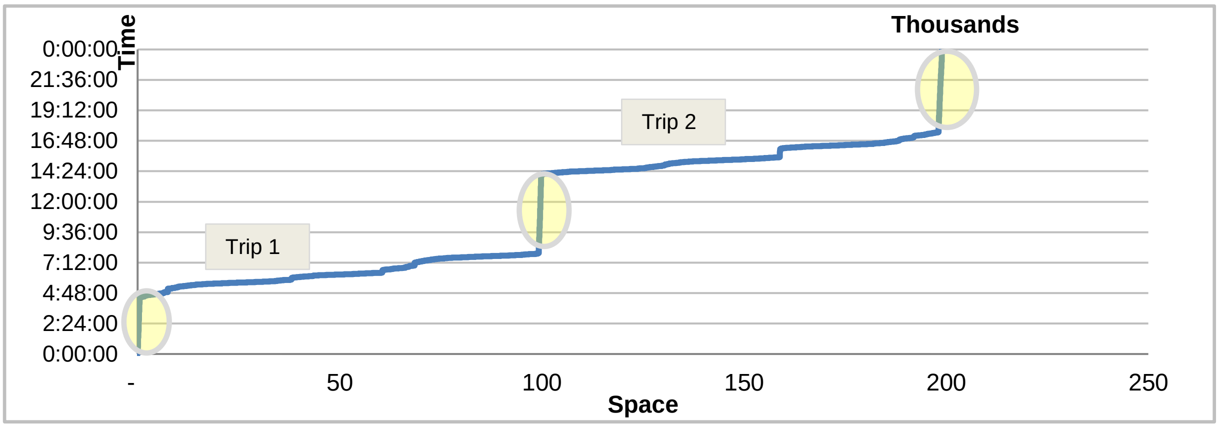

Figure 16: Space-Time diagram for a complete day

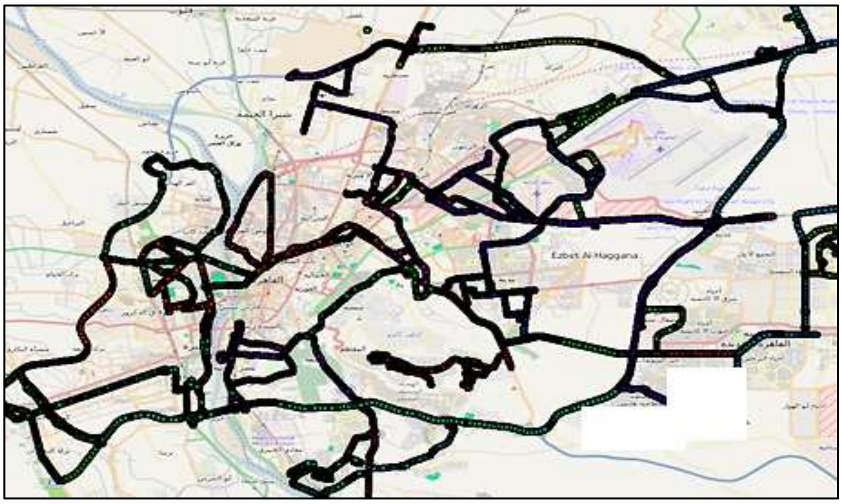

Figure 17: Traces of Vehicles on 1-9-2013 as returned by the GPS files projected on top of OpenStreetMap in ArcMap

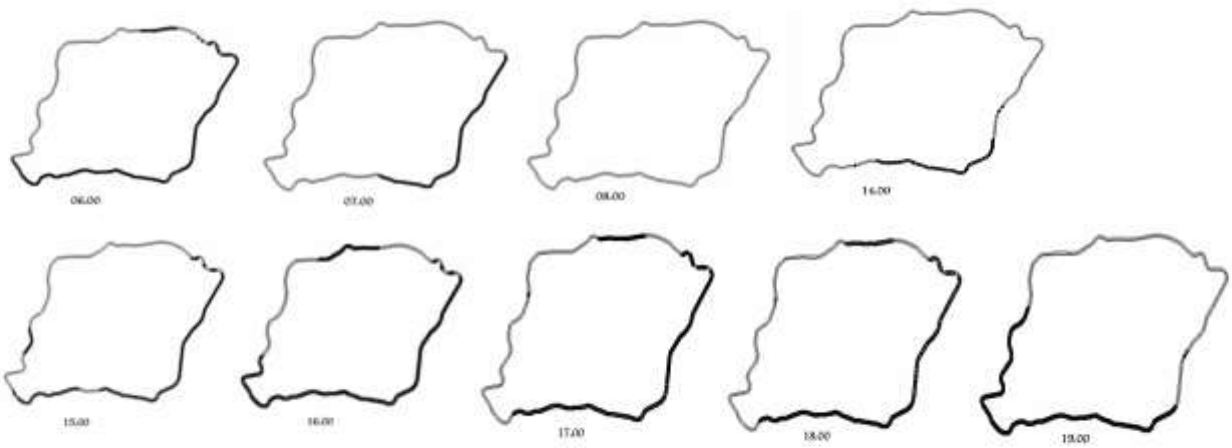

Figure 18: Hourly traffic data available along Ring Road

5. Discussion and Results1

The final test was implemented on the Ring Road during March 2014 for hour 16:00. The dataset is of 3.85 GB and consists of 2,442 TXT files. The files were first parsed by using an XML applet before running the developed GPS-LR tool. The tested roads were the Ring Road, EL-Suez Road, El-Shaheed Corridor and El-Mosheer Tantawy Road. The Ring Road tested section is from Waraq Al-Arab Interchange to Saad El-Din El-Shazely Interchange and is 70.18 km length. The Suez Road tested link is that from the Ring Road till El-Thawra Road and is 8.237 km length. El-Shaheed Corridor is 10.2 km length. EL-Mosheer Tantawy Road is 6.2 km length. The GPS data was extracted by using GPS-LR tool for each day on the designated roads above excluding Fridays that almost have no operation. The GPS coverage was computed per day using Equation 1. The average GPS daily coverage for the Ring Road was 70.1±10.3%. El-Suez Road, El-Shaheed Corridor and El-Mosheer Tantawy Road had 100% coverage. The daily coverage for the Ring Road and El-Suez Road is shown in Figure 19 and Figure 20, respectively.

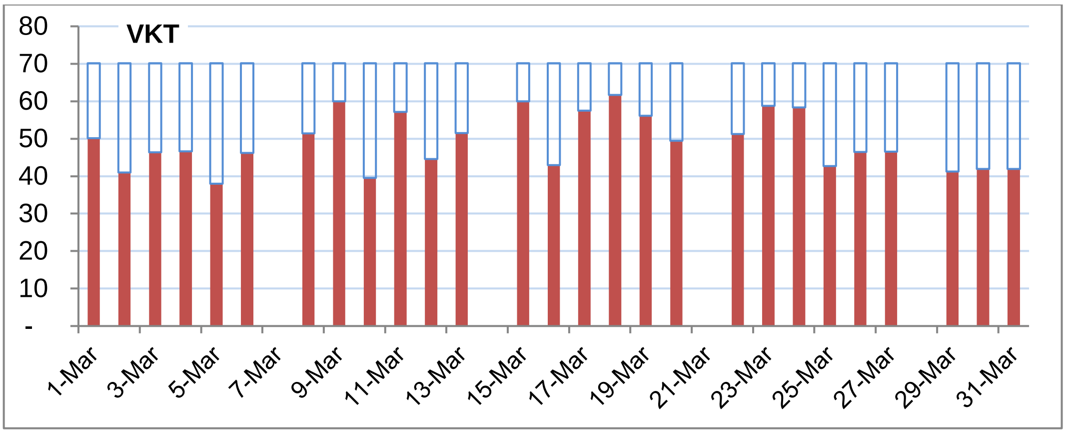

Figure 19: Variation in the daily VKT along the Ring Road during March 2014

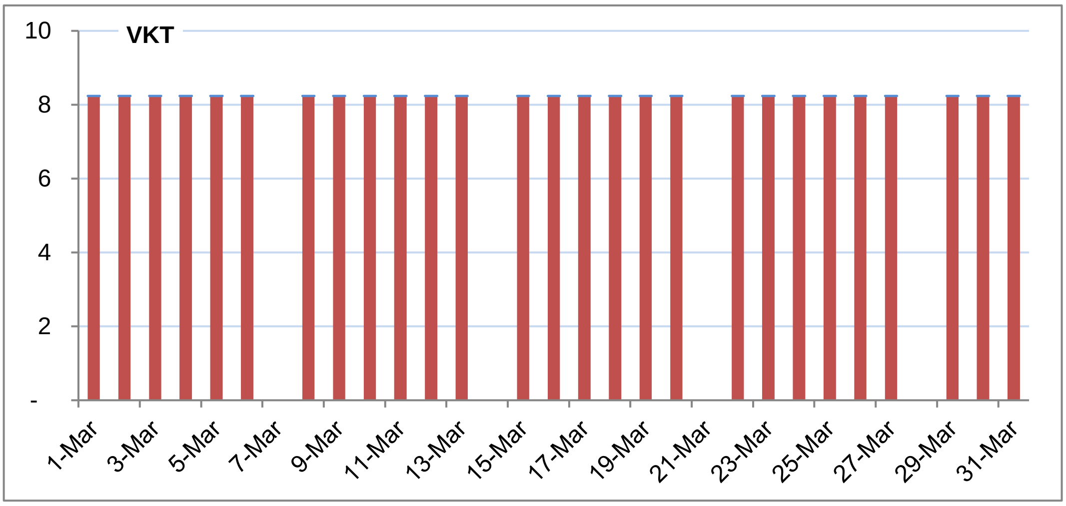

Figure 20: Variation in the daily VKT along the El-Suez Road during March 2014

The cost estimation of the PVD is based on estimating the budgets needed to collect this data by using vehicles dedicated for the purpose of data collection only. The budgets should include the cost of GPS equipment, the cost of vehicles operation, in addition to the cost of driving man-hours. Nonetheless, the cost of data collection, transmission, and storage should also be included. The expenses of a taxi to travel one km can substitute for the operational cost of the vehicle, including the man-hour driving cost. In Egypt, that taxi fares start with 3.00 LE with an incremental cost of 1.3 LE per VKT and 0.2 LE per waiting minute. As a conservative approach, the monetary value of a GPS trace of 1 km will only equal to the cost of traveling 1 km by a taxi (1.3 LE). Thus, the cost of travelling for 10,028 VKT per day is 13,036 LE summing to a value of 4.22 M LE per year.

6. CONCLUSIONS

In this paper, a traffic datacenter based on GPS data was presented. Although the data was obtained only from one organization with a fleet of 80 vehicles, the GPS data was easily and very accurately extracted on the designated roads using the developed GIS-LR model.

GPS data showed a very consistent coverage throughout the weekdays of March 2014. However, the road coverage is highly dependent on the areas the areas the PVD frequently visit. Suez Road, El-Shaheed Corridor, and El-Mosheer Tantawy Road had 100% GPS coverage. Whereas, the Ring Road had 70.1±10.3% average GPS coverage. Nonetheless, no data was available on any roads during Fridays. The monetary value of the traces of only one organization (80 vehicles) is about of 4.22 M LE per year.

The potential of covering the GCMA area with PVD obtained from organizations fleet is very promising. Yet, to well cover the network during weekdays and weekends, as well, GPS data should include vehicles that operate normally on weekends such as; taxis, public buses, and trucks and travel throughout the network during many hours.

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Cairo Downtown compactness as a visionary thinking for a sustainable urban form

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Abstract: *The compact urban form is considered one of the planning & urban design strategies that could control and develop more sustainable cities, in the environmental, social and economic dimensions. The relationship between urban form and sustainability is now one of the most important debated issues, according to the international environmental agenda. This paper attempts to clarify the latest thinking conducted to high density benefits and how to reach a sustained community. There is a widespread consensus that progress towards sustainable development is essential. From this debate, strong arguments are emerging to support the compact city as one of the most sustainable urban forms. However, many policies, management and recommended characteristics are needed in compactness to achieve sustainability; otherwise the urban form will be affected negatively. The compactness of land use patterns could affect the sustainability positively and negatively, and the challenges are mainly associated with environmental quality, social and economic acceptability. The perceived benefits of this strategy include: saving agricultural land, reduced energy consumption& pollution, better public transport services and less car dependency, liveability while the challenges need to be tackled.*

Thus, the paper presents Downtown compactness and interrelations between high densities with urban form, ending with a visionary thinking that can show how Downtown Cairo can be a compact urban form as a successful model of sustainable urban development. Finally, findings and recommendations will be proposed. There is a high density and compactness in Egypt built area due to the informality in urban form, and other developing countries, policies, regulations, urban strategies, and management tools for development consider the high density issue which already exists. The compactness in downtown Egypt will be studied, since the area is already compact but with an absence of regulations and policies, lack of open spaces, green pockets, CO^2 emissions, car dependency, and many synergies that need new visionary interventions with some development strategies as a suggestion to renovate the city to be a sustainable compact one.

***Keywords*: **Compact urban form; Intensification; Non-motorized system; sustainable urban development.

1. Introduction

Egypt inner core has a unique urban form and structure which is characterized by compact built-up areas, narrow streets and small alleys, and mixed use and amenities which contribute to this very dense urban form. On the other side, there is also the growth of informal urban areas, which take from the agricultural land and led to lack vacant land, and the open public spaces. Claudio argued that informal settlements in Egypt, especially Cairo, and Giza had many negative impacts on the urban environment like air pollution and congestion, poverty and severs health problems due to the excessive compactness without any management or policy system. There are reasons for some new communities' failure to attract the population from the Cairo or Giza, and this is due to the following:

• The lack of appropriate public transportation system.
• The lack of good urban economic base.
• The scattered urban morphology of the urban environment.
• The absence of mixed use activities, since there is segregation, and mono functionality of land.
• Lack of affordable housing, and high price housing (Claudio, 2004).

There are further problems in Egypt related to the air quality deterioration, congestion problems and pollution since there is a lack of traffic-management interventions and wide spreading of informal transportation. As Claudio argued, that the demand for transportation and parking areas will increase as long as high density, and informal densification increases, and the problems exacerbate when there are street vendors, which affect the quality of pedestrian streets; there is also an increasing of car dependency due to the ring road and new town's peripheries development (Claudio, 2004). Absence of government regulations for using public spaces, land use, and planning of city growth causes all the adverse effect of compact urban settings. The question now is how could Cairo be able to cope with sustainable development? There is a problem of rapid urbanization; the urban pattern grows chaotically with non- maintained public transportation system. Down town as compact urban area will be shown, and studied with some suggested planning strategies according to some findings from previous urban case studies that conducted to the same topic.

According to the final report of DRPTC (Development Research and technological planning centre) of Cairo University, GC is the largest urban area in Egypt, and it is considered as one of the most populous metropolises of the world. It is expected that between 2000 to 2015, Cairo will be the 10th rank within mega cities across the world in the period (DRTPC, 2009) based on (Figure 1) statistics.

At the turn of the 21st century, GC started to get its contemporary structure as a "main dense urban are**a**" which varied in socioeconomic levels. These dense areas encircled by the Ring Road and an "outer belt" of 8 new satellite cities as shown in (Figure 2). The main dense area can be further sub-divided into a "core area" and a "surrounding peripheries". The "core area" is the historical part of Cairo. It includes the original CBD "Khedival Cairo" or Down town of the late 18th century and "Islamic Cairo" of the more historic era of the 5thcentury. Major activities are still settled in the core like government agencies, commercial activities, and retail. This core is characterized by population concentration and high densities. Also, it is not compatible with the provision of appropriate public transportation and parking facilities (DRTPC, 2009).

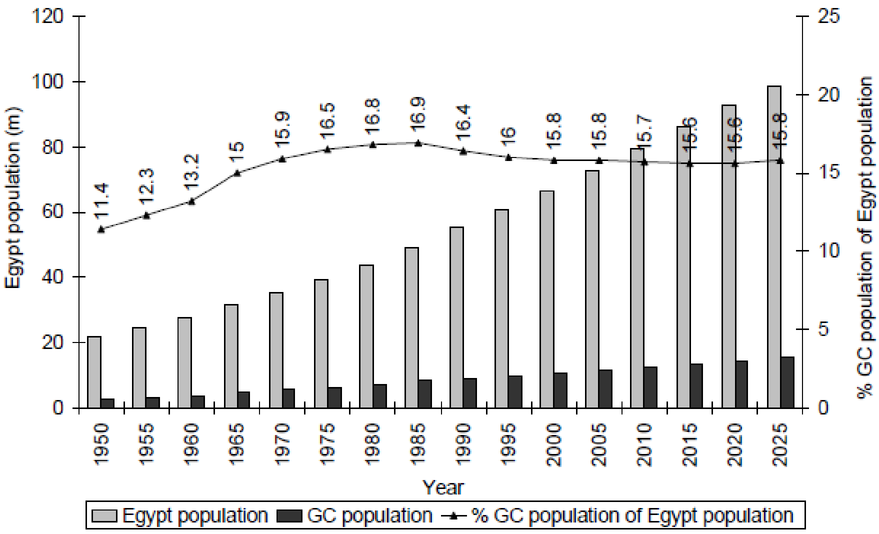


Figure 1: The evolution of Greater Cairo population versus Egypt population (DRTPC, 2009).

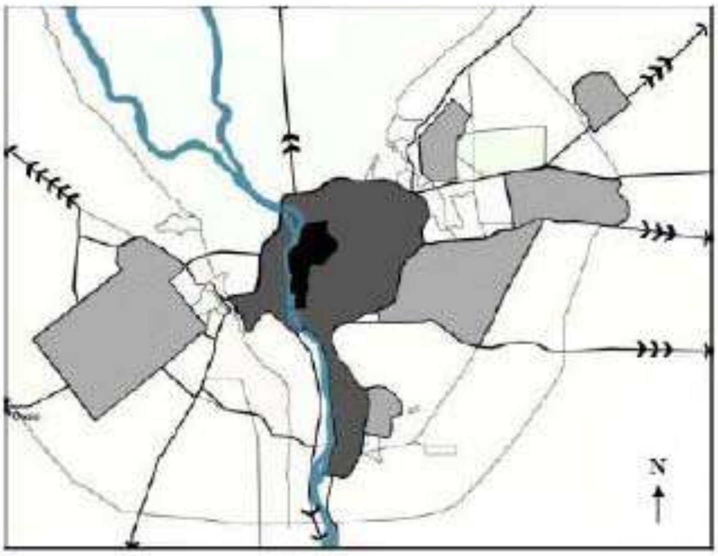


Figure 2: Current structure of Greater Cairo and the development corridors.
NB: The numbers of arrows present the extent of development on the 6 development corridors. **(**DRTPC, 2009)

Sims observed in his book "Understanding Cairo" that the private car becomes the main mode of transport, which can be described as an avalanche to become. The private car ownership is increasing very rapidly. In fact, there are millions of people in GC who have never even ridden a private car, due to the economics of the 21st century, which witness this rapid expansion on private cars between the middle classes and more wealth. The private car is definitely the major contributor to the traffic congestion, which accounts for roughly two-thirds of all vehicles on the streets of the GC region, related to the other kinds of buses, trucks, metro and motorcycles. In addition, the parking of the private cars has blocked the main and secondary streets, which has made walking in Cairo's street a nightmare (Sims, 2010). But what about cycling and walking in Egypt? Such questions need to be tackled an investigated to see how it could be integrated in the urban planning framework towards sustainable spatiality while also considering the socioeconomic processes in Downtown Cairo.

2. Downtown Cairo compactness literature review

Downtown Cairo is a historical city core of Egypt. It has the potentiality of offered spaces to walk, and different land uses which attract a diversity of users and developers, and help in more social interaction. Also, the Nile as a source of life gives the ability to achieve liveable open spaces and revitalize the whole area of downtown. Many researchers and writers study the downtown as a preferred topic and point of interest. In 2012, Sahar Attia issues" *Revitalization of Downtown as a centre for social democracy and sustainable growth*", she addressed the issues of downtown sustainability in relation to the implications of post conflict of social, economic and environmental challenges (Attia, 2012). Ravazzoli and Tossi explained some of the informal practices in Cairo streetscape, and related to the downtown. They mentioned the overcrowding, and traffic problems which led to the high-middle class transformation from the Downtown. Moreover, there is abandonment of many valuable and historical buildings due to lack of maintenance (Ravazzoli & Toso, 2013). Many thoughts about urban transformation in downtown were introduced, especially in relation the Nile banks, since it plays an important role in the formation of the city image, and to study the spatial configurations and create a network of open spaces with pedestrian friendly zones that help in refurbishing the city with a smart urban transportation system toward a sustainable life (Attia, 2012).

So, it is obvious that towards a more sustainable life and community in downtown Cairo, many interventions need to be introduced with the promotion of liveable open spaces which contribute in more social interaction and social equality. Walkability, less car dependent, pedestrian friendly zones also help to create a social life in spaces, in addition to the necessity to keep the identity of the place and its historical value. Accordingly, the study of Downtown Cairo compactness could start by understanding the physical aspects of urban form.

2.1 High Density

Downtown area in Egypt has compact, dense, and a walkable urban pattern which considered as a fundamental part of experiencing the city. There is a high density of population who live in the area beside the visitors who come from different places to go through the multifunction buildings there, since downtown is a mixed use area with different amenities.

2.2 Open Space in Downtown

There are many public spaces in downtown, some of them have a historical value, and potential to achieve liveability, and some of the others need interventions to be pedestrian friendly. One of these spaces is Tahrir Square; one of the most important urban spaces in

Downtown. As Mohamed Elshahid observes from his urban perspective, Tahrir square has different characteristics and identity of the others, it isn't a typical one. While the square hasn't clear architectural edge as an open space which could be described as fragmented, there are many additional obstacles like the vehicle traffic, congestion, and destruction of pedestrian zones due to political regimes as shown in (Figure 3). Obviously, the people find their own way to make it works.

Figure 3: Tahrir square traffic flow
(Google web,2014)

There are also a great complexity of the pedestrian zones, mixed use activities and amenities in relation to the traffic movement. These circular squares have distinctive characteristics of the centralized statues of Egypt modern historical figures. The traffic problem in transportation also affects the public spaces, and quality of life in the area. Lack of open spaces due to the cars, and urban traffic flow is obvious in Downtown, with unplanned and pleasant pedestrian zone in the streets as shown in (Figure 3).

2.3 Transportation in Downtown

Downtown is linked with the other districts around in different levels with the main streets and the interrelation between these streets and the main nodes, some of these nodes are very crowded like Tahrir square. Downtown is the core of the GC region as it was mentioned before, which has dense and compact urban form, beside many problems in the distribution of urban pattern, and lack of public transportation system which considered the main catastrophe of the area with missed management and policy strategy implementation. Downtown streets which were designed in 1874 can't handle what happened now, and then a lot of traffic problems have been occurring. One of these problems comes from:

- Cars which penetrate the downtown headed for visiting the place, and then parking on the streets which aren't enough for these numbers, or parking underneath some of the buildings, or in El-Bostan multi-story building. The cars use the narrow streets as parking area which make a traffic problem, and for public transportation, there are some buses going on the 26th of July streets according to our study area.
- Cars which penetrate the area, and to reach another area like the ones' who comes from or to El-Azhar bridge to go to the eastern and western areas of downtown, and then have

to pass from Adli street, Talaat Harb street, 26th of July street. All these relations cause a huge problem in Downtown traffic also, since it blocks the pedestrian movement areas and its network (Elkhorazaty, 2006).

2.4 Urban Fabric and Land Use Management in Downtown

Most of downtown streets have functioned as a commercial retail, and recreational services, with spreading of street vendors and their informal activities everywhere. These informal activities affect the sidewalks, pedestrian zones, and obstruct the shops in the ground floor, making the more intense traffic flux. This chaotic situation is due to the spread of street vendors without any arrangement of the distribution, and within the absence of regulations and policies (Ravazzoli & Toso, 2013). Although street vendors are a big issue in Downtown streets with their obstruction to pedestrian walkability, they are part of the place which gives more life to the area, and considered as an economic source that introduce vibrant activities to people. So, to conclude the problems in downtown from the feasibility study of the area:

1. Problems in Pedestrian movements and its network due to high intensity of traffic and street vendors and their informal activities.
2. Lack of parking area in the downtown and its distribution among the streets.
3. Spatial quality and the formation of urban fabric affected negatively.
4. Visitors to the Downtown make more traffic problem.

After proposing the literature review of the Downtown Cairo with the previous mentioned aspects, and defining the problems that should be tackled, it is important for the next step to go through the research methodology to analyse, observe and find solutions.

3. Research methodology of Downtown Compactness

Accordingly, the research methodology is tackling the Downtown Cairo based on the scholarly literature of the area compactness and density analysis to see how its urban form could contribute to sustainability through reaching an assessment method that links between the physical built environment; open spaces, high density of urban form, mixed use activities an mobility situation with their positive and negative effect on the other dimensions of sustainability; the social, environmental and economic aspects as shown in(Figure 4) .

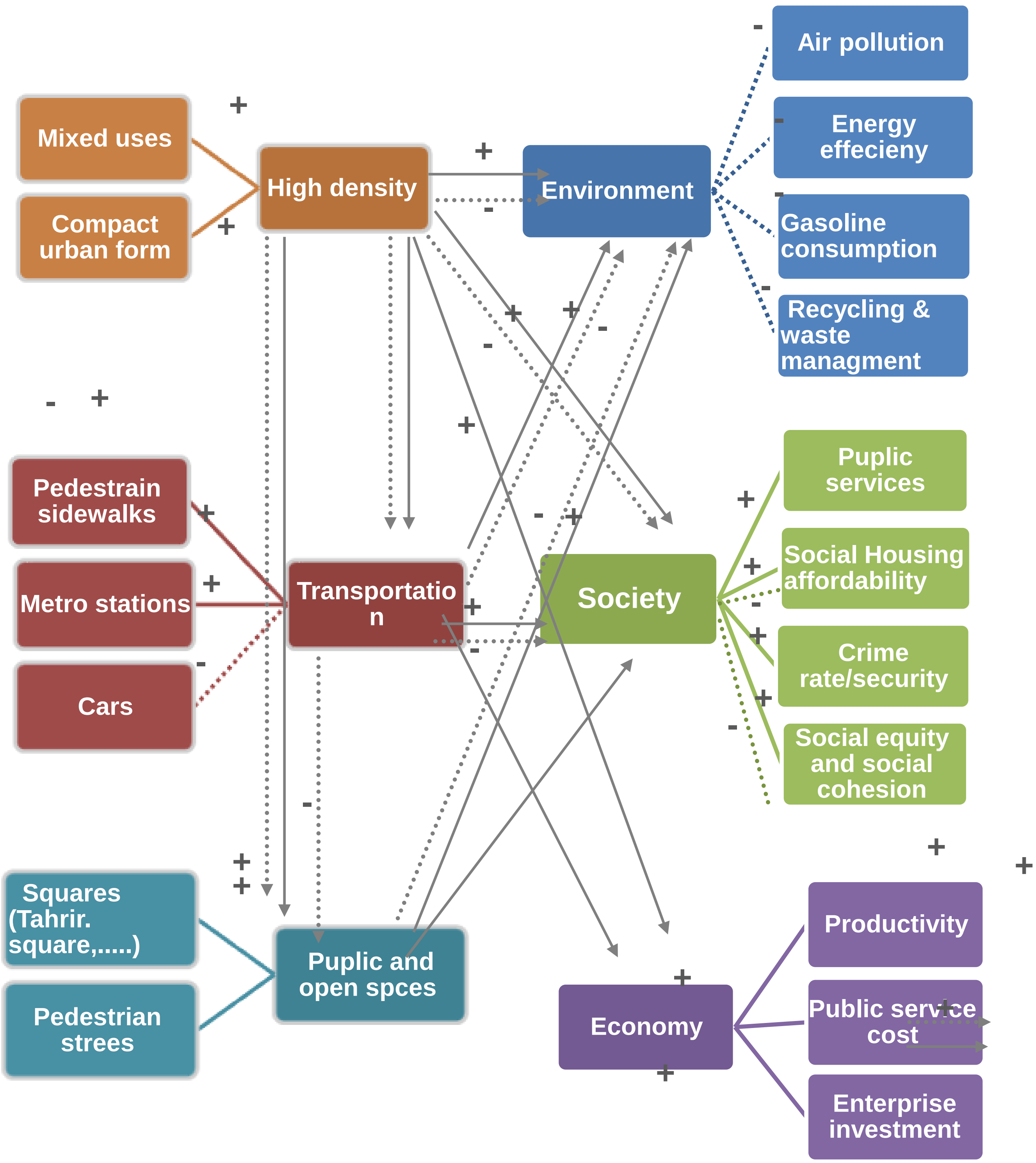
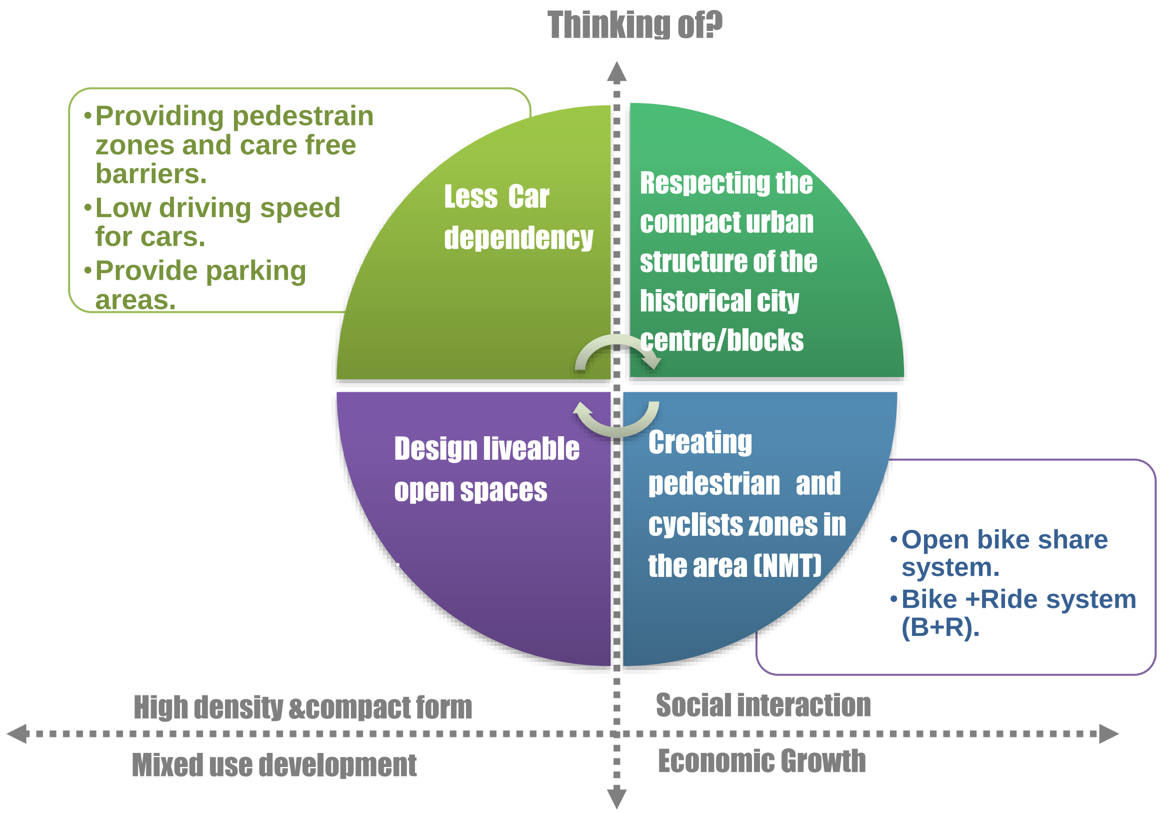


Figure 4: An evaluation path diagram of Downtown Cairo according to the compact cities main policies and dimensions of sustainability (Researcher, 2015)

Based on the previous assessment, Downtown has high density, and mixed use development, with traffic congestion due to car usage and at the same time there are many metro stations which are considered as potential spots in the area. The pedestrian sidewalks in downtown are inefficient, due to street vendors and informal activities that spread there. Some of open spaces in the selected area of the downtown depend on the historical value of the squares, and the others need new interventions towards more livable spaces. Thus, the second part of the research method is to propose new intervention strategies that could re-envision the area as a place of mind.

3.1 Downtown Intervention Strategies

Downtown compact area has many problems as it was mentioned before which needs thinking of new strategies of urban development planning to have a sustainable urban form. The density tends to be implemented as something developers want, but there are public values which need to be considered smartly in addition to the densification process. Thinking of the sustainable urban planning aspects (Figure 5) as strategy level could be a start to re-envision Downtown as a network of spatial and social relations to e investigate in further research by enhancing innovative methodological practice to reach complex adaptive system.



Aspects interrelation could make a change to a better environment with more social interaction and enhancing the economic growth in Downtown, to achieve the actual meaning of compactness toward a more sustainable life. Many compact policies need to be achieved in Downtown especially in the transportation sector, which has many problems in Egypt and causes environmental disasters with deterioration of air quality and spaces liveability, on the other side Downtown has a high density with mixed use development which helps in social interaction, social cohesion, and economic productivity. Negotiating connectivity could repower the space with NMT (Non-motorized system), connecting different programs and activity in the area, since these activities add to vitality and life quality.

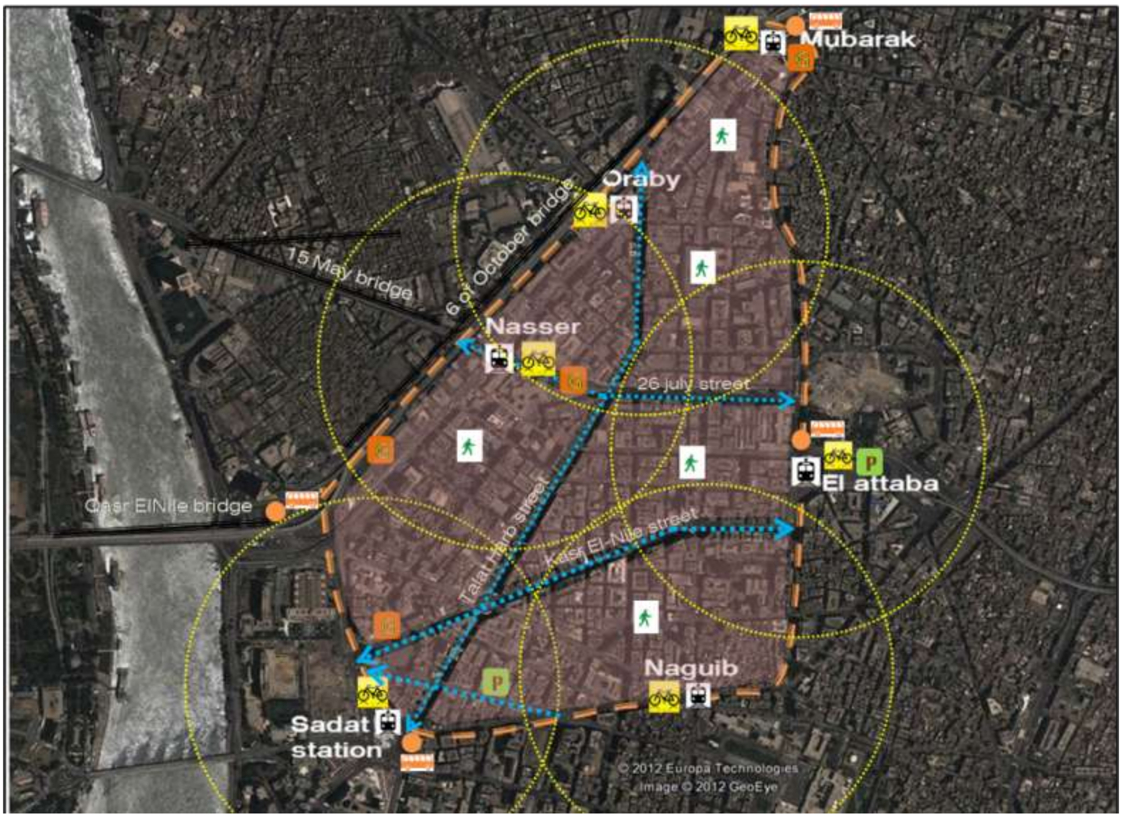
3.1.1 Transportation Network Development in Downtown Area -Macro Scale

The start of implementing Bike+Ride system will be through an overview of the rail system at the beginning to use its potential in the integration with the visionary biking network which extends to reach 2 km from each metro station as seen in (Figure 6). There is one extension line from Shobra El-khaima to Munib, the second one from El-Marg to Helwan, and as Sims mentioned, the third one is on the construction of the first phase, which recently has begun on the al-‘ Abbasiya- Ataba’ section and supposed to be extended from Cairo international airport to Shehab street and Gamat al-Duwal al Arabia, the first phase has completed in 2010, and the whole line not expected to be completed until 2022 as a kind of improving the quality of life and the surface traffic circulation (Sims, 2010) .

Downtown is the selected area, due to its compactness, high density, valued historical background which attracts people from different area to commute there, and many metro stations which ease the connection from the surrounding context to the area. Next step is to know how biking strategy could work as visionary multi-dimensional planning approach in downtown and how to face all the traffic problems which are there based on the area potentials reaching to a visionary strategy with some recommendations that could be taken into consideration in the future.

3.1.2 Transportation network development in Downtown area -Micro scale

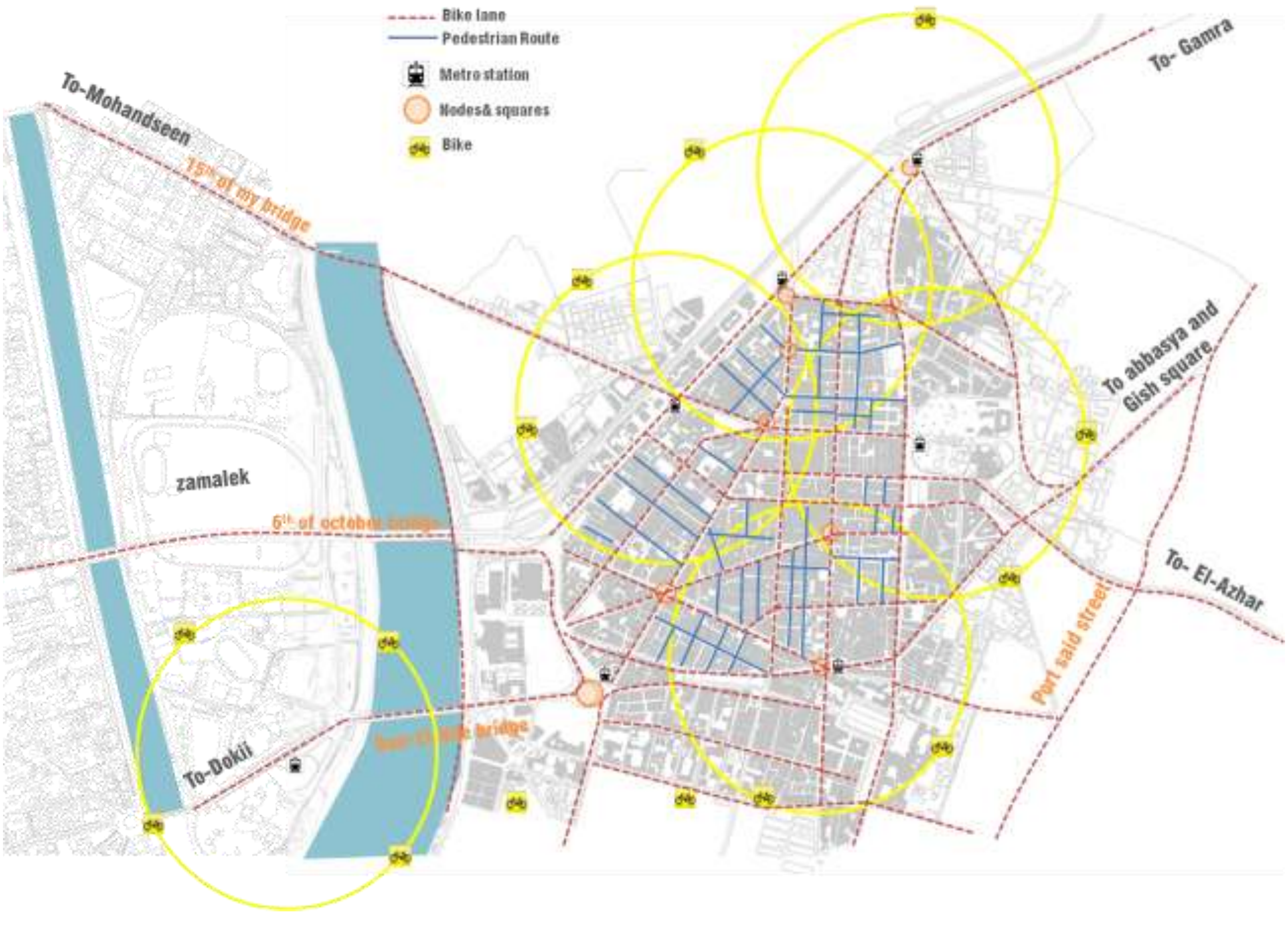
The aim of the Downtown case study is to drop shadow on the traffic problems of the centre and then try to implement a Bike+Ride system with visionary feasibility study to offer a place which promotes a lifestyle of wellness. Sustainability could be accomplished with an attempt to have more development in mobility system which could be integrated with other dimensions like the viability of open spaces, density of blocks and how to make use of the alleys in downtown, and reduce CO^2 emissions towards sustainable compact environment. (Figure 7) shows the new integration of different transportation modes, especially enhancing the usage of 1 Km diameter of bikes system to be a dynamic mode of transportation from each metro station as an experimental style to formulate the area into more pedestrian zones, and only the main roads are accessed by cars to reduce the traffic congestion in the area.

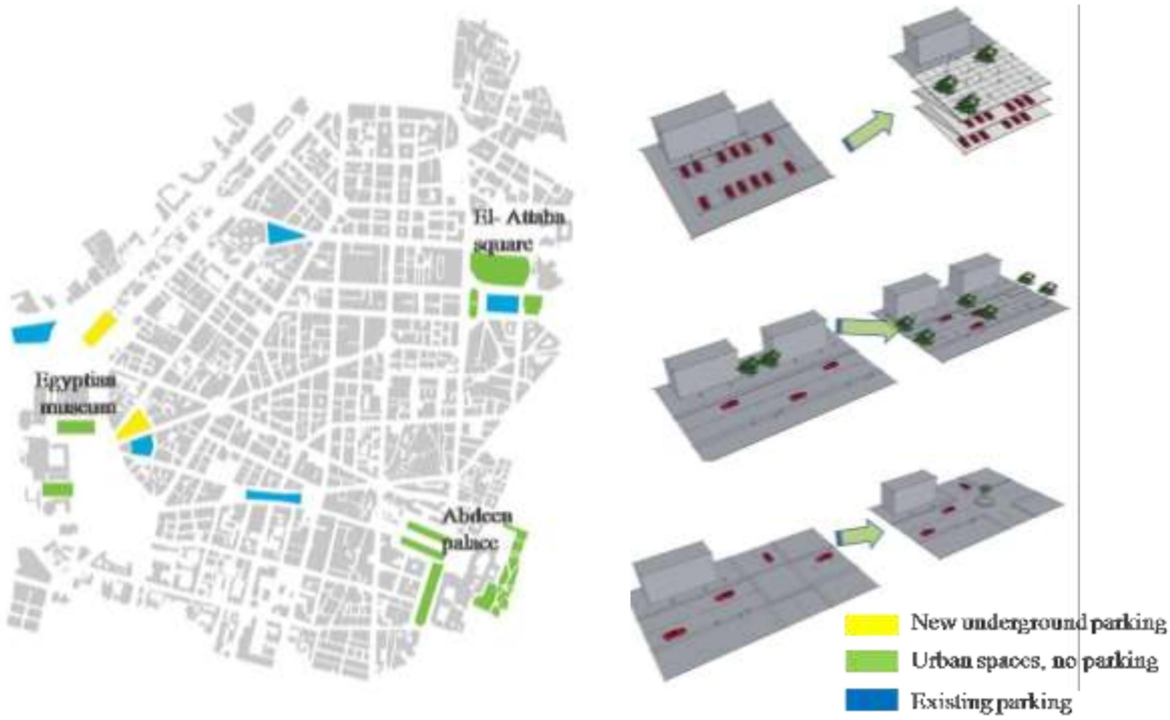


The bicycle is able to penetrate the narrow winding alleys, while the car can't do so and just can cross the large block on the surrounding areas. The bicycle has the advantage of being the fast mode of transit in traffic situations. In the case of downtown typology, there is a potential of having a smaller network of streets which can cut across, as opposed to the fenced mega-blocks which must be travelled around. In more detailed, the traffic diagram of different transportation modes focusing on pedestrian network, biking lanes and its integration with metro stations is shown in (Figure 8).

Restructuring parking and increasing public spaces

Parking plots restriction is very crucial to reduce the traffic congestion, and creating more areas for open and public spaces by forming a new underground parking, and charging the green public spaces which already exist to preserve them from being deteriorated and occupied as a parking area. As shown in (Figure 9), there are some valuable spaces which should be always maintained such as (El-Attaba square, Abdeen palace square, the area in front of the Egyptian museum, etc.……), other areas are already existing as parking, and other places are suggested to be transformed into a new underground parking to reduce the traffic flow problems and add more vibrant life to the area with the vital green open spaces.





4. Discussion and conclusion

As 1qa conclusion, Cairo has many environmental problems which also affect the social and economic level. As many developing countries, policies and regulations are missing, which make the city far away from sustainability, Downtown Cairo has many potentials, and as well many problems. The area needs new sustainable interventions and strategies, especially in the transportation sector to overcome the environmental degradation. This could be applied in a perspective of using biking system, creating pedestrian zones and to be integrated with the other modes of transportation, especially rail system which is already a potential in Downtown in many spots. Effective transportation system could affect the open spaces q1uality which needs more development to reach the city liveability. Compact urban form cannot be utopia theory, but it could be an effective planning strategy to avoid further increase of urban sprawl and achieve quality of life, but with existing of policy approaches, regulations, spatial and network planning in all the sustainable aspects.

Compact urban form as an approach or guideline towards more sustainable urban form can't be used in every city, since each one has its own socioeconomic circumstances, urban sprawl, culture and political issues, but with some policy approaches, regulations, spatial and network planning in all sustainable aspects; the compact city could be a successful strategy to achieve sustainable urban development. These strategies and policies of compactness are needed to work through the national urban policy framework, and wide strategic planning with special tools in social, economic and environmental aspects of sustainability to overcome the urban sprawl, and achieve the quality of life. As it was analysed and studied in the research, for further development in the future these aspects should be taken into considerations from all the stakeholders, organizations and community participation. These are some recommendations for further futuristic development to have sustainable compact urban form:

- *Maximize the use of land resources.*
- *Promote public transportation system, walkability and biking with less car dependency to reduce CO^2 emissions, and seek for a healthier life.*
- *More green spaces, and enhance the quality of public spaces which considered the lung of the city and foster a" sense of place".*
- *Reduce energy demand.*
- *Get better access to services and a diversity of activities.*
- *Encourage dense urban development, and strength rural-urban links.*
- *Enhance the provision of the affordable housing.*

These polices and strategies need to be responded to the different circumstances, and how those could be utilized as a complementary part of the urban development to minimize the negative effect of a compact city, and achieve the positive side of compactness. Beside proposing polices and strategies, it is also important to a better understanding of compact city and it's today urban context implications within the terms of sustainable urban growth.

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الخورازاتى، تامر (اكتوبر ٢٠٠٦) مدخل للإطار التخطيطى لمشروعات التطوير العمرانى لمنطقة وسط البلد. بحث مقدم إلى اللجنة العلمية الدائمة للتخطيط الإقليمى والعمرانى .

Development of interactive cluster for urban development in Egypt

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Abstract: *Economic growth, globalization, and urbanization have triggered an unprecedented trend on planet earth. The United Nations (UN) now predicts that the global population will reach 10.1 billion by 2100. (Ween, 2014) More intriguing prediction is there will be more than 70% of the human population live in the urban region by then. Most of the urbanization shift happening in the developing nations and this transformative tendency stimulate social, economic, political, demographic, cultural, and environmental challenges as well as opportunities. However, this type of urban sprawling has also comprised many obstacles such as overpopulation, the inefficiency of land use, lack of essential amenities, infrastructure, and urgency of seeking a sustainable development approach for a hybrid of an architectural approach.*

Egypt also experiences the similar urbanization shift; the government is trying to tackle the challenges imposed by urban sprawling, yet the progress is rather formidable. The country has its characteristic, on the one hand, is to maintain growth progressively and on the other hand is to regenerate the large proportions of informal settlements. By investigating the Egyptian context and conducting case studies at the local level enable the implication of development. A qualitative and quantitative research will be conducted. Qualitative research refers to field studies, case studies, observation, and interview. Quantitative research refers to surveys, user case scenarios, simulation, design, and prototyping. An adaptable, affordable, reconfigurable, inclusive, and modular construction system called Interactive Cluster will be developed. The proposed concept will focus on addressing issues imposed from the redevelopment of informal settlements, whereas the similar solution can also be applied in the construction of the new urban project. Carefully select advanced construction method to ensure the feasibility and value creation potential of the concept will fit in with the local context. The system allows the building to transform into the heights, volume, and function by interact with the user or the demand locally. The impact of the concept will provide a unique business model for the designer, policy maker, and investors to support the urbanization trend and also provide a practical solution for regenerating informal settlement in the future.

Keywords: advanced construction, adaptable, affordable, reconfigurable.

1. INTRODUCTION

For the first time in human history, there are more than half of the world population now call the city home. This profound trend is increasingly noticeable in developing nations, and this was no exception in Egypt. Urbanization trend also imposes many challenges to the country and added new constraints to its development of infrastructure, social, economic, organizational and sustainability. One of the most profound obstacles caused by urban expansion in Egypt is planning future sustainable urban development while upgrading the existing informal settlements, (Sejourne, 2006). Cities such as Cairo, which has been deeply influenced by a population boom, urban sprawl, and implication of globalization, thus it is at the forefront battling the issue above. As the symbolic, historical, economic, political and culture capital of the country, which with more than 20million inhabitants that share a common disease with many other megacities around the world, (Denis, 1996). Evidently, the survival of Cairo is overshadowed by inadequate infrastructure, traffic congestion, unemployment, pollution and increasing numbers of informal settlements dominating on the formal urban region.

In the context of Cairo, the moment of informal settlement first started during the 1960s and 1970s, when the country experiences this new form of rapid urbanization. The informal settlement became a quick and affordable solution to accommodate the city’s lower or even the middle classes. Between the 1970s and the 1990s approximately 80% of new build housing project in the city were informally constructed. Informality usually associates with the building often built without regard for the planning, policy, building regulation, unsafe and especially those illegally convert agricultural land into residential usage. In the way, the building is developed on a non-official land market manipulated private stakeholders. The typical construction method is used in situ concrete structural framework and with red brickwork as an infill. The height and the configuration of the building may vary somewhat between five storeys to ten storeys. There were projects organized by the government bodies or international agencies trying to solve the issue, which many of those projects were not implemented, yet projects such as Ismailia demonstration project, Helwan New Communities, and Ibni bayetek were finally implemented to regenerate the area as well as to provide new core housing units for the communities. The impacts of those projects were not obvious regarding improving the living conditions of the occupants. Major drawbacks of the projects include, poor design of the building, lack of basic access to services, lack of transportation, and the building cannot adapt o the changes of user’s requirements and diverse needs in the social, economic aspect. (Helal, 2016)

This is a common issue faced in not just the construction of informal buildings also an informal urban development that building cannot a response to the changes imposed by the growing tendency of rapid urbanization. Therefore, the need to develop an adaptable, affordable, reconfigurable, inclusive, and modular construction system becomes apparent. This paper describes and proposes a hybrid of architectural approach, which provides an entire construction system that will be designed with the consideration of Cairo’s unique characteristics. The concept is developed as part of the ongoing funded research project; Affordable and adjustable living and mobility for sustainable integrated urban systems in Egypt, (A^2L-Mobilius). The project is jointly funded by the Germany Ministry of Education and Research and the Science and Technology Development Funds of the Arab Republic of Egypt. Detail description of the A^2L-Mobilius project will be illustrated in a later section. The proposed concept will focus on addressing issues imposed from the redevelopment of informal settlements, whereas the similar solution can also be applied in the construction of the new urban project. The outcomes also inspire other developing countries that face similar circumstances. The design and trade-off of the concept will be discussed in detail later in the paper.

2. LITERATURE REVIEW

The consequences of rapid urbanization have been a tough challenge to solve by many governments. However, the trend is irreversible, people have the right to move to the cities where can potentially provide a better life for them. Changes in urban social conditions and residential migrations have taken its toll on the future development of many cities, such as Cairo. In Great Cairo (Cairo, Giza, Kaliobiya) comprise 4 out of 30 slums or informal settlements in the world: Imbaba, Ezbet EL Haggana, City of the dead cemeteries and Manshiyat Naser with a total population of approximately 3.3 million. Most of the area suffers the similar issues of accessibility, narrow streets, the absence of vacant land and open spaces, very high residential densities, (Khalifa, 2011) and inadequate infrastructure and services (World Bank, 2008).

2.1. Constraints and advantages

The informal settlements in Cairo have their characteristics also carries some tricky facts, which in many cases improvements and preservation are needed simultaneously. Many agricultural lands were illegally invaded by the expansion of informal settlement. The only way to reclaim the land back to its owner is to demolish and relocate the current occupants. Inevitably, it will generate a vast amount of construction waste. Since the 1970s, there are numbers of public projects called New Towns that intended to abstract population from the informal area to a centralized location. However, the satisfaction level is lower than expected due to the relocated location is far from the town center and lack of employment opportunities and public services. So here is a question for the planner to answer; why do people choose to live in an inadequate informal area where seems chaotic rather than to be relocated to the modern comfortable New Town? To be able to change someone’s standard of living has a lot deeper implication than just moving them away from the current situation. For example, cultural, social, economic, physiological correspondence is vital aspects when dealing with regeneration programs.

Within the informal area, buildings were built without planning permission or complying with building regulations, and that is why locals call it ‘ashwa’iyyat, meaning ‘disordered’ or ‘haphazard’. Amazingly, according to some research, there are very few so-called shantytowns and dangerous ‘slums’ in Cairo. The overall quality of the building is decent. Because of the nature of those unplanned buildings and the informal settlement, until now an accurate data about the area still does not exist. As the government cannot accumulate the data, then it is tough to execute correct, effective policy, plans, and budgets to improve the living condition of the residents.

What is the main attraction of the informal settlement apart from the affordable rental price? First is its social diversity, different from what many people may expect, an informal settlement in Cairo does accommodate not only the poor, but also a wide range of the spectrum of people, such as students, civil servants, artisans, business owners and even judges. Informal areas are not unstructured, unorganized, and chaotic. In contrast, it is well structured, self-efficient, most of the time self-financed and built. It is inspiring, full of life and constantly changing which offers a strong sense of community, cooperation safety, and social interaction. Furthermore, it is many multifunctional locations is within walking distance, so the community has lower energy consumption rate than its city counterparts. Surprisingly, after adding those features together, it seems like something that city planner, urban designer, and policy maker are looking for, (Shehayeb, 2009).

According to the analysis, the proposed building system has to take aspects above into consideration. The building has to offer maximum flexibility to cope with the changes caused by social, economic, and demographic changes in society. The design of the building has to be determined by the location, user's requirements to accommodate the various household size, occupation, and lifestyle. To be able to achieve affordable cost the building needs to be designed as modular systems to achieve mass customization as well as standardization.

By adopting a platform strategy which means the building will be divided systemically into different levels, for example, the base building level and infill level, (Kendall, 2000). The base building level is the load-bearing structure of the building and the infill level to be equipped with the functional accessories of the building. In general, the base level can be standard components that can be mass produced to reduce the cost of unit production, besides the infill level can be translated as self-contained, decentralized customized that will suit the individual demand. Some of the relevant research topics will be described in detail below.

2.2. Open building concept

Mass produced, prefabricated building system became a popular choice for architects and engineers. The concept of Open-Building (OB) also knew as a Support / Infill (S/I), Skeleton Housing, Supports and reconfigurable, Houses that grow, etc. – are now represented one of the most flexible construction principles. The building has been designed in different levels: a support structure, infill system, fit-out, and appliances. These have been reinterpreted and updated to harness the benefits of state-of–the–art industrial production, emerging information and digital technologies, (Pan, 2015) improved logistics and changing social values and market structures. (Kendall, 2000). The OB concept has huge implications for the development of the proposed building system. To be able to design an adaptable building type the characteristic of the OB concept has to be considered throughout the designing stage.

2.3. Active building concept

In general, similar to the open building concept, the active buildings will be divided into four levels; a support structure, infill, façade and information cluster. When to use an abstract way to consider an active building as a human body; for instance If we consider the structure and envelope of the building to be the skeletal system and the skin, then the nervous system and cardiovascular system would be the technological, managerial, production and assembly systems of the building, (Pan, 2015). Each level aware any changes that due to happen, occurring or already happened between each other regarding configuration, maintenance, customer demand and function. In this case, the level of awareness will be demonstrated through the entire building process; design, construction, use phase, maintenance and recycle. In this sense, everything can be customized, relocated and optimized for the user's preferences, (Pan, 2015). The active building concept will inspire the design concept of the proposed building system, especially in the sense of developing a proactive building system.

2.4. Universal Construction System (UCS)

According to some researchers, that an industrialized building system can be described as a set of interconnected building elements that act together to form a building that performs many functions. The UCS concept reflects the potential of using an industrialized building system to solve the issues caused by conventional issues. It can be applied to various types and configurations of construction projects. UCS can be systematically divided into four categories: structure, composition, production and construction. In general, structural systems include a series of beams and columns that are interconnected and provide a flexible box-shaped support system. Component systems contain wall elements, floor elements and interior fixtures plus the services of the building. Each part can be easily assembled or disassembled to allow the building system to be regularly upgraded. Production systems involve off-site manufacturing of all UCS building elements and can be used as an on-site field factory. Construction systems consist of all on-site technological, managerial and operational assembly activities. A range of construction equipment and single-task construction robots were included by the author to increase overall construction efficiency as well as reducing construction waste, (Pan, 2013). The UCS concept demonstrated a comprehensive solution how to design a flexible building system with the concrete elements, and how to improve the production and the assembly process by use automation technology. In this context, the UCS concept will be considered when designing the supporting structure of the proposed building system.

3. RESEARCH METHODOLOGY

Beside literature review, a qualitative and quantitative research will be conducted. In this case, qualitative research refers to field studies, case studies, observation, and interview. Quantitative research refers to surveys, user case scenarios, simulation, design, and prototyping. A systemic research approach will be applied that enables to locate stakeholders, categorization and prioritization of each one of them. The stakeholders will be identified and categorized, and their expected impacts on the design will be analyzed. Each impact specification is going to translate into a requirement. These requirements consist of functional requirement and the non-functional requirement that provide the foundation for the further development task. The qualitative research will be conducted by the Egyptian partners from the German University in Cairo. Numbers of cases studies will provide extensive information related to the concept as well as inspiration to the proposed design. The qualitative research will be conducted by the Egyptian partners from the German University in Cairo. The theoretical design of the building system will be carried out by Technical University of Munich (TUM). Dissemination evaluation and prototypes will be constructed jointly by two universities.

3.1. Open source social housing project

Alejandro Aravena, he is the 2016 Pritzker Prize winner and famous for his in incremental affordable building design. This year he released four social house design aim to tackle the challenges caused by rapid urbanization globally. The designs including plans, elevations, sections, and site plans are open source to the public that anyone can download from anywhere in the world. The design offers the basic structure of the building, namely; structural frame, building envelope and basic services at an affordable cost. Another feature of the design promotes the participation from the end user. After the building is erected, if there is any alteration or reconfiguration of the building, then it is up to the occupants to expand it into an adjacent space. Of course, that depends on if the occupants can finance the project. The goal and principle of this example have indicated the enormous potential to address the issues of unprecedented urbanization and urban poverty that the building can be erected over time to ease financial burden self-financed build project, ("Alejandro Aravena makes housing," 2016). This project completed by Alejandro Aravena shows the potential to use OB concept and open source media in the regeneration project. That is why it serves as an excellent case study for this project.

3.2. Kashgar old town regeneration project

Kashgar is an ancient city in Xinjiang province, located on the famous Silk Road which is the westernmost city in China. Today the city has approximately 3.5 million population; the city has unique historical and cultural routes throughout the history it has been ruled by Turkic, Mongol, and Tibetan empires and the Han Chinese. Despite the modern city from the surface, there are still many old settlements within the ancient town requires urgent regeneration. The objectives of the projects are; preserve the urban fabric of the old town while improving infrastructures and building quality. The initial project phase consisted of 29 dwellings approximately 3499 sm^2 of floor space. Most of the buildings are lacking the protection that comes with adequate seismic engineering. The project aims to provide a customized seismic protection solution on each building. Archived images and the local survey were conducted during the project to preserve the original appearance of the street. The buildings are commonly built with a concrete frame structure and with red brick infills which are similar to those in Cairo. Instead of demolishing the existing building, most of the structure of the building is reused. The owner of the building will be invited to join the renovation work and participate in the decoctions making process, especially in the latter part of the project such as the decoration of the roof, railings, stairs, column, doors, windows, and mashrabiya will show a strong indication of the owner's involvement. This example demonstrated the balance between regeneration and preservation of an ancient town. A house is not merely a relic yet requires a dynamic approach, on the one hand, keep the authentic property to reflect on the lifestyle and local culture, on the other hand, integrate new technology, a way of thinking to enhance the standard of life, ("Kashgar old town," 2016). This project demonstrated how to successfully engage in a regeneration project in a culturally rich context. On the one hand, improving the living standard of the residents by upgrading the existing buildings. On the other hand, protect the culture heritage of the local region and respect the way of living as well as preserving the unique architectural style. This approach has significant implications for the way how to design the proposed building system and how the system fit in the local context.

3.3. A²L-Mobilius

The A²L-Mobilius stands for Affordable and Adjustable Living and Mobility for Sustainable Integrated Urban Systems in Egypt. This research was partly financed by project grant from the

Federal Ministry of Education and Research Project AL2Mobilius, Grant Number GERF IB 033, A²L-Mobilius 01DH14003. The objective of the project gradually regenerates one of the chosen informal settlements in Cairo by inserting an intelligent, modular building system which can evolve and transform over time. The proposed modular building system is called DPU (Decentralized Processing Unit) and includes three main subsystems which are a living system, working system, and mobility system. Those DPU systems and the proposed building system are compatible with existing building which can be simply plugged into the existing building structure. The building system will be able to grow or evolve over several generations within an existing informal settlement so that it step by step replaces the old unstructured environment by a more structured environment that provides better tools, technologies and living conditions for the residents. (“A²L-Mobilius,” 2016) This is an ongoing research project the outcome of the project can significantly benefit the regeneration process in Cairo. The method developed through the project will be served as a guideline to inspire both the government and the academics.

4. PROPOSED DESIGN

The proposed design is called Interactive cluster, which comprises five elements; a structural frame system, a panelized system, a modular infill system, a formwork system, and functional module. The proposed system can be utilized for a vast range of new build project, and it is also compatible with existing building renovation, extension project.

Structural frame system offers load bearing property; it will essentially form a skeletal structure, which formed by reinforced concrete beams and columns. Depends on the customer’s requirements the design of the system may vary. One of the concepts is instead of using welded connection methods, the beams and columns are bolted together to enable the connection joints to be disconnected when required. The flexible connection approach also offers design freedom in which the shape of the structural skeleton design can be easily adapted to the requirements of the clients or designers. However, this will increase production cost, so if the customer has the lower budget, then the system can be made from a conventional cast-in-place method. Also, the structure frame system can be used as a choice for reinforcing building that is structurally unstable or damaged.

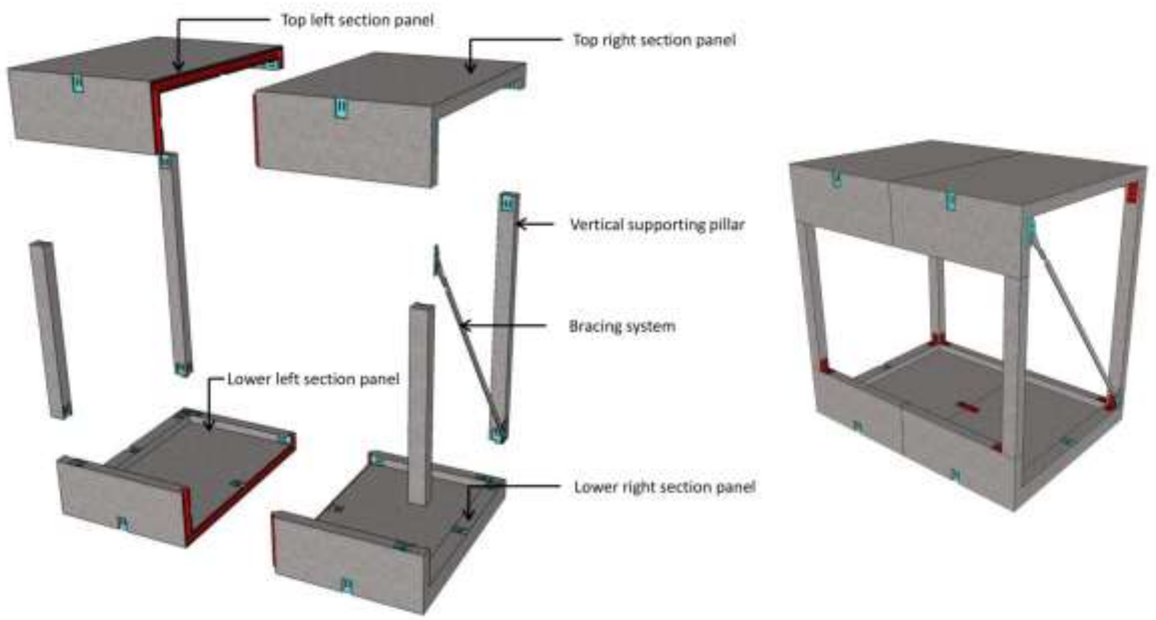

Figure 1: Panelized system

The proposed system consists of five main components; top left section panel, top right section panel, lower left section panel, lower right section panel, and vertical supporting pillars. When it is necessary to steel cross bracing system may add to stabilize the structure. Four pieces of panels connected by bolting joints, then supported by the pillars to form the box structure. The panels are made of reinforced concrete, yet the reinforcing method may vary with the availability of local materials and the budget of the client. The size and weight of the panel were designed with the consideration of the transportation and hoist method that apply during delivery and on-site assembly phase. Currently, there is research conducted on using bamboo-based or plant-based fibre, their thermal and structural performance has indicated that organic plant fibre reinforcement has a similar property as steel rebar reinforcement. Besides this method, the waste residue of construction, dust of waste foundry sand, and fly ash can be applied as an alternative aggregate for lightweight concrete production. Above method can offer an affordable option for the production of the proposed panel system as the materials is widely available and the manufacturing process is relatively low-tech and cost effective. (Qi et al., 2011) The panels can be cast by using the proposed formwork on-site. When if there is not enough space on-site to accommodate this cast-in-place method the production can be carried out in an off-site facility. (Figure 1)

The modular infill system provides a framework that will accommodate different ranges of functional modules. The framework consists of the wall frame and floor module, that both are easily connected with the box structure and detachable when replacement is needed. Basic electrical wiring and pipework will run through the framework, by adding a layer of plasterboard internally to provide a finished wall finish. The material for the wall frame can be locally sourced, as shown in the (Figure 2) in this case, the material choice is chip wood. The floor module is made of fire retardant polystyrene material; the design enables flexible installation of pipe work and other services. The floorboards will be located above the floor model and also, it is easily removable to gain access to the pipes and services.

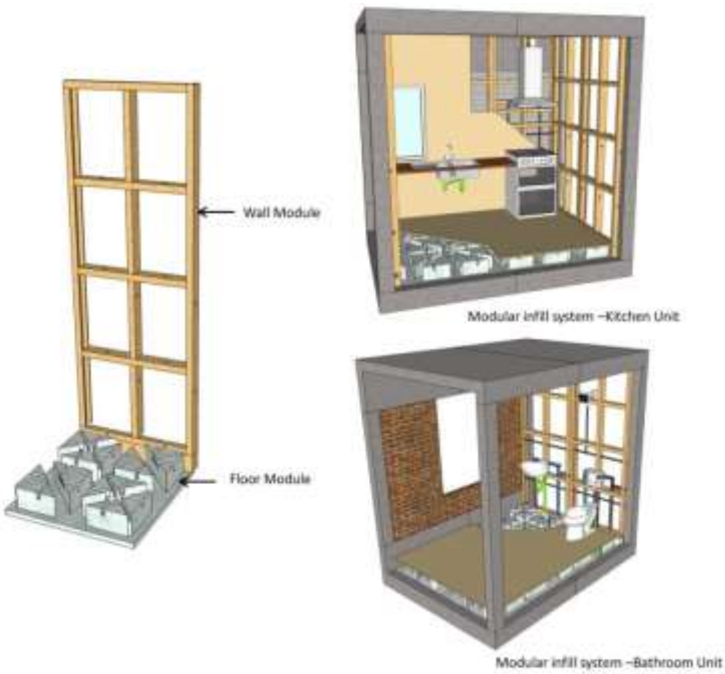

Figure 2: Modular infill system

The functional module is the sub-systems that will provide a specific function. It is an accessory for the proposed Interactive cluster that can be integrated with the modular infill system or act as an individual technology input sub-system. The function module can be added based on the customer's personal requirement. The typical modules are; energy saving module, recycling module, workstation module, and mobility module.

Formwork system is specially designed to produce the Panelized system. Again, the material sources for such system may vary which depends on the availability at the local level. As illustrated in the (Figure 3) in this case it is made from reclaimed wood pallets. The formwork needs to be easily transportable, durable and affordable

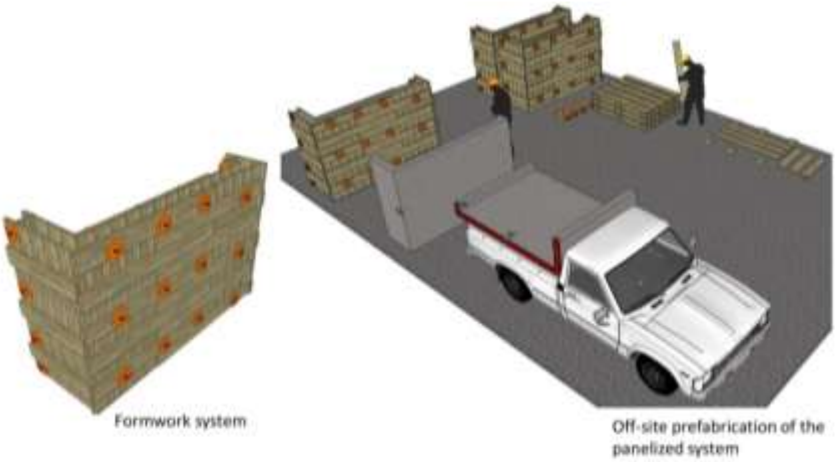

Figure 3: Formwork system

4.1. Proposed construction method

The Interactive cluster is proposed for regenerating the informal settlements. When to propose a construction method within this context that the geographic location, social, demographic characteristics of the area need to be thoroughly evaluated. There are constraints associated with developing such system, such as lack of local skilled labor which is familiar with the construction of prefabricated modular elements, inadequate infrastructure to support the system. Despite these constraints, there are also opportunities when the system is successfully implemented. For instance, the proposed building will be no longer remains static, but adaptable and reconfigurable, this is enabled by the modular design.

In this paper, three construction cases will be analyzed. The first case demonstrates the expansion of an existing building. As shown in (Figure 4) the formwork systems are delivered on-site by a pickup truck. The casting of the panelized system has taken place; the worker can use basic hoist system to move the cured panel to the assembly position. The proposed extension is added to the front elevation of the existing building. For this reason, addition, structural support column, and beam were constructed in a conventional on-site casting method to support the extension above.

The second case demonstrates the construction of a large-scale extension at the front of the existing property. The structure of the existing property is inadequate to support the proposed work. Therefore an additional structural support system was added to enhance the existing structure as well as provide load-bearing capacity for the proposed work. Similar to the first case, the prefabrication task is carried out on-site by using basic tools and the proposed formwork system.

The third case demonstrates the construction sequence of a newly built property. After the foundation is in place, the structural frame system will be erected. In this case, the structural skeleton is produced with conventional cast-in-place method. Once the structural frame is completed, the prefabricated panels will be hoisted to the assembly position and to be attached to the structural frame. (Figure 5) The void space in the box structure will be filled with bricks and internally fitted with the modular infill system. There is a proposed balcony which is also erected with the conventional cast-in-place method. The complete building has shown a variety of material usage, for example, bricks, galvanized sheet metal, and composite panels. The roof garden provides an opportunity for urban farming, farming functional module such as aquaponics and vertical growing technologies can be introduced to the roof garden. Last but not least, a side extension is taking shape which demonstrates the structure could expand when requires.

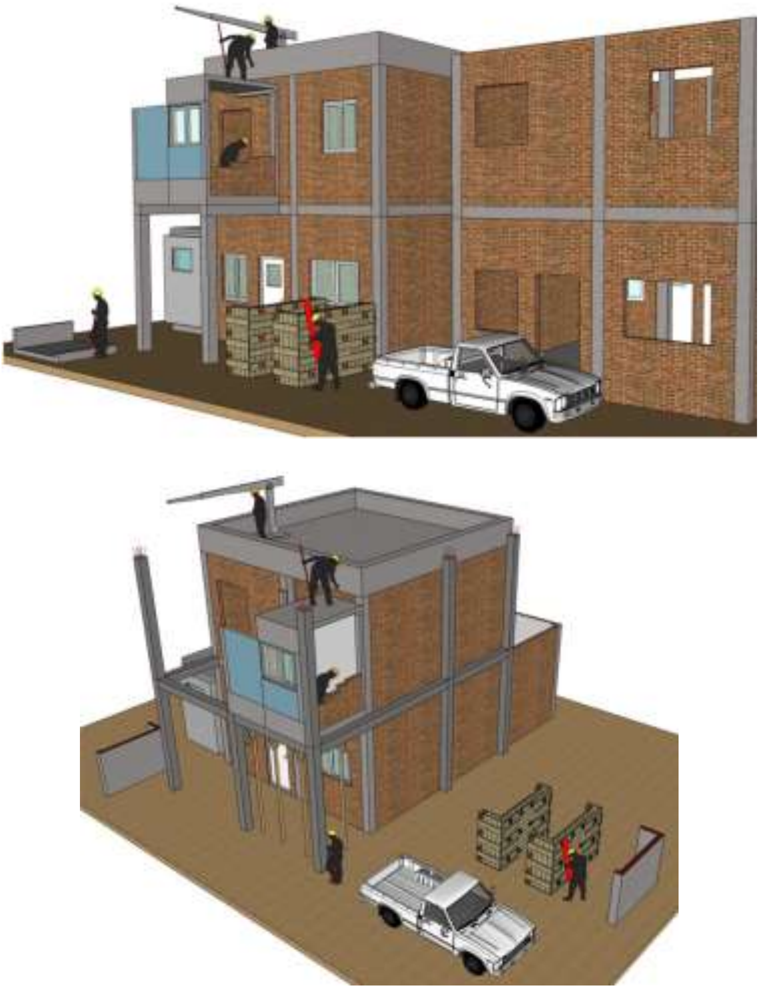

Figure 4: Extension of an existing building

The Interactive cluster is designed to offer maximum flexibility during its use-life. To reflect the term “interactive” the system is divided into four levels which are domestic level, unit level, building level and urban level. Within the context of the domestic level, the appliances can be adapted and altered to suit current demands such as infill walls, functional modules, kitchen unit, and bathroom unit. For example, the kitchen unit can be easily upgraded or reconfigured and then reconnected with the services during the renovation. Regarding the unit level, the building system can be disassembled and reassembled when requires. This approach minimizes the impact posed on the existing building or neighboring building. Alternatively, the function of the building can be modified; e.g. from residential to commercial, by installing different functional modules when required. Building level demonstrates that the entire building can be relocated. This feature is extremely useful when to regenerate informal settlements. The building is no longer being demolished, but relocated which could reduce construction wastes as well as avoid social tension during the demolition process. Finally, in the urban level, the building system can adapt to the fast urban development and maximize building lifespan. A new urban region can quickly be constructed using the proposed system; buildings from one settlement can be relocated where necessary. (Pan, 2015)

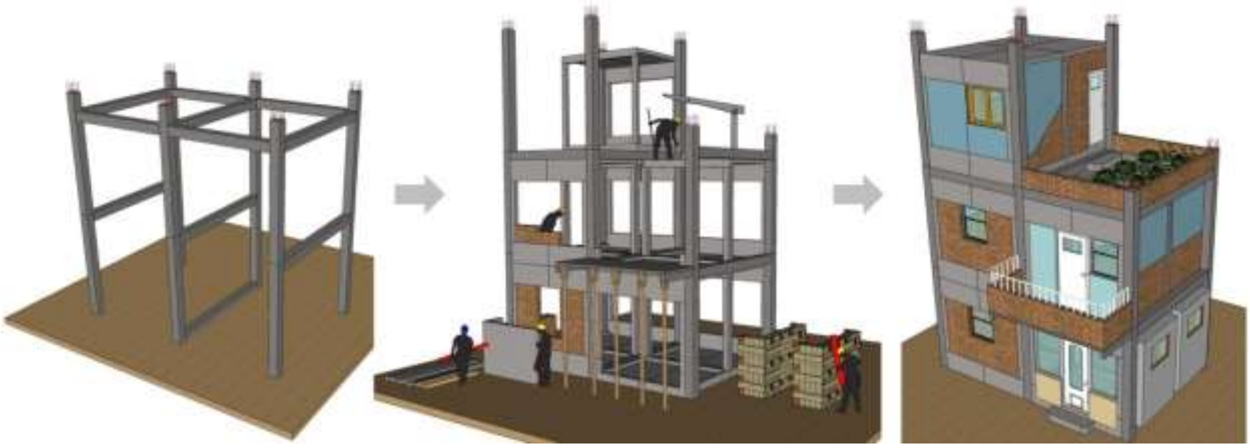

Figure 5: New built construction sample

4.2. Proposed business model

The Interactive cluster emphasizes that a building should not only be permanent but should also offer flexibility and interchangeability throughout its lifespan. The building system is based on the principle of open building concepts; it is highly standardized yet customized. It is possible to be implemented in various configurations and specifications to match client's requirements. Mostly, the system can be produced with basic tools, both on-site and off-site which are affordable for a wider group of customers. Overall, the system has a huge potential to be promoted as a successful hybrid construction system in solving regeneration of informal settlements.

The marketing strategy will determine by the stakeholder groups. For instance, the end user group includes occupants of the building, and stakeholder groups consist of government, investors, contractors and suppliers. The Interactive cluster does not belong to a single commercial domain. It provides a complex market chain and offers across the commercial disciplinary practice. The main markets consist of; architectural, real estate, manufacturing, logistic, distribution, assembly, and maintenance.

The design stage begins with an open source online platform where clients can upload their requirements. The requirement will be available for anyone interested in designing the system by using building component, modules provided in the online design library. The online design library serves as an online catalogue design tool for the public. Once the design is finished, it will be submitted for an inspection by a qualified engineer. If the design is accurate and complies with rules and regulations, then it will be transferred to the manufacturing facilities. Before the demand to achieve economies of scale, the production of the building elements will be conducted locally, preferably within walking distance from the building site. The tasks can be produced by smaller local contractors with basic tools, and skills to save costs as well as provide employment opportunities locally. Alternatively, once the demand reaches economies of scale, the production will be allocated to an off-site facility.

Regarding sustainability, the system will eliminate construction waste, especially in the slum context where the domestic waste treatment has already imposed a huge burden on the local authority, and it will utilize construction land more efficiently and sustainability. Second-hand building components can be upgraded or traded in exchange for the new components, therefore, extending the building lifespan. At the current stage, a construction project in the Cairo slum is unregulated and unplanned. The methods people use are often dangerous and time-consuming, and inefficient. The proposed building system leverage the construction activities in the informal settlement from the current stage progressively move towards a systematized and safer operation.

5. FUTURE STUDY

The Interactive cluster still in its conceptual stage, yet the system provides a huge potential to solve issues imposed from the redevelopment of informal settlements or construction of the new urban project in developing countries. For future reference, an extensive field survey is necessary to evaluate the diverse situation in the local community and identify stakeholder group and their requirements. The project team to test the concept in a full-scale prototype is essential during the dissemination phase. Based on the result of this theoretical approach, a detailed action plan will be drafted to tackle the implementation task in the informal local context.

6. DISCUSSION AND CONCLUSIONS

This paper has given a theoretical overview of the concept of the Interactive cluster and how the proposed system would solve the issues imposed on the regeneration of the informal settlements in Cairo. The system allows the building to transform into the heights, volume, and function based on the demand locally. The concept and the proposed business model will provide a unique opportunity for all stakeholders to embrace the urbanization trend and also provide a practical solution for regenerating informal settlement in the future. However, it still requires further research, implementation and pilot project in the future to verify the effectiveness and practicality of the system. Currently, the proposed system has the potential to solve upgrading of the existing building, expansion in an individual user level, family, and local level. Furthermore, once the system reaches economies of scale, it will be used to construct a larger scale regeneration project by the governmental entities.

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Technology Era City Models and Governance Urban Innovation

Integrated Planning

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Abstract *Urbanization and Globalization are two main factors that affected the Cities Future. Many cities around the world witnessed urban transformation due to their shift towards technology and knowledge-based economy. The concept of "growing" cities is based on implementing integrative planning policies introduces different types of city models. These various models offer a branding tool for cities of the digital age. Therefore, the paper is comparing between five of the most popular models recommended for city transformation is the technology era, the examined models through the study are the Knowledge City, Smart City, Capable city, Liveable City and resilient city. Since the aim of such City standards is to provide sustainable development is to increase life quality for the city residence. Therefore, to achieve such sustainable development in the various city models, integrated planning is required, where it demands Good Governance urban innovation and management. However, technology, social, economic aspects are changing the traditional notion of Public and Private intervention and service models. Therefore, Urban service standards, as an essential ingredient of integrative planning implementation, obligating planners to consider not only the urban physical structures of a city but also to make civil society as part of the city governance being more efficient and effective. The paper aims to demonstrate the selected city models and the Governance characteristics about the used management modes (3PPP & 4PPPP). Furthermore, the paper will examine a comparative analysis methodology of the Five City's models, considering their major characteristics, development strategy, and governance mode. Concluding the Knowledge City framework is introduced as a city model most appropriate for the Contemporary urban transformation of cities of the current technology era.*

Keywords: Good Governance, Knowledge, Technology, Public/Private intervention, Frugal Government, Urban Service Modes (3Ps/4Ps), City models.

1. INTRODUCTION

Urbanization is evolving rapidly but, this urbanization process is unfolding unevenly around the globe. A rapid process of urbanization is taking place particularly in Asia, Africa and Latin America (UN-reports 2011). Global population is moving to the urban area, creating pressure on development path of cities. Indicators such as structural poverty, the rapid increase in energy costs, depletion of non-renewable resources, global climatic changes, and high pollution growth are signs of deteriorating built environment in cities. Since half, the world population is living in an urban context and by the year 2050, seventy percent of the world inhabitants will be living in cities with ever less capacity to adapt to systemic challenges. Urbanization is a wide-ranging concept; it is the course of changes of people's production models, living styles and values caused by productivity progress, as well as a significant hallmark to measure the economy, society, culture and technology of a nation and region.The metaphor used by Sir Peter Hall in his quote: "It is easier to send a man to the moon than to plan and design a city" highlights the complexity of the city production process. Although after the downfall of the Roman Empire for many years' people weren't concerned how city are produced because the urban Structure of Cities was created through an organic process. But the middle age organic urbanization process provides complexity qualities that until now enormous preservation efforts are deployed. Existing urbanization typologies could be described as organic, industrial (18th and 19th centuries) and modern urbanization. Nowadays cities development competition is influenced by the capability to invite, generate, maintain and foster knowledge, innovation, and creativity. Cities are searching for branding factors which need a lot of means of collaboration globally with other cities and locally with the private sector adding a new role for cities in the global competitive platform (Metaxiotis et al. 2010).

2. Research methodology

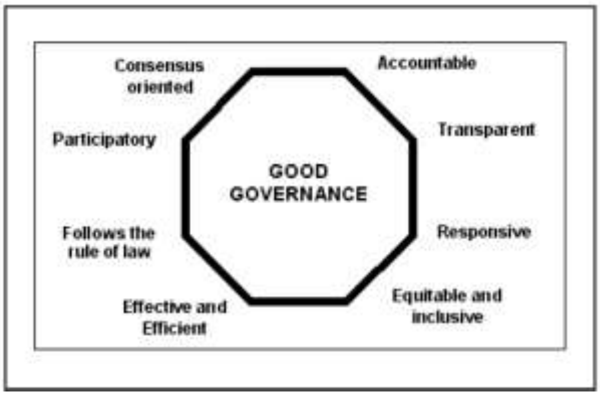
The research method adopted in this paper is starting with an exploration of literature to define and analyze what is good governance. Also, the theoretical background is highlighting urban service modes of governance. Moreover, different scholars' attempts to classify city models and management models that are suitable for current technology and knowledge era. The paper will use an analytical framework governance highlighting their role in producing different city models and typologies. The study conducts a comparative analysis of five city models currently most used in the digital age city transformation paradigms. The choice of these models was based on two criteria. First, all selected models are based on technology and knowledge economy. Second, these models realization depends on the role of governance as a key player in the city transformation process. Demonstrating urbanization - globalization concepts and their reflection on cities standards, putting into consideration how Creativity and Urban innovation are strongly related to Knowledge and technology. Having a theoretical base of Governance and integrated planning emphasizing the criteria of good governance with several types of the urban service models mentioning their advantages and drawbacks. Highlighting the different city models comparing the main features of each model. The comparison is based on three primary variables characteristics, central policy, and governance mode. Finally from the in-depth study of management modes and city models, a framework of knowledge city is recommended as the most appropriate model for the current city of the technology era.

3. Literature review

Globalization is leading cities to be more competitive, transforming social, political and technological structures. As a result of these changes research is focusing on interventions of city making process to analyze city paradigms to adapt to the modern city's needs. Cities can be a symbol of political power, economic wealth and creative innovation (Chin et.al, 2010). Contemporary city models are promoting competitive strategies to help cities to connect with the global city network, one of the most important sets are knowledge and technology policies. In the 21st century, many cities around the world have faced significant urban transformation due to the cities shift towards knowledge-based economy and technology integration, creating new settlement models (Castells,2000; Baum et al.;2007).Christensen et al. (2009) define technology generally as including not just machines or devices but the methodology, scientific knowledge and whatever else affecting the way assembly is carried out. Technological (or methodological) enablers allow problems to be addressed on a smaller scale, with lower costs, and with fewer human skill than was precisely needed. Also, technology is a result of innovation and would help to promote innovation further. While, the ICT cost has dropped down expressively over the past two decades, and the technology evolution has made many things possible, from smartphones to smart supplementary restraint systems in cars (Levy and Murnane, 2004). Therefore, this development of technology and ICT created an emerging economy (knowledge-based economy) Therefore, this economy transformation has created pressure for the urban development pattern is needed.

Throughout 2015, especially in the climate change conference in Paris, a massive attention focused on city leadership about overcoming city making challenges. Also, Highlighting the raising of the role of local leadership to overcome global urbanization challenges. The integrated process of city development depends mainly on the governance characteristics. The “governance “is not a new concept, but deep-rooted to the human civilization (Gardner et al., 2016). “Governance” can be defined as the decision-making process and the procedure connecting these decisions to implementation. There are several contexts where Governance can be used such as international governance, regional governance, corporate governance and local governance. Meanwhile, the process of decision-making and the progression of implementation of these decisions are considered management, examining formal and informal actors in the governance model to analyze the decision process and enforcement methods. Therefore, Government as a structure is a single player of governance. All other players other than administration and the military are grouped together as part of the “Civil Society” (Unescap.org, 2009).

According to UN Economic and Social Commission for Asia and the Pacific defining the good governance key features are as following (fig 1); 1.Participation, 2.Consensus,Oriented, 3.accountability, 4.transparency, 5.responsibility ,6. Efficient and effective,7.equitable, inclusively. Finally, 8. the ruling of law follows. Not only the voice of society minority (especially the most vulnerable) are heard in the decision-making process, but also, the present and future society need to be taken into account (sustainable development). However, to have an overview of mechanisms supporting integrated planning, and associated challenges across the planning cycle. A major component of this integrated process is the institutional system. A set of governance initiatives about the concepts of contemporary city urban systems will be highlighted. The paper will focus on the Frugal government action and reflect on different urban service models (3P and 4P). also studying any governance model includes the study of the stakeholders public sector and privet sector. Next section shows the stakeholders relation to urban interventions and urban management in the digital city age.



3.1. Interested parties and Urban Management innovation

3.1.1. Public Sector Intervention

Public management planning enhances potential distribution of smart technologies. Since ICT helps in structuring and framing out planning and city management initiatives. Also, enabling more efficient resource and implementation with the presence of transparency. Moreover, ICT data enables resource integration within city systems through identifying value at stake and the involved actors, an approach which will adopt implementation of local policies leading to integrated creative solutions for waste management, buildings, water and energy on different levels starting from the district level to city level. Such approach supports entrepreneurial and sustainability ambitions for the utility / mobility and other sects. (Eschergroup.com, 2016)

3.1.2. Private Sector Intervention

The private segment is in a position to perform a pivotal part in accelerating integrated planning and sustainable growth. For this to happen, capacity building is required to create new skill sets related to green industries and jobs. Greater awareness of the benefits and opportunities of integrated planning and collaborative approaches also needs to be built to foster the identification of business and investment opportunities that economically, socially and environmentally viable over the longer term (PAGE, 2016). The private sector is critical to achieving the sustainable development goals and transitioning to inclusive, greener economies putting into consideration the increasingly globally interconnected nature of markets, markets corporations key players in natural resource decisions. Though the private sector is becoming increasingly involved with sustainability agenda, there are lots of needs to done to ensure that it is integrated into the process and that strong links are developed with governance and other stakeholders. Moreover, private financial requirements to be mobilized, for example, investment in renewable energies, affordable housing, proper water treatment (PAGE, 2016).

3.2. 3 PPPs and 4 PPPPS Urban Service Model of Governance:

Public Private Partnership (3PPP) is a widely used method to provide basic socio-economic infrastructure and services (Thomas Ng et.al, 2012). There are many specific 3PPP managing departments to identify the role of private sector in public service distribution, which tends to vary from city to city (Catapult Programme, 2014). However, In the 3 PPPs initiative can face various challenges to be encountered causing unwanted project failure (Goldstein and Mele, 2016). Primary failure is found in the opposition of the stakeholder. Therefore, scholars stressed the important fact of involving the Public (People) within the 3PPPs scheme, for example public-private-people-partnerships (4PPPP) better than an only dual horizontal relationship between the private and public divisions. Moreover, the 4 PPPPs service model operation framework embraces a bottom-up approach with participatory strategies bringing the public engagement visibly for the infrastructure policy-making and planning. With such approach and community engagement strategies , decision-making process by policy creators, who are usually holding the definitive decision authority, will be concerned with the citizens active participation and engagement (Thomas Ng et.al, 2012).

The available Literature is discussing each urban model individually without linking various paradigms together. Also, Governance management models are not discussed in relation to urban city models.Therefore this study will contribute to analysis various city development patterns. Also, linking governance models and characteristics to city development standards Also, the Study is highlighting the Governance model role in these city models. Finally, the study is recommending a framework for the city model used as a city transformation model for the technological era.

4. Discussion

Adverse impacts of rapid urbanization have forced city authorities' focus on finding city models without compromising the quality of living for future generations. (Chin et.al 2010). These urbanization process generated challenges, and globalization has major short-comes that need the emerging of a new paradigm that develops better urban city structures to overcome the past development process outcomes by rethinking the tools that are used to shape contemporary cities (Friedman 2005). This position creation is considered the city new development paradigms linking the global knowledge economy pressure on the local urban context (Yigitcanlar et al. 2008a;2008b).

4.1. Technology and Knowledge era city Models:

Each city model is discussed individually, against three primary considerations: the key players, design characteristics and challenges; highlighting governance model actions can help result in game-changing outcomes in city development. This study will explore contemporary city models definitions (Knowledge city, smart city, liveable city, resilience city and capable city) and provide a comprehensive analysis to these paradigms. Also, the paper is linking these digital era models to the city leadership and governor role in the development agenda.

4.1.1. KNOWLEDGE CITY:

Knowledge-Based Urban Development (KBUD) is a tool to forefront cities in the world-wide competition (Yigitcanlar and Velibeyoglu,2008 c).Thus, KBUD can be a successful tool in certain conditions have to be included within the city urban systems such as technology and knowledge infrastructures; promoting talent and creativity for the Human Capital and global economy connections (Van Winden and Berg,2007).KBUD is a management approach to economic growth strategy applicable to human organizations (Carrillo,2002). This method transforms and renewal pattern of the city to a Knowledge City through three primary development paths, Economic Development: an economic model depending on skills forms of knowledge and creativity (Lever, 2002). human and social development: increase human capital talent and expertise (Gonzalez et.al.,2005). Urban development: knowledge district key player in the citywide spatial development (Yigitcanlar and Martinez-Fernandez, 2007).

Knowledge city and the KBUD strategy are considered an important emerging mechanism in the development of the contemporary city. Although there is enormous competition between cities to be knowledge city, a hand full of cities only that have promoted themselves to be KC.(e.g.Barcelona, Singapore, Ottawa, Helsinki, Boston) (Yigitcanlar and Martinez-Fernandez, 2007).While, further cities urban development agendas are focusing to target the KBUD strategies (Ergazakis et al.,2004).Knight 1995 has linked KBUD to be the base of sustainable urban development using the global knowledge as a transformation tool to the local urban development. The Organization for Economic Co-operation and Development management framework regarding comprehensive and regional development linking knowledge management to urban development (OECD,2001;2005) this frame can be referred to as one of the first KBUD strategies (Yigitcanlar,2011a). Also, AEUB linked the KBUD with the quality of life enhancement in the city development to the city sustainable development objectives and strategies. Highlighting KBUD to emerging towns is considered as phenomena. also exploring its ability and a tool to enhance city competitiveness by expanding knowledge-based economy clusters (Yigitcanlar,2011b) by changing KBUD from a management strategy to a process of city transformation.

Knowledge cities (KC) are the formation of abstract forms replacing physical commodity, these Knowledge space contribute to the knowledge economy and provide opportunities for innovation, creation and knowledge exchange (Ergazakis et al., 2004). KC is based on creating the state -of - art product using knowledge, research, and technology that Private, public and people sectors value to generate better services (Carrillo,2006) also promoting high-quality conditions for creativity, innovation, and technology (Landry, 2008). Lesson learned from best practice of five flourishing knowledge cities examined by Yingitcanlar– Austin, Barcelona, Helsinki, Melbourne, Singapore – are as following (2009, p.240)

1. Long-term effective development plan, vision, and strategy
2. social wellbeing and political process
3. the global and cultural identity of the city adaptability;
4. urban innovative creation;
5. Strong financial funding, corporation, and strategic investments;
6. Intensification life Quality of urban systems, and; economical efficient and accessibility to cutting-edge communication systems
7. Metropolitan web-portal – e-government;
8. Research excellence – R&D institutions, universities;
9. Residents value creation – skill development, social outcomes, employment;

4.1.2. SMART CITY:

A sustainable city Model strongly related to knowledge and technology, a smart city in the literature is defined by various ways depending on stakeholder’s role. However, smart cities are used as a marketing tool by service providers underlining that Smart means using intelligent technology and services. While city governors use the smart concept to promote the state-of-art policies in the global arena. Thus, both of these major stakeholders have defined smart cities about the availability of technology and supporting systems. On the other hand, researchers’ definition is established on the analysis of the performance of the urban structures within the city. The model of the smart city is still not agreed upon, since, smart cities have various definitions and the inconsistency of using the” SMART CITY “label (Tranos and Gertner, 2012). It is necessary to define smart cities appropriately to promote this highly potential concept and to exploit the most form of implementation (Chin.H.C. et.al. 2010).

To summarize the definitions of the Smart cities can be concluded into three main points

First: “A Smart City” is a self-running mode depending on the use of ICT that can sense, diagnose and heal potential turbulences in urban systems (Hall;2000). The city integrates sensors and actuators on the infrastructures of its urban system and operates through a management system depending on reducing the involvement of human being in the operation of the urban systems (Palmisano,2009). Therefore, use of ICT would allow urban systems to achieve optimum functionality through an integrated design and adaptive capabilities (Alobaidan, 2009).

Second:” A Smart City” is a holistic system of its urban systems (IBM, 2009): transportation, healthcare, utilities, education, housing public safety and security, communication and business. These systems instrument and interconnects to overall system with a higher level of intelligence. Close collaboration between a city’s three stakeholder groups (people, public and private) is necessary for an effective and efficient operation of city as a holistic system (Giffinger et al., 2007).

Third: “A Smart City” is a city that aims to improve the quality of life of its inhabitants, becoming economically and environmentally sustainable through efficient resources utilization (Figge;2009). The use of ICT services integrated with governance initiated management systems allows effective use of resources to achieve the common set of goals for its urban systems (Wladawsky-Berger;2009).

Main aspects that can be highlighted from these several definitions of Smart cities (Glaeser, E.L.;2006, Giffinger et al.;2007, IBM;2009, Wladawsky-Berger;2009) are as following:

1. Smart City vision: self-running mode using ICT
2. ICT infrastructure, services availability and quality
3. Smart concept to promote the state-of-art policies in the global arena
4. human capital Role, learning, and education development of smart cities
5. Smart city as a complex urban system
6. Smart city performance
7. Public and private collaboration

4.1.3. CAPABLE CITY:

The leading aspect of country’s National Development Plan is building a city, would be developing a city with “Capability”, a term with two different meanings, depending on the context. The first refers to human capacity related to conditions, opportunities that enable people to lead their lives that they desire. The second relates to the Capacity of the City to serve as an enabler of human capability, for example “to address the twin challenges of poverty and inequity. Moreover, the need is for a city with the ability to play a transformative and development role, with well-run and coordinated City institutions staffed by skilled public servants committed to the common interest and capable of regularly distributing high-quality services to all citizens. Given the rapid urbanization rate and that numerous city contain primary drivers of economic growth, poverty, and inequity. The state-wide capability cannot be achieved without capable governance. The centrality of the local administration generally and cities correctly is reflected in government's “back to basics” policy, introduced to address the wide-ranging problems undermining the capability of local government to function effectively. Among other things, the back to basics strategy stresses the need to appoint appropriately skilled managers in municipalities (Powell and Donovan,2015).

4.1.4. LIVABLE CITY:

Liveability is referred to special urban system features; that contribute to the social, physical well-being alongside the personal development of all residents with respecting both History imprint and the urban rights of those who are not born yet and highlighting the rejection of wasting natural resources which must be left intact for the whole human kind. As Cools argues that the city should be treated as a living organism since the urban development is like life that needs the balancing act to ensure the proper city function (1997). Therefore participation processes are the livable city brain.While, the city vision, plans, and implementation programs are considered the city nervous system. Both brain and nervous system are responsible for transforming urban structures. However, the public realm of the liveable city is considered as the heart of the city, and the primary identity defines the city organs are all the urban system building up the city nodes (neighborhoods, clusters, other hubs, etc.) and connecting network (infrastructure, street network, etc.). The city as a living organism is a complex structure with the relation between parts and whole creating the web of livability. (Holden and Connelly, 2006).

4.1.5. RESILIENT CITY:

“A resilient city is the one that has developed capacities to help absorb future shocks and stresses to it's economic and technical systems and infrastructures so to be still able to maintain substantially the same functions, structures, systems and identity” (Resilientcity.org, 2010)

Resilience seems only addressing the crisis of city suggesting a general measurement of sustainability. It reflects the city’s ability to persevere an emergency situation, to continue its core operation despite overwhelming challenges. Beyond disaster preparedness, resilient systems are common systems that are scaled up and dealing with a system of urgency is like dealing with a standard system but with more management. Urban resilience is like an immune system for the City. “Making Cities Resilient” campaign by the United Nations Office for Disaster Risk Reduction addresses issues of local leadership and public risk on the sustainable urbanization principles established by the UN-Habitat World Urban Campaign. (Unisdr.org, 2016). According to Rogers (1999), Urban resilience is contingent three main factors

1. The information technology and exchange (technology revolution).
2. The Ecological threat surrounding a greater accepting of consequences of our rapid natural resource consumption and the significance of sustainable development
3. The Social Transformation - new lifestyle choices

4.2. Governance Modes:

Governors mode is a key player in the realizing of such city models. The leadership and Governor policies on the city scale are argued to be a way to solve global urban problems according to Barber 'mayors rule the world' (2013). Urban governors are considered an expanding academic field(Pierre,1999,2011) but, currently, literature is linking urban governance with technology and innovation (Meijer & Bolivar, 2015). This study is contributing in linking governance management innovation to urban development models of the digital age.

4.2.1. 3PPPs Urban Service Mode:

In the Public-Private collaboration studies on the local level. The importance of highlighting the differences between the Public-Private PPP models is essential. There are three typical types of PPPs model implemented through transferring inter-organizational concepts from governance forms to an internal management of a multi sector-organizational partnership. The ideal organization types are Organic PPPs, Symbolic PPPs, and instrumental PPPs. Organic PPPs depend on a self-managed network based on trust. While Symbolic PPPs, are based on a hierarchy operating approach of a Public-Private partnership through a command chain system. Organic PPPs rely on a self-managed system based on trust. (Goldstein and Mele, 2016). The number of Urban planning fields where PPPs models are found and implemented is rapidly on the increasing specially PPPs solution became popular especially regarding the provision infrastructure areas (example: facilities, parking, etc.), housing projects, urban regeneration, and development. Projects and integrative urban development including the internal city. Lately, PPP arrangement in Public service provision field became popular. But unfortunately, the application of PPP's model has some Challenges; there are some remarkable obstacles to a successful realization of PPP's model configuration. Such as The long interval of the planning process, the complexity of different projects, the holdup and postpone problems began by a modification of partners position. Also, the cultural variances between public-private partners, the role of the public is funding and the guidelines of competitiveness for public projects that are communicated by official players such as European Commission (Nijkamp et.al, 2002).

4.2.2. 4PPPPs Urban Service Mode:

The private sector's participation in PPPs service model is often rejected by developmental organizations, where these structures illustrate the relationship between the public-private and People (community) parties interact and affect each other shaping equitable and productive partnerships. Supposedly PPPs service model initiates equal partnerships between Public and Private actors. As a principal actor, Governance in PPPS model framework plays an important role but unfortunately in some cases their participation might be found insufficient to give desired expected public outcomes. The People (Community) is the weakest actor in the 3ppp model. Also, it is found that the private sector is not a central factor in the development process, and its participation in the PPPs model is always insufficient, mentioning the fact of how private sector actors are usually centered on profit making to the extent of forgetting their social responsibility (Lehavi, 2016). People (Community), in the 3PPPs model, are not considered as a crucial actor in formulating the development plans. In the 3PPPs, People can only express their concerns and requests in certain milestones where they are merely notified by the process of work in some development projects. Public participation had been traditionally partial in infrastructure projects and integrated planning. It is noticed the lack and neglect of their early involvement in the Public Welfare development projects (Table 1). Therefore in 4PPPPs model, the

People (Community) participation is an essential, crucial feature in the integrated planning process and development knowledge possessed by different stakeholders (Public-Private Actors and Decision makers). The 4PPPPs framework is the important urban service model in the Frugal Governance Urban Innovation (Thomas Ng, Wong, and Wong, 2012).

4.2.3.

Good governance depending on people as a receiver (3PPP mode)	Good governance depending on people as a participator (4PPP mode)
Participation: organized participation needs freedom of expression and civil society association.participation can be either direct or intermediate with institutions or legislatures	**Equity and Inclusiveness**: involvement of all groups, especially the most vulnerable, assure the well being of the society mainstream.
Transparency: following regulation and rules to take a decision and enforce them. Also, Data and the information is accessible and available (easily acceptable means and forms) for inhabitants affected by these decisions enforcement.	**Effectiveness and Efficiency**: Good governance means providing processes and institutions by making the best use of resources (sustainable use) meeting the society needs.
Responsiveness, Good governance management provides service to the whole society and identifying the entire community needs. Not only the governance is a provider, but it is related to the time Spain the service is provided.	**Rule of Law**: Rule of Law: Good governance requires the enforcement of a fair legal framework, offering human right protection specially minorities .also,the law implementation should be an independent judiciary.
Accountability is fundamental requirements for agood governance. The quality of being accountable should be wholistic not only involving the government but also including private and civic sectors.	**Consensus-oriented:** Good Governance should have diverse broad consensus to include the whole community interest. this requires a long-term human sustainable development approach that adapts to diverse social, cultural and historical contexts in the community.

4.2.4. Frugal Governance:

Thomas Jefferson said about Frugal government: “A wise and frugal Government, which shall restrain men from injuring one another yet leave them otherwise free to regulate their pursuits of industry and improvement, and which shall not take from the mouth of labor the bread it has earned.The sum of good Government necessary to complete the circle of our felicities” (1801). Efficiency, effectiveness, and quality of service delivery are globally considered against fiscal restraints, social demands, and reputational factors. The satisfactory resolution of most of the emerging and existing community challenges is contingent large-scale citizen engagement and proactivity. Frugal Government requires new thinking, managing change, and based on that:

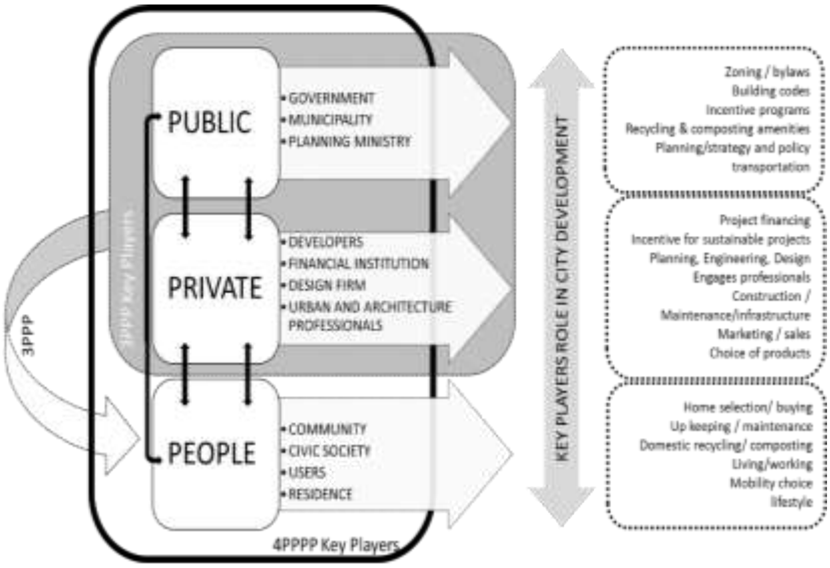
1. It is parsimonious in the use of potential financial resources as well human creativity, imagination, and collaboration both inside and outside the public sector.
2. It is user (Community) centered and value driven boosting benefit versus cost of public service delivery per user – defining and expressing value in differential terms between benefit and cost, both in non-monetary (subjective) as well as monetary (objective) terms.
3. It adopts the diligence of a good family man in finding, measuring and distributing available resources in the direction of sustainable innovation – acting as a point of reference for the behavior of all the members of its own “governance system”:

citizens, businesses, third sector operators, academics, media and other stakeholders.

The above calls for a new capacity of policy makers and civil servants to set shared goals for civil society, as well as mobilize (most of the) people in their fulfillment or at least complying with them – which is the essence of leadership.

4.3. Governance model in relation to City development:

Development of cities the public-private partnership (PPP) is becoming a city development route commonly adopted as a strategy in developed and developing nations. However, The PPP implementation can flexibly adapt to different contexts in different ways depending on the country vision. Although the City development using PPP is the contribution of the private sector in all or any of



development process (fig 2) (Design, construction, finance, services, and operation) (Alfen, 2009). But the provision of the city by private sector participation is resisted widely especially in providing basic urban services such as infrastructure and affordable housing.

Therefore, the resistance is due to two reasons either that the urban service is profit driven or that the urban service would be long term project to solve an urban problem. As a result, the public sector would counterattack private sector participation. Therefore, keeping the public well informed and supportive of the urban project is an on-going challenge for all governance. The public authority should help the integration of stakeholders by easing continuous dialogue to providing comprehensive data regarding public issues to relieve speculation and unfounded public concerns. However, the importance of environmental sustainability factor is now globally recognized in housing and urban regeneration policy and strategies as a method to overcome the increasing degradation of the built environments, Though, in the majority of countries, the PPP implementation responsibility related to the urban sector is either in the finance or infrastructure. Therefore, PPP projects tend to focus on economic aspects rather than a balance between the three pillars of sustainability (Economy, Environment and Social). Accordingly, several urban sector PPPS lack the integration of essential principles of sustainable development into the planning and implementation process.

4.4. Comparing the city Models

This research is examining five city models commonly recommended to face globally city transformation tools in the technology era. However, these models development is based on the technology and knowledge economy.Moreover, the development strategy for each model adds a unique character for each model. Also, these types can be divided into two groups when considering governance mode. The first group depends on the private -public partnership (Smart, Capable, Resilience) which can be seen as an urban intervention from above. The Smart City, we find a good relationship between technology and public -private intervention to enhance the public services. In the Capable city we find a good relation between economics – society and environment but mainly dominated by the public sector (Government). The Resilient City is mostly based on the strength of economic factors and the ability of the public-private partnership on passing crises. The second group depends on the involvement of the 4 PPPPs which indicates an urban intervention as a bottom-up planning approach.Consists (Knowledge city and Livable City). The Knowledge City, there is a strong connection between the Society and Socio-Economic factors based on experience. While, the livable city, Nature and Society have the leading role in the city approach. In both city models, the 4PPPPs service model is actively implemented where the society has an essential role in the management governance process (Moskalyk, 2011)

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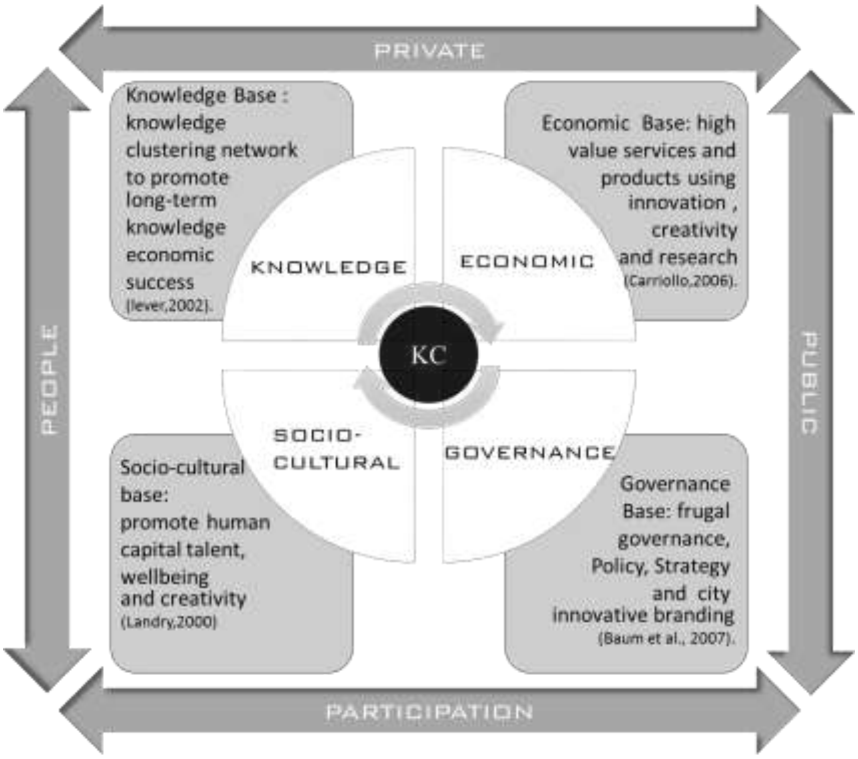
	KNOWLEDGE CITY	SMART CITY	CAPABLE CITY	LIVABLE CITY	RESILIENCE CITY
CHARACTERISTICS	1. Knowledge base 2. Economical base 3. Socio-cultural base 4. Governor base (Yigitcanlar, 2011 ;Mostafa and Mohamed, 2016)	1. Smart economy 2. Smart mobility 3. Smart government 4. Smart living 5. Smart people 6. Smart environment (Centre of Regional Science, 2007)	1. Capable people 2. Capable governance 3. Capable policy 4. Capable economy (Powell and Donovan ,2015).	1. Compact city form 2. Sustainable infrastructure accessibility and mobility 3. Environment, activity and culture 4. Participation governance (Levi and Lopez, 2010)	1. Leadership and strategy 2. Health and wellbeing 3. Economy and society 4. Infrastructure and environment (Silva, 2013)
DEVELOPMENT STRATEGY	Knowledge based urban development	ICT technology network and communication	City Management and enabling people	Quality of life and public realm	Sustainable economy and equality
GOVERNANCE MODE	Frugal governance (4PPP)	3PPP	3PPP	4PPP	3PPP

5. CONCLUSIONS

In conclusion, through the paper the several types of city models putting the good governance features as a milestone of achieving the objectives of the City of the digital age. Based on the methodology and analysis of management innovation modes (3PPPs and 4PPPPs) for urban service policies. Each Model was distinguished by its development strategy while all models share the fact that knowledge and technology economy is transforming the urban city structure. For example, the Smart City was based on ICT network connectivity (Information Technology) in its governance system and communication with civil society Smart management, smart people, Smart services. The main objective of Smart City is to create an intelligent system in every city component. On the other hand, the Capable city was based on the Governance institutions ability staffed by Skilled public representing and committed to the common good and capable of delivering consistently high-quality services for all citizens. The Resilient City is based on the concept that a city can face any crises (social, economic, environmental, etc.) and be capable of functioning well and serving the social welfare with high-quality services providing social equality. The Livable City is mainly fighting against the natural resources waste that is needed for Sustaining future generation, in this sense, the city is examined as a living organism respecting both the imprint of history and nature). The urban structure can only be livable if all its parts contribute (Physical,Social, and wellbeing) to inhabitants development with highlighting that we deal with the living organism as a whole, in other words, parts and whole creating the ecosystem complexity of the city. Through the analytical comparison between city models, the paper argues that the Knowledge city is the most holistic approach to the city transformation needed in the technology era (fig.3). The framework introduces the knowledge city consists of four bases (knowledge, economic,socio-cultural and governance bases).The relation between knowledge and economic bases relies on private sector intervention. On the other hand, public sector involvement bridges the economic and governance bases. Moreover, the socio-cultural base is connected due to people intrusion to the knowledge base. Finally socio-cultural and shareholder bases are connected by all the shareholders (Public-private-people)participation mechanism



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Theme II

Technology and a smart built environment

Utilizing Palm Rachis for Eco-Friendly and Flexible Construction in Egypt

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Abstract: *Natural building concept is concerned with utilizing local materials in construction using the inherited skills in order to minimize economic costs and environmental threats. However, the deterioration of the economic status in most of the rural villages in Upper Egypt leads to the usage of wastes and junk to build unsafe covered structures for public areas due to the high costs of conventional building materials such as steel and concrete.*

Palm rachis is one of the most abundant pruning wastes that were used traditionally in simple and cheap construction in rural areas of Egypt and the Middle East. Lately, Palm Rachis was used as the main building material in the construction of the traditional Qattara Heritage Village in UAE and Siwan Eco-lodges in Egypt. This enriched the originality of the Cultural and Environmental Tourism's architectural language. This paper aims to study Palm Rachis as an innovative building material that can be used for constructing multi-purpose light and covered structures.

However, previous structures utilizing palm rachis did not improve to cover wide spans while sustaining high flexibility in form and function in the design of multifunctional public halls. This paper suggests using palm rachis to build arched space truss system that is characterized by simplicity in joints, flexibility in form and function and high structural integrity. This aim is served firstly by investigating the previous examples of Palm Rachis structures, then designing a structural system using Palm Rachis that's structurally analyzed using a scaled physical model and digital analysis using SAP2000 in order to address the potentials of the system .This system prove to be durable, simple and highly qualified for further structural analysis to identify the structural details in depth. This paper is presented to natural building materials researchers, natural builders and activists and Environmental Tourism stakeholders.

Keywords: Multifunctional Halls, Mechanical Properties, Palm Rachis, Physical Model, Simulation

1. INTRODUCTION

The construction industry consumes more than 40% of the global resources which are mostly un-renewable, along with being responsible for over 30% of the greenhouse gas emissions according to the United Nation Environment Estimations (Asdurbali et al., 2015). The unmanaged extraction of un-renewable resources, fossil fuel- dependent manufacturing and poor disposal strategies cause continuous damaging to the environment and threaten the equilibrium of eco-systems (Magwood, 2014). Moreover, economic costs of conventional building materials increase due to the unbalanced supply and demand of un-renewable resources. In addition to that, rural and poor communities employ wastes and scraps as fast and cheap materials in order to build shelters. The result is un-safe and non-biodegradable construction that is toxic for man and environment (Taher and Ibrahim, 2014).

Figure 21: Dharavi slum in Mumbai, India (Taher and Ibrahim, 2014)

Figure 22: Informal Expansion on Agricultural Land in Egypt (Khalifa, 2011)

Therefore, the concept of Natural Building rose as an international concept to develop poor societies from the inside. Building with natural materials encourages societies to build with their own hands using local materials they are familiar with, empowers them by being the true stakeholders of their houses and teaches them the professional methods in order to sustain the independent development on the long term. This leads to decreasing the economic costs, environmental impacts and the enforcement of the social structure and culture. (Kennedy,2004).

Date Palm residues are one of the most important agricultural residues that are used traditionally in cheap and rural construction in Egypt. As the most abundant pruning residue, Palm Rachis is a renewable resource of natural sheathing materials in rural housing .

In addition to that, contemporary Eco-Lodges and Cultural museums utilize Date Palm Rachis, as Date Palm Rachis enriches the traditional originality of such Cultural and Environmental Tourism oriented projects (Elmously, 2005). Adrere Amellal, an Eco-Lodge in Siwa Oasis in Egypt, utilized palm rachis and trunks in the construction of roofs and shades (Alamuddin, 2001). In UAE, the entire construction of indoor and outdoor structures depended on palm rachis and trunks in Qattara Heritage Village in Al-Ain (Piesik,2012).

Figure 23: Roofing by Palm Rachis in in Qattara Heritage village in UAE (Piesik,2012)

Figure 24: Palm Trunk and Rachis used for traditional roofing in Sinai.(Ibrahim, 2010)

Figure 25: Roofing by Palm Rachis Adrere Amellal Eco-Lodge(Alamuddin, 2001)

On the other hand, the utilization of Date Palm Rachis did not develop solidly to be the main structural material of rural construction instead of relying on palm trunks and imported timber in Egypt. Practically speaking, because of the natural asymmetry of Palm Rachis cellular structure, the absence of the understanding of the complicated nature and mechanical properties was always the main obstruction while using structural analysis prior to actual building. This obligated most of the previous researchers such as (Piesik, 2012) and (Peter Sheehan et al., 2015) to depend entirely on building physical models in order to design the members structurally according to the onsite structural behaviour of the members.

However, physical models are not the only proof needed to validate the structural efficiency of a given system, as unpredictable forces such as wind can be very critical that they can cause the structure to fail later on. In addition to that, full scaled models of a suggested system may not be safe for workers if the system fails especially if the system is heavy and complicated in order to cover wide spans over 8m. These limitations reflected on the works of (Piesik, 2012) and (Peter Sheehan et al., 2015) ,that are discussed later in this paper, as the systems had to depend on strict grids and internal vertical supports in order to enhance the structure temporarily according to the onsite behaviour and ensure safety during the building process. This decreased the structural integrity and flexibility of the form and function of the resulting systems.

Therefore, the knowledge gap lies within examining a system both physically and digitally in order to design palm rachis based structural systems that are durable, simple, in addition to achieving flexibility in form and future extensions and function without using internal vertical supports or strict grids. This paper aims to develop a new multifunctional structural system utilizing Palm Rachis to achieve the best simplicity, structural integrity and flexibility in form and function, while maintaining the aspects of availability of materials and ease of construction.

This aim is served firstly by investigating the previous examples of Palm Rachis structures, then designing a new structural system using Palm Rachis that's structurally analyzed using a scaled physical model and digital analysis using SAP2000 in order to identify the structural potentials and limitations of the system.

2. LITERATURE REVIEW

2.1. Date Palm Pruning Residues

2.1.1. Date Palm Rachis

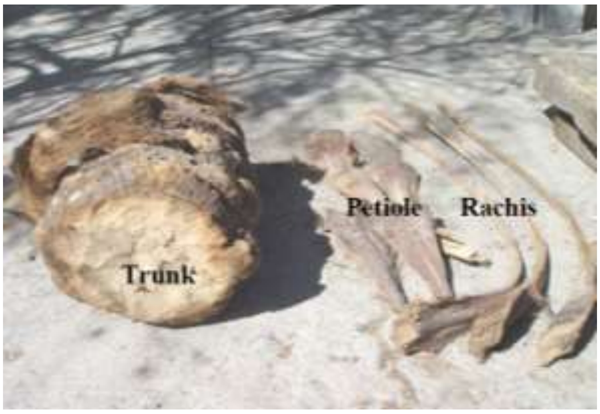

Figure 26: Dried Date Palm Main Parts (Mahdavi, 2010)

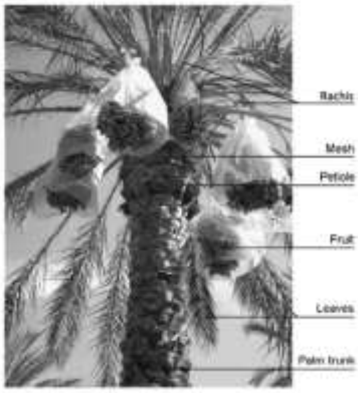

Figure 27: Date Palm Main Parts (Asdurabali et al., 2015)

Palm Rachis occupies the largest percentage of the pruning residues quantities of palm trees, with 9.75 ton/year per palm and 105.3 thousand ton/year in Egypt which counts for 32% of the total residues (Elmously, 2005). This fact encouraged multiple researchers to investigate the possibilities of direct utilization of Palm Rachis in construction with the minimum fabrication to obtain the least environmental impacts and economic costs.

Table 3: Estimation of Quantities of Residues of Pruning Annually Available of Date Palm Trees (Elmously,2005)

Quantity Available annually (air dry weight-10% moisture content	**Palm Rachis**	**Palm leaflet**	**Stem**	**Coir**	**Petiole**	**Total (ton/ year)**
Per palm, kg (mature female)	9.75	8.00	7.00	1.25	4.4	30.4
Total in Egypt, thousand tons	105.3	86.4	75.6	13.5	86.4	328.3

2.1.2. Date Palm Rachis as a Structural Material

Wood and natural materials that consist of fibres such as Palm Rachis are considered as anisotropic materials (Mascia and Lahr, 2006). Anisotropic materials are characterized by different behaviours in the longitudinal, radial and tangential axes. In addition, shearing behaviour is highly dependable on the extensional behaviour due to temperature change.

In order to facilitate calculations in terms of engineering elastic models, natural materials such as wood are usually treated as an orthotropic materials, supposing in the linear orthotropic model that there are 3 planes of symmetry parallel to the 3 axes of the material, and in the same time the shear behaviour is supposed to be independent of the extensional behaviour and temperature change (Mascia and Lahr, 2006).

The tangential and radial directions in wood are identified according to their intersection with the annual growth rings. Tangential direction is perpendicular to fibres and tangential to the growth rings, while Radial direction is also perpendicular to fibres but perpendicular to the growth rings (Green et al., 2010). However, due to the lack of growth rings in palm rachis, the mechanical properties which are perpendicular to fibres are similar in both tangential and radial directions.

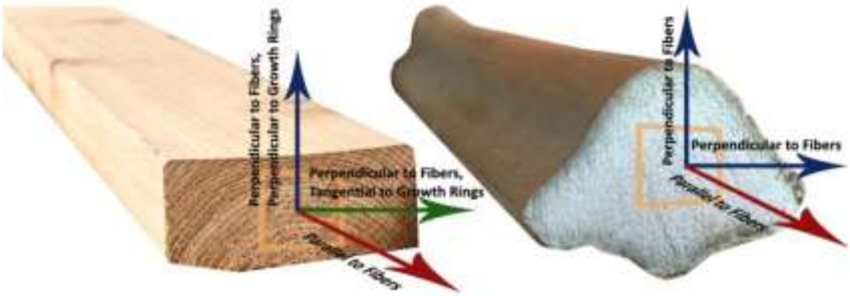

Figure 28: Comparison of the Material Axes between Timber and Palm Rachis (Author)

However, and due to the novelty of Palm Rachis as a building material, no previous tests were undertaken to identify the mechanical properties of Date Palm Rachis according to the material axes. The mechanical properties measurements are to be presented later in this paper.

2.2. Previous Experiments of Utilizing Date Palm Rachis in Construction

2.2.1. Post and Beam Palm Rachis Bundles

A simple shade was constructed by the authors and local workers, in El Qayat Village in Minya Governorate, in order to observe closely the quality of the available skills of the locals and to estimate the time of construction. The construction system was a simple post and beam system made entirely from Palm Rachis Bundles. This idea was inspired from the vertical piling of fresh Rachis in order to dry. It was found that a small bundle of 2-5 Rachises can actually erect independently, thus the bundle acts as a light post if it’s planted in the soil.

The construction of 2x3m shade took only 4 hours. Columns were made of 5-rachis bundles and were planted 20cm deep in wet soil, while beams were made of 2-rachis bundles. The connections depended entirely on linen ropes according to the inherited techniques of sheathing using palm Rachis.

Figure 29: Planting the base of columns (Author)

Figure 30: Adding vertical and horizontal bracings (Author)

Figure 31 : The Shade after Completion (Author)

The resulting shade was a very simple, fast and cheap construction that was built entirely by the local workers. However, there were 3 main disadvantages: the deflection that happened to the beams of the longer side while achieving low flexibility and small spans, and the full dependence on ropes in the connection which could be stronger if the connections depended on friction or interlocking between the bundles at the corners. These disadvantages added to the challenge of designing the new structural system.

2.2.2. Arched Palm Midribs Bundles

Piesik (2012) made the first attempt to construct using Arched Palm Rachis Bundles in order to exploit the curved nature of palm Rachis. The vault was constructed using arched bundles of palm Rachis with circular cross section of 20cm diameter to cover a span of 13 m. Due to the small cross section, every arch was supported by 4 palm trunks on intervals of 3.25 m approximately. The weight of each arch is about 500 kg. The construction procedures are simple. Firstly, one end of each bundle is planted 30cm deep in wet soil. Secondly, scaffolds and ladders are used to bend the bundles and tie them to the palm trunks using ropes. Finally, palm Rachis purlins are arranged and tied to the arches in order to put the woven mat above for finishing. However, in spite of the significance of that new construction system, it’s criticized of using internal trunks every 3.25 m which can interrupt the continuity of the multifunctional activities inside.

Figure 32: The Vault during Construction (Piesik,2012)

Figure 33 : Interior Columns (Piesik, 2012)

Figure 34: Rope based Connections.(Piesik,2012)

2.2.3. Cross Arched Palm Midribs Bundles

Sheehan et al. (2015) constructed a food shelter in Al-Ain UNESCO world heritage site in UAE using cross arched Palm Rachis Bundles. The idea was an improvement from the vault in (Piesik, 2012). The idea is based on assigning 2 perpendicular grids of arched Palm Rachises where the load of each arch is totally distributed on the perpendicular grid of arches. The grid made an 8x8m module that was repeated in 3 rows and 3 columns to make a 24x24 module (Sheehan et al.,2015). The arches ends are implanted in concrete foundation boxes to provide high fixation. Ropes were used to ensure the stability of the overlaps of the arches. For covering, light tent fabrics was used and fixed to basic nodes to make a tent-like form (Sheehan et al., 2015). In spite of using no trunks as internal vertical supporters, future extensions are limited to repeating whole modules, while at the same time; the continuity of the space is interrupted by the ends of the arches at the edges of the modules. In addition to that, the tent-like form that was used due to the double curvature in the structure will be difficult to comply with the rural context in Egypt.

Figure 35: Cross Arched Module (Sheehan et al., 2015)

Figure 36: Covered Module(Sheehan et al., 2015)

2.3. Objectives of the Developed System

According to the discussed literature review, the new suggested system in this paper should be characterized of the following:

A. Structural integrity: covers the widest span that is capable to cover multifunctional halls.
B. Form and function flexibility: free of strict grids and internal supports that may interrupt the continuity indoor functions.
C. Simple yet Durable connections: non-dependent solely on ropes for connections, as ropes will be the weakest points of the system due to their low climatic and structural durability.

3. METHODOLOGY

3.1. Scaled Physical Modelling

Scaled physical modelling method was chosen in order to imitate the steps of real life construction of the developed structure system, in addition to dealing with the consecutive problems of construction. Moreover, close details such as bundling, bracings and connections can be more studied and expressed in the physical model. Therefore, those details can be easily explained on model rather than digital models (Voulgarlis and Morkel, 2010).

3.2. Mechanical Properties Measurement

The measurements were taken according to the European Standard EN 408 : 2003, which is concerned in the determination of the mechanical properties of Structural timber and glued laminated timber. The measurements were measured according to Baladi Date Palm Rachis brought from Minya Governorate, and took place in the Metalloid Laboratory in Faculty of Engineering, Ain shams University, Egypt.

3.3. Digital Structural Simulation

Digital simulation is used to identify the structural limitations of the system and to examine multiple spans using SAP2000. SAP2000 is a common structural program to analyse simple and complicated structural cases using predefined properties of concrete and steel. However, predefined properties for natural materials such as timber and Palm Rachis are not included due to their complexity as anisotropic materials. Therefore, the required properties are defined manually in the program in order to calculate axial forces and bending moment on the members' sections.

4. DISCUSSION

4.1. Structural development of Arched Palm Rachis Bundles

4.1.1. Structural Integrity: Arched Space Truss

According to the systems discussed earlier in the literature review, the cross arched bundles interdependence (Sheehan et al., 2015) was the main solution to the need of intermediate columns that were used in the vault (Piesik,2012). This was accomplished by turning the whole structural mesh from a plane 2 dimensional arch into a 3 dimensional structural dome. This solution originally imitates the main concept of Space Trusses.

Space truss is widely used since the middle of the 20th century to cover wide spans using interacting light members without disturbing internal supporters (Ambrose and Tripney, 2012). The main concept depends on the assembly of group of members that are arranged according to the force movement direction in the 3 dimensions. Space trusses originated from plane grid truss that would have high bending moment when used to cover wide spans. This moment is supported by increasing the cross sections of the members or by adding another grid, thus turning into a 3 dimensional truss i.e. space truss (Lan, 2005). However, in spite of the flexibility, lightness and integrity of the system, the main challenge remains to be the critical design of joints, especially while speaking of naturally varied members such as Palm Rachis bundles.

4.1.2. Friction Connection: Parabolic Arch

The main structural concept of Arches is transforming all the bending moment into compression forces while decreasing tension forces as much as possible. The ideal arch is an arch that depends totally on transforming the bending moments into compression forces while loads are distributed evenly along the perimeter. This arch's shape takes the pure compression form i.e. a parabola. The compression forces in the parabolic arch allow using friction connection, as the tension forces resulting from bending that would dismantle the arch range from minimal to none (Ambrose and Tripney, 2012).

As a result, in order to take advantage of parabolic arches in terms of stability and low complexity friction connections, many bridges are designed to merge the concepts of parabolic arches and space truss to take the form of arched space truss. Therefore, Parabolic Arched Space Truss is the chosen structure system to design and simulate using

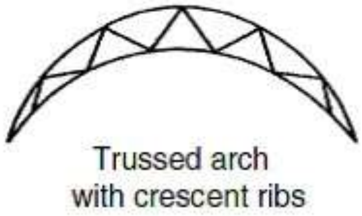

Figure 37: Trussed Arch with Crescent Ribs (Ambrose amd Tripney, 2012)

Figure 38: Changchun Yidong Bridge in Shanghai (Sonoploi,1998)

Palm Rachis bundles.

4.1.3. Suggested Structural System

The suggested structural system was assigned the span of 8m. This span was chosen to understand the limitations of the system by modifying the covered span according to the primary simulation results. The arched space truss has the height of 6m in order to maintain the ratio of the parabolic arch. The covered span between the 2 arched space trusses is 6m axis to axis as a primary extension experiment. 2 flat cantilevers were added to estimate the form flexibility of the system. The cross sections of the system were assigned according to the previous works of (Piesik, 2012) and (Sheehan et al., 2015) in addition to the workability investigated in the field work in Al Qayat Village.

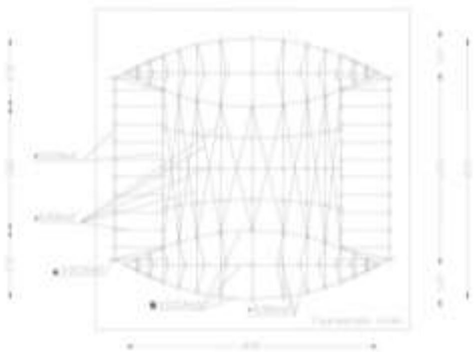

Figure 39: Plan and Cross sections of the system (Author)

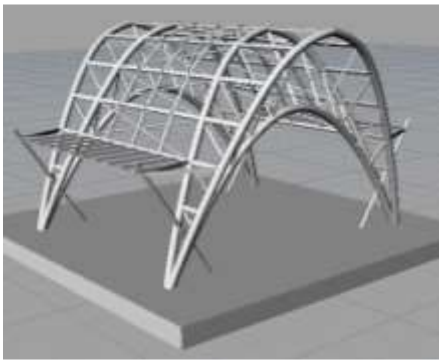

Figure 40: 3D Model for the system by Rhinoceros 5 (Author)

4.2. Physical Model Procedures

Figure 41: Fixing the supports and beams for using friction connections (Author)

Figure 42: Adding the space truss supports using friction connections (Author)

Figure 43: The final shape of the Physical Model (Author)

The physical model was chosen to be in 1:20 scale due to the available space limitation. The used material is dried Palm Rachises that were sliced as thin as possible to imitate the true members, as each member on the model imitates 4-6 members in real life. The whole structure was fixed on a Plywood board.

4.3. Mechanical Properties Measurements

Figure 44: Compression Test Perpendicular to Fibers (Author)

Figure 45: Bending Test -Shear Modulus via Variable Span Method (Author)

Figure 46: Bending Test - Longitudinal Modulus of Elasticity (Author)

The longitudinal modulus of Elasticity was measured using bending (EN 408-2003), while the perpendicular modulus of Elasticity was measured using compression (EN 408-2003). The Shear modulus was calculated using the Variable Span Method using flexural test (EN 408-2003). Due to the complexity of the measurements and limitations of the laboratory, the Poisson Ratio and Stresses were assumed according to the properties of Spruce Wood (Green et al., 2010) that was proven to be close to Date Palm Midribs (Elmously,2001).

Table 4: Mechanical Properties of Date Palm Rachis according to EN408-2003 (Moisture Content=7%)

Property Description	**Value**
Longitudinal Modulus of Elasticity –E_L	10287.8 MPa
Tangential Modulus of Elasticity-E_T	105.45 MPa
Radial Modulus of Elasticity-E_R	105.45 MPa
Longitudinal-Radial Poisson's Ratio-V_{LR}	0.372
Longitudinal-Tangential Poisson's Ratio-V_{LT}	0.467
Radial-Tangential Poisson's Ratio-V_{RT}	0.435
Longitudinal-Radial Shear Modulus-G_{LR}	109.2 MPa
Longitudinal-Tangential Shear Modulus-G_{LT}	109.2 MPa
Radial-Tangential Shear Modulus-G_{RT}	39.05 MPa
Mass per Unit Volume	0.95 gm/cm^3
Effective Yield Stress	45 MPa
Effective Tensile Stress	54 MPa

4.4. Digital Simulation

The materials properties were defined manually into SAP2000, and then the values of Normal Forces and Bending Moments due to Dead Loads and Wind Loads combined were calculated in order to check the safety of the system while covering variable spans. The connections were assigned to be firm friction connections and the bundles were assigned to be fully coherent.

Despite the suggested structure is to cover the span of 8m, the spans of 12m and 16m were simulated as well. These multiple simulations were executed in order to assess the maximum potentials of the structure according to additional challenges such as the accuracy of execution and additional loads such as unexpected wind, lighting features, air conditioning, covering and etc.

The structural check was based on Allowable Stress Design method (ASD), where the actual loads are used in structural calculations, because of the lack of safety adjustments of Palm Rachis as a relatively new structural material. The digital structural check in SAP2000 used the combined stress interaction (CSI) equations, which is used for members such as wall studs and roof truss members that experience bending stress in addition to axial loading in wooden structures (Residential Structural Design Guide, 2000). Combined actual bending and axial compression design is checked as the following:

$$\left[\frac{f_a}{F_a}\right]^2 + \left[\frac{f_b}{F_b}\right]^2 \leq 1$$

f_a is the actual axial load (compression or tension), F_a is the allowable axial load (compression or tension), f_b is the actual bending load and F_b is the allowable bending load.

Clear Covered Span = 8m

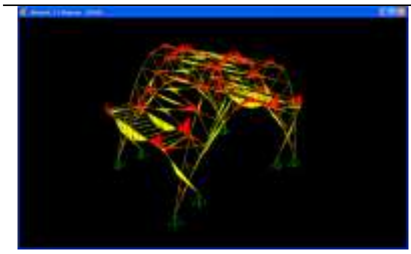

Figure 47 Bending Moment Visualization (Red - +ve, Yellow- -ve)

Figure 48 Axial Forces Visualization (Red- Compression, Yellow –Tension)

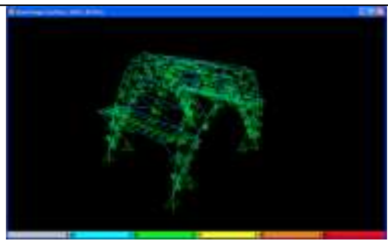

Figure 49 Stresses Check (Green-Safe, Red-Unsafe)

Clear Covered Span= 12m

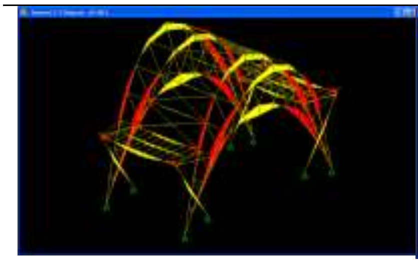

Figure 50: Bending Moment Visualization (Red - +ve, Yellow- -ve)

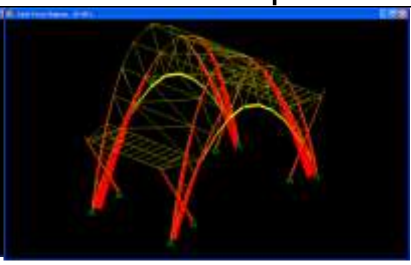

Figure 51: Axial Forces Visualization (Red- Compression, Yellow –Tension)

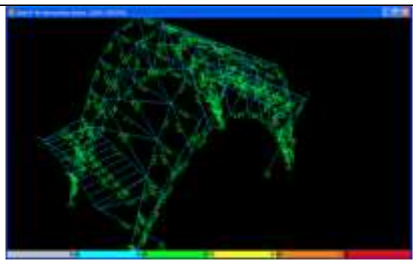

Figure 52: Stresses Check (Green-Safe, Red-Unsafe)

Clear Covered Span= 16m

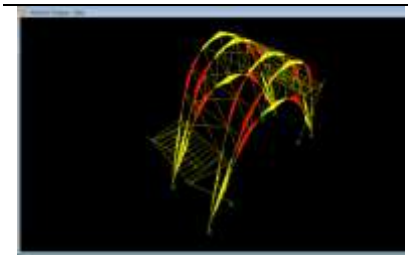

Figure 53: Bending Moment Visualization (Red - +ve, Yellow- -ve)

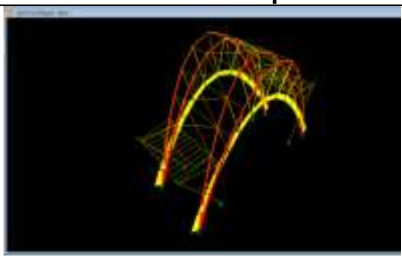

Figure 54: Axial Forces Visualization (Red- Compression, Yellow –Tension)

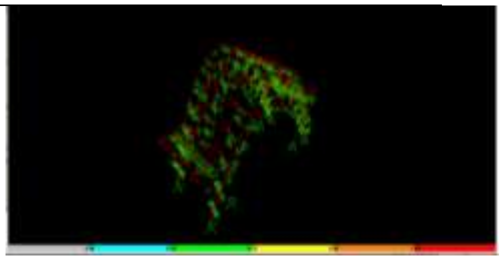

Figure 55: Stresses Check (Green-Safe, Red-Unsafe)

The results from the digital simulation showed that the system is safe while covering 8 and 12m. However the system failed at covering 16m due to high buckling at the cross sections of the bracings.

5. CONCLUSION

Date Palm Rachis is a promising material in terms of construction. In this paper, several previous experiments of building using palm rachis were reviewed. The experiments showed the high potential of the material. However, the resulting systems were not characterised by high flexibility in form and fuction. Therefore, the parabolic arched space truss structure was designed using Date Palm Rachis in order to introduce a versatile structure that can be used to cover multifunctional halls and public activities.

The scaled physical model was constructed in order to predict the ease of construction and durability. The model proves to be simple, fast and required economic amounts of materials relatively. The connections prove to be highly durable under reasonable pressure.

The results from the digital simulation showed that the system is highly recommended to cover spans up to 12m. In addition to that, the majority of the normal forces along the members are compression, which means that friction connections are suitable for the structure as long as the used arches are parabolic.

This system can be used for multifunctional public halls such as markets, sport halls and recreational areas. This system provides the necessary flexibility, simplicity of connections and structural integrity, while depending on simple construction utilizing the highly available Date Palm Rachis.

These findings open the door for further structural studies regarding the spacing between the arches, the intensity of the bracings, the coverings and protection against fire and degradation.

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Adoption of appropriate technology in construction

A pilot study of compressed earth blocks uptake in Kamuli District –Uganda

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The use of compressed soil blocks (CSB) in the construction of housing in Uganda can be traced back to the slum upgrading projects of the early 1990's (DCDM, 2003a; 2003b). 25 years on, the propagation of a technology that has seen improved supply of housing in India, South America and Southern Africa has had little impact on the supply of housing in Uganda. Basing itself in the diffusion theory, this study provides insights into how failure of adoption can be managed or reduced.

In an effort to better understand how current and future innovations may be better conceived and rolled out, the level to which the perception of critical adoption dimensions affect diffusion are queried in the propagation of compressed earth block as a building material. The study was undertaken based on the innovation decision model, querying identified opinion leaders in communities where CEB technology has been utilised about their opinion on the technology.

The study found that perceived economic advantage of a technology is a decisive factor for its adoption in spite of awareness of promising alternatives. The study identified that while interpersonal communication channels are important in the formulation of opinions, these present a limited opportunity for awareness of a critical number for adoption to gain momentum. The study having tested methods of identifying opinion leaders, forwards the notion that awareness drives focused on these individuals, emphasising the lifecycle cost benefits of CEB has the potential to lead to an increase in demand and adoption. Furthermore increase in demand can lead to a reduction in price of CEB through a greater sharing of fixed overhead costs.

Key words: Appropriate Technology, Compressed Earth Block, Adoption

1. INTRODUCTION

Access to housing the world over is a particular challenge for all income groups. In the global south however, it continues to be a stark problem due to low incomes, lack of access to housing finance facilities and supply bottlenecks from centralised institutions.

Building materials purchase, transportation and handling presents a major percentage of overall financial, social and environmental construction costs in the procurement of conventional tropical housing. In Uganda, various innovations have been fronted to overcome these challenges and make appropriate housing more accessible. Of particular interest to this research is the Compressed Earth Block (CEB) and its variants. Earth is a familiar construction material in the region and has been in use for generations; it would then seem that Compressed Earth Blocks would very quickly become the material of choice for housing construction, especially within the low income groups. However, this is not the case.

Traditional housing construction entailed the use of earth, wattle and wooden poles with a covering of thatch roof; today, these methods are stigmatised as being backward as the population adopts “modern” materials. The situation at hand has been augmented by adopted building codes that shun traditional materials, labelling them as temporary and therefore unfit for urban construction (UN-Habitat, 2010), serving to increase the cost of housing supply.

It has to be noted that fired clay brick, which is the predominant building material today (UBOS, 2010; Hashemi et al., 2015) has a number of detrimental short and long-term impacts. These include: cutting of virgin non renewable forests for wood fuel; inefficient firing that leads to energy wastage and a high associated embodied energy; smoke pollution and associated respiratory health problems, and destruction of wetlands during clay excavation(Oteng'i and Neyole, 2007, UN Habitat, 1991). To alleviate these challenges, CEB has been fronted, aimed at not only improving traditional earth masonry and reducing the demand supply gap of quality construction materials, but also counter the negative environmental impacts that are associated with the production of fired clay brick.

Compressed Earth Block (CEB) or Compressed Soil Block (CSB) is the modern descendent of the moulded earth block, more commonly known as the adobe block. The idea of compacting earth to improve the quality and performance of moulded earth blocks is, however, far from new, it was with wooden tamps that the first compressed earth blocks were produced, and this process is still used in some parts of the world. The turning point in the use of presses and in the way in which compressed earth blocks were used for building and architectural purposes came in 1952, following the invention of the CINVA-RAM press, designed by Raul Ramirez at the Inter American Housing Centre (CINVA) centre in Bogota, Columbia (UN-Habitat, 2009; Titan Brick, 2013.) Since then, a number of technologies have been implemented for the production of CEBs with varying success.

The use of CEBs in the construction of walling in housing was introduced by the Uganda government financed slum-upgrading projects in the early 90s with varying degrees of success. Since then, a number of private and public institutions have utilised the technology, bringing public awareness up. However, the reach of these institutions has remained limited, so much so that in the Uganda National Household Survey 2012/2013, CEB is not listed among the major construction materials in use.

This has been attributed to a variety of factors; according to UN-Habitat (2009) technologies such as Interlocking Stabilised Soil Blocks (ISSB) – a CEB variant - have not been integrated into the educational curricula of secondary vocational institutions and tertiary engineering and architectural institutions, and thus adoption has been slow. Further still, ibid suggests that a key challenge affecting the propagation of the technology is changing the mentality of the companies and individuals already manufacturing and using conventional methods of construction such as burned bricks and concrete blocks. In addition, UN-Habitat (2010) indicates that a lack of official recognition and incorporation in the building regulations of emerging technologies affects their acceptance negatively. While the arguments presented are valid, the study at identifies the fact that the grounds presented are limited to the implementing side and takes little note of the prevailing attitudes of the would be users of the technology.

The study at hand investigates the recipients of innovative technology, querying the social-technical systems within which diffusion of innovations occurs by investigating perception of would be adopters towards CEB; furthermore, the study analyses factors that influence adoption from opinion leaders perspectives with empirical insights.

2. DIFFUSION THEORY AS A FRAMEWORK FOR RESEARCH

The diffusion theory provides an excellent platform to decipher how practices in construction go from innovation to standard industry practices. Diffusion in general is the process by which an innovation is communicated through certain channels over time among the members of a social system. Rogers (1983) states that communication is a process in which participants create and share information with one another in order to reach a mutual understanding or convergence. When a change agent seeks to persuade, and approaches a client to adopt an innovation, it can be realised that such an event is only one part of a total process in which information is exchanged; with more deliberate observation it can be seen that their interaction continues through several cycles, and is a process of information exchange.

Further still, (Rogers, 1983) designates diffusion as a special type of communication because it involves the propagation of an innovation. An innovation is an idea, practice or object that is perceived as new by an adoption unit, which might be an individual or society. This newness implies that there is a degree of uncertainty - here meaning a lack of: predictability and performance information in the minds of potential adopters owing to no prior application.

Various literature (Rogers, 1983; Robinson, 2009; University of Twente, 2015) infer that there are a number of close knit and often interrelated factors that influence the rate of diffusion or adoption of new technologies, these are: the characteristics of innovation itself; communication channels used to propagate information about and the innovation; the effect of time and consequences; and the context or social system within which the innovation is spreading.

The factors presented are complex social constructs and it is therefore important to examine the frameworks within which they interact. Theoretical models help to explain, predict, and understand phenomena and, in some cases, to challenge and extend existing knowledge within the limits of critical bounding assumptions. According to Koebel et al. (2004) diffusion is modelled extensively as either the diffusion process or the adoption process with the difference being that diffusion models focus on the overall rate and timing of the diffusion of an innovation within a specific industrial sector, while adoption models focus on the characteristics of the person, firm or society adopting an innovation and the decision to adopt. Currently, there is very little evidence to suggest that CEB is being taken up as a construction material in Uganda; therefore, of particular interest to this study is the innovation adoption model, to identify why this state of affairs exists. Key to adoption models is the innovation - decision process defined as a mental process where a would be adopter seeks information at various stages in order to decrease uncertainty about an innovation's expected consequences.

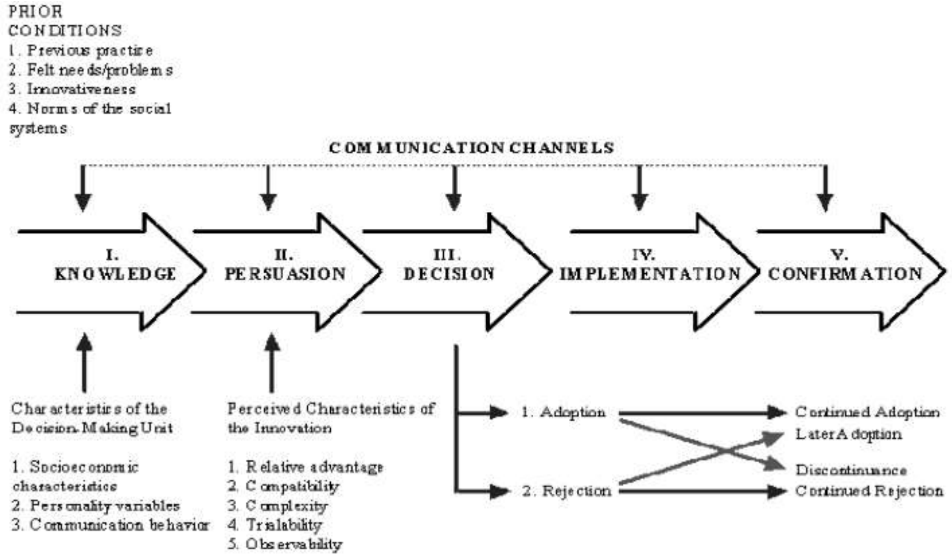

Figure 1: Innovation decision model adapted from Rogers in Mustapha (2006)

Mustapha (2006) expounds on the notion presented by Kobe et al. (2003) presenting four theories common to diffusion studies: Innovation decision process, individual innovativeness, rate of adoption, and perceived attributes. The author states that among these, the most widely used theoretical approach is the innovation decision model. This process, has four key stages: Knowledge - a person becomes aware of an innovation and has some idea of how it functions; persuasion – a person forms a favourable or unfavourable attitude toward the innovation; decision – a person engages in activities that lead to a choice to adopt or reject the innovation; implementation – a person puts an innovation into use; confirmation – a person evaluates the results of an innovation-decision already made.

In order for a population or an individual to adopt an innovation, there must be awareness of the innovation. The drivers for initial awareness are debatable with arguments suggesting that information can either be sought out by potential adopters or furnished by a change agent (Koebel et al., 2004.) However, there is consensus that awareness is a key driver for adoption. According to Robinson (2009) and Rogers (1983), mass media and interpersonal communication, are the key channels of dissemination with regard to the spread of innovations. However, Robinson (2009) suggests that mass media are more effective in creating knowledge of innovations, whereas interpersonal channels are more effective in forming and changing attitudes toward a new idea, and thus influencing the decision to adopt or reject a new idea.

The study by approaching various actors in the construction industry and utilising a cross-referencing methodology identified Haileybury Youth Trust (HYT) Uganda, a community based NGO involved in CEB propagation as a possible partner in the study exercise. HYT Uganda is funded by various charities from the United Kingdom and trains local youth volunteers for a one-year period in soil selection, mix preparation, CEB manufacture and construction techniques. The aim of the HYT is to increase the use of low-cost carbon saving techniques, specifically CEB, impart necessary skills to meet the growing demand for infrastructure and improve livelihoods (HYT Uganda, 2014.)

HYT being engaged in the construction of a 4-classroom block, 2 staff houses and a kitchen in 8 schools in Kamuli district, Eastern Uganda plays the role of change agent, creating awareness and disseminating information through various channels about CEB. The construction of the aforementioned school infrastructure over several sites represents a large application of CEB in an accessible area for research study.

The degree to which an adoption unit is relatively earlier in taking on new ideas than other members of a social system is referred to as innovativeness. Adoption models that expound on the innovative nature of individuals within a society are largely based on the work of Everett Rogers, who categorizes the innovative character of adopters as a function of time and as a probability distribution (Koebel et al., 2004; Eder et al., 2015). Here, it is suggested that different types of adopters have distinctive individual profiles in terms of age, education, income, risk tolerance, and these affect the individuals propensity to take on a new technology. There are 6 distinct groups of people: innovators, early adopters, early majority, late majority, laggards and non-adopters.

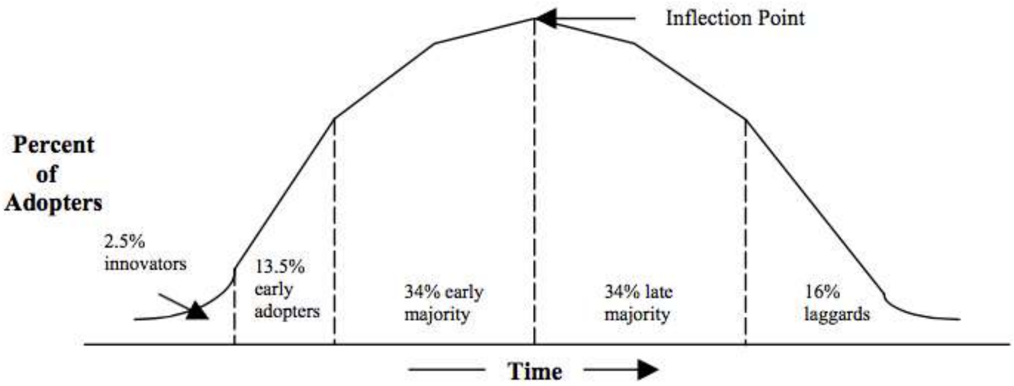

Figure 2: Adoption curve (Koebel et al., 2004)

Innovators are those who want a certain product as soon as it becomes available. Innovators are willing to take risks, and have financial capabilities. Early adopters are a larger group who also seek new products but may look more into functionality and are more integrated in the local system than are the innovators. The early majority is the first mass of people to adopt a product. The early majority interact frequently with their peers but rarely hold positions of opinion leadership within the social system (Eder et al., 2015; Robinson, 2009.) The late majority adopts when the majority of the market is already familiar with the product. According to Robinson (2009) the relative scarcity of resources within this group means that most of the uncertainty about a new idea must be removed before this group of people feel the need to adopt. The final group to adopt an innovation are the laggards, with the non-adopters not taking up the innovation.

In order to determine adoption trends and the underlying reasons for adoption, the study sought out opinion leaders within HYT's area of operation; opinion leaders are individuals who are influential within the social system and who spread information about an innovation. These individuals are often local and generally are to be found among the early adopters (Eder et al., 2015; Feder and Savastano, 2006.) Furthermore, Valente and Davis (1999) state that the diffusion network relies on opinion leaders to initiate the diffusion of a new idea or practice. They can function as champions for the new practice and accelerate the diffusion process and will often function as the theoretical underpinning to peer education programmes.

The study at hand utilised network analysis, a set of methods that enables researchers to locate individuals who are more central to a community and thus perhaps more influential to identify the appropriate opinion leaders to query. Chatman (1987) expounds on the concept of network analysis stating that there are three main methods to measure the existence of opinion leaders: sociometric, designation by key informants, and self-designation. While the sociometric method has the greatest degree of objectivity – here all members of a social environment are tasked to identify opinion leaders and the networks between individuals are analysed, the study utilised designation by key informants. This method was chosen for over the sociometric method for two reasons; first, sociometric analysis requires considerable time and financial resources, both of which were constrained, and second not all members of the environment were accessible. Furthermore, self-designation was considered inappropriate because the considerable bias augmented by the fact that the study had little information on the society in question. The designation by key informants process identified 20 opinion leaders, 5 each from 4 different sites, accessible to the study: Nakibungulya, Kisege, Bugonda Butaga, and Makanda, in HYT's area of operations.

To capture the diffusion mechanisms important to homebuilders, we developed a questionnaire to measure the variables that were identified in the literature review as influencing technology adoption, and theses were filled out during structured interviews. In an area where literacy is low, the method allowed the research team to consistently probe respondents for in depth opinions and the reasoning behind these opinions through conversation with the aid of an interpreter.

The survey tool was divided into two distinct parts. The first section collected background information such as the respondents' age, sex, employment status and position in the community. This information provides a qualitative background enabling researchers to ascertain the position and context of the views presented by the respondent.

The second part of the questionnaire queried the innovation decision process: First, the communication channels through which the respondent learnt about the technology, and the length of time that has elapsed since first learning about the technology. Following on, having learnt about CEB, the research tool gathered information about the amount of knowledge an individual has on CEB, whether they have formed a favourable or unfavourable attitude towards the use of CEB as a construction material; this being a result of , the adopter's perception of the inherent qualities of CEB. Here questions pertaining to the innovation's consistency with the populations' values and relative advantage in terms of: economic advantage, social prestige, and convenience / satisfaction were asked. Having developed an opinion; the study participant was queried on the course of action taken. The research tool collected this data by employing a 3-point scale, whose responses were backed by 5 secondary questions. The use of multiple interrelated scales enables response verification.

The survey tool rounded off by asking respondents to comment on issues that they felt were pertinent but had not been touched upon by the research team.

3. RESULTS AND DISCUSSION

The study collected information form a total of 19 respondents who included technical personnel involved in the training of youth, locals and administrators in the schools where HYT was active. In common was the fact that the majority of individuals identified as opinion leaders had positions in local leadership at various levels; 4 of the respondents are formal leaders in the local council system, while 7 are informal leaders within the community structure. The importance of formal leaders is highlighted by Nypan (1970) whose study in East Africa concludes that the involvement of formal leadership in the diffusion of innovations has a positive impact as they occupy a central position within their communities. The author notes that often, formal leaders' influence often extends beyond their official duties. The role of formal leadership versus informal leadership in the adoption of appropriate construction technology in the global south is an area worthy of investigation.

The identified opinion leaders were comprised of 4 females and 15 males. The average age of the group was found to be 43 years. The average age of male opinion leaders was slightly less, at 41 years, than their female counterparts whose average age was found to be 49 years. It should also be noted that the female members of the opinion leadership group were more highly educated than their male counterparts with 3 out of the 4 having a tertiary education. This in the studies view indicates a bias towards male opinion leaders with women being judged on more stringent measures to be accepted as opinion leaders.

Table 1: Education level of selected opinion leaders

	No formal education	Primary education	Secondary education	Tertiary education
Male	1	3	5	6
Female	0	0	1	3

3.1 Communication channels

There are two main communication channels through which an innovation can be spread, that is, mass communication channels and interpersonal communication channels. Results collected show that the majority of respondents 18/19 learnt about CEB from interpersonal modes of communication that included friends 7/19, and site visits 11/19 organised by a contact in the peddling organisation, benefiting institution or personal initiative after work started on site. Only 1 individual noted receiving information through what may be deemed as a mass communication method, and this was an announcement made by the local council chairperson.

It should be noted that while interpersonal communication is important for changing attitudes amongst peers, mass communication plays a major role in in creating knowledge of innovations (Robinson, 2009; Rogers 1983.) From the data collected, one may form the opinion that failure to utilise mass media as a communication to has limited public awareness about the opportunity presented by CEB as a construction material. Extending beyond the area of the study, the research teams experience in Uganda suggests that there is little mass media coverage of CEB on communication channels such as TV, radio and social media, thereby extending the phenomenon of lack of awareness to a country level. However, this theory remains to be proven. Also worth investigating is the potential of localised information sources such as: an announcer, a leaflet, the school principal, a government official, the mayor, a teacher as a distinct category who according to Lin and Burt (1975) are capable of customizing a message for either an individual, a small group of individuals, or a rural village.

3.2 Knowledge

From the data collected, it was determined that the majority of respondents 12/19 have known CEB between 1 to 5 years, 5/12 respondents have known about CEB for between 5 and 7 years, while 2 have known about CEB for over 7 years. With this information, the study proceeded to query the respondents' amount of knowledge on CEB. It was found that the majority of respondents have practical knowledge on CEB, that is, they have been involved in the production process (14/19), acknowledge interlock (16/19), and can identify the material mixture (16/19). This can be attributed to the high number of respondents who have learnt about CEB from interpersonal communication and site visits. It was not surprising that only 3 respondents were able to quote facts about CEB from literature, these also being individuals who have known about CEB the longest.

In the innovation diffusion model, it has been shown that early adopters have generally outstanding social economic characteristics (Chatman, 1987, Cosmas and Sheth, 1980, Eder et al., 2015, Feder and Savastano, 2006) However, owing to the fact that the pilot survey did not collect information from the wider community, the existing data set is insufficient to draw conclusions on the social economic characteristics of the selected group as compared to the wider community. This however is an important consideration for future research.

3.3 Persuasion

In the innovation decision model, the inherent characteristics of the innovation play a major role in persuading individuals in a society to adopt an innovation. The inherent characteristics determine the innovations relative advantage; determine whether an innovation is consistent with the existing norms and values; determine the complexity or ease of use of the innovation; and also govern whether an innovation can be easily applied at a favourable scale for benefits to be judged before adoption (Robinson, 2009).

While it has already been determined that CEB is easy to use, and earth construction is consistent with the values of the population in the area of study as per the discussion presented earlier (Gooding and Thomas 1995; UN-Habitat. 2009; Nambatya, 2015), the study sought respondents' opinions with regards to the modernity of CEB construction. The purpose of this line of questioning was to determine whether CEB in construction is currently desirable and will remain so in the near future. 17/19 respondents viewed ISSB as being a modern construction material. 2 individuals responded viewing CEB as a conventional material, with 1 individual adding that while the material has been in use for a while its employment in the region is not commonplace, highlighting the possibility of gaps in communication and demonstration methods. None of the respondents considered CEB a primitive material indicating overall, a positive view of CEB, currently and in the near future.

3.3.1 Relative advantage

Relative advantage is the degree to which an innovation is perceived as better than the idea it supersedes by a particular group of users, measured in terms that matter to those users, like: economic advantage, social prestige obtained form construction, and convenience or satisfaction. It should be noted that there are no absolute rules for what constitutes “relative advantage,“ but rather it depends on the particular perceptions and needs of the user group (Robinson, 2009.) Participants in the study were required to first, rank the fore mentioned criteria according importance, note down any additional parameters for consideration. They were then tasked to follow this up by scoring the major walling construction materials: CEB, concrete block and brick in the agreed upon criteria. Results show that convenience/satisfaction is an important sub parameter for relative advantage, with 61% (11/18) respondents saying this is the biggest consideration when faced with constructing a dwelling. Economic advantage had 24% (4/17) respondents saying that it was the most important consideration, while social prestige had 22% (4/18). However, it must be noted that many more people responded in favour of economic advantage 70% (12/17) as being the second most important consideration. 22% (4/18) respondents had convenience as the second most important consideration, while 6% (1/18) had social prestige as the second most important consideration. In scoring 1 was the most important consideration, while 3 was the least important, and averaging the scores: convenience scored 1.5, economic advantage 1.8 and social prestige scored 2.8 making it the least important consideration. The results also show that economic advantage and convenience/ satisfaction are nearly equal considerations in the choice of building materials consistent with the findings of Greenhalgh et al. (2004) who suggest that economic benefit is oftentimes the most important measure of relative advantage.

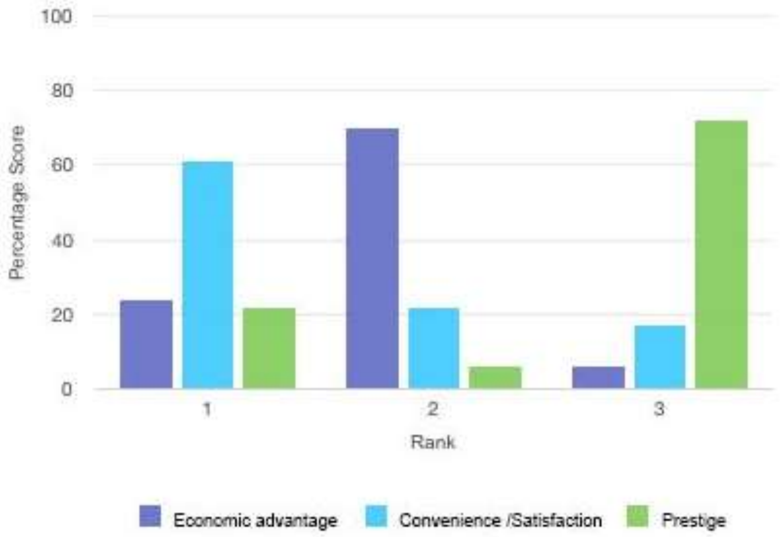

Figure 3:Comparison of drivers for material selection

In order to compare the relative advantage of key walling materials (CEB, burnt brick, and concrete blocks) respondents were asked to rank them against each other in terms of perceived cost of construction, perceived prestige form society when utilised in construction and the perceived convenience/ satisfaction obtained when a specific material is utilised.

Economic advantage

The collected results indicate that burnt brick is considered cheaper to use in construction than CEB or concrete blocks. It must however be noted that the perceived difference in savings made during construction between CEB and brick is very small – 47.5% (9/19) think that savings will be made when burnt brick is utilised as opposed to 42% (8/19) who consider CEB the cheaper option. The major disparity between the two materials arises from the 32% (6/19) who perceive CEB to be the most expensive as compared to the 5% (1/19) who suggest that brick is the most expensive. Overall, respondents deem concrete block as the most expensive option 75% (12/16.) This state of affairs may be due to the following reasons as deduced during the survey

- Addition of cement to soil is viewed as wastage; respondents fail to quantitatively comprehend material wastage in mortar joints due to poor construction techniques common in Uganda
- Due to the informal nature of residential construction, the time cost of construction is rarely considered.
- The lump sum required for production of CEB, for machine hire and cement purchase is often viewed as very high. This is especially brought into focus when one considers that there is no evidence of lifecycle cost comparisons by construction practitioners and homeowners.
- Bricks are considered cheap because they do not require specialised training to make. In the area of the study, brick clumps of varying size and quality were observed at numerous homesteads.

Satisfaction/ Convenience

In considering the criterion satisfaction/ convenience, 95% (18/19) of the participants indicated that the most satisfaction would be attained from the use of CEB with none indicating satisfaction from the use of brick. Respondents identified the higher speed of construction and pleasing aesthetic of the smooth CEB blocks compared to brick as the major considerations for their responses – these indicate that observable results have helped form a positive perception towards CEB. 56% (9/16) indicated that brick would provide the least satisfaction. However a lack of reliable data on time and associated cost savings accrued by use of CEB means that only individuals who have seen CEB construction being undertaken, as is the case with the respondents of the study, hold this opinion.

Prestige

When queried about the prestige obtained from use of a material for construction, CEB was ranked highest with 74% (14/19), No participant indicated that social prestige would obtained by use of brick. This can be attributed to the fact that brick is a common and easily obtainable material.

3.3.2 Decision

Having determined factors important to adoption and the perception of the sample group towards CEB, the study investigated whether the identified opinion leaders had engaged in activities that affirm adoption or rejection. The data collected indicates that while respondents have acted as middlemen for the application of CEB (5/19), participated in awareness drives (9/19), influenced attitudes at workplace or social circle (10/19), only 2 respondents are actively involved in personal construction using CEB. This state of affairs may be attributed to the fact that brick, the common building material is perceived to have a greater economic advantage over CEB – analysis of data collected indicated that economic advantage is a key consideration in choice of building material.

4. Conclusion

This study provides a benchmark from which the adoption and diffusion of sustainable construction practices, materials and technologies can be investigated and improved. The adoption of sustainable practices is key in an age where demand for infrastructure in the global south is increasing, in the shadow of a growing awareness of the earth's finite resources. The study at hand highlights the fact that in low-income societies, such as those found in the rural Uganda context where the pilot study was carried out, the actions of opinion leaders absent of focused awareness campaigns and financial support is not sufficient to overcome the barriers to adoption – mainly economic, even for a technology perceived as more satisfying, convenient and prestigious.

The study having tested methods of identifying opinion leaders, forwards the notion that awareness drives focused on these individuals, emphasising the lifecycle cost benefits of CEB has the potential to lead to an increase in demand and adoption. Furthermore increase in demand can lead to a reduction in price of CEB through a greater sharing of fixed overhead costs. Also, as material use becomes more common, the fallacy that CEB is for use by well-funded foreign NGOs will be disproved, further reducing bias.

It is important to note that during the formulation of the study, interaction with stakeholders in the production and use of CEB indicated that in urban settings, the adoption of the technology is further undermined material failure and poor observable results resulting from substandard workmanship. It is envisioned that a comprehensive study can be carried out in both a rural and urban setting to ensure that the existing dichotomy is captured leading to the construction of an appropriate diffusion and adoption strategy.

In the Ugandan context, the relative absence of large-scale developers implies that the relationship between building infrastructure owners and small-scale contractors (builders) is key in the process of material and technology selection, and application. Unfortunately, little is known about the communication channels and social networks builders use to learn about innovations or influence their adoption practices. Similarly, there are numerous questions about how builders assess relative advantage; how they estimate the consumer's reaction; existing information gaps between builders and consumers and the importance of word-of-mouth among builders. This should be considered as a key area of study, as the end users, who are the main focus of this investigation, cannot be considered as independent actors.

Acknowledgements

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Optimizing reinforced concrete sections for sustainability using HSC

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Abstract: In the building industry, cement which is the main constituent of concrete, is responsible for around 7% of the human generated carbon dioxide emissions and consumes massive amounts of energy. HSC (High Strength Concrete) offers significant sustainability potential, as it can result in smaller cross sections for structural elements and better aesthetics, eventually reduced own weights and this result in material savings which can be translated to lower carbon dioxide emissions and energy consumption. Since the use of HSC in axial load bearing elements is well known to be much more feasible compared to other structural elements, structural columns in a case study were designed according to the provisions of the Eurocode, using concrete compressive strength of 30, 60 and 90 MPa. The amount of concrete associated with each strength used was assessed and optimized where possible. The overall material saving was then calculated. Moreover, some HSC concrete mixes were collected form the literature review and assessed for sustainability in terms of the associated embodied energy and carbon dioxide emissions of each mix. Finally, the total carbon dioxide emissions reduction and energy saving potential were evaluated for implementing an integrated sustainability approach. This approach is based on simultaneously using HSC for structural design of columns along with incorporating sustainability optimized HSC concrete mixtures or so called “green concrete”. As a final result, it was found that the structural columns could be built with 80% less environmental impact using the investigated approaches in comparison to normal building techniques. Such results could deem encouraging for the structural designers to request the use of HSC for their projects.

Keywords: Carbon footprint, Embodied energy, High strength concrete, Sustainability

1. INTRODUCTION

The human species seems to be acting irresponsibly towards the environment. Since the industrial revolution which started back in the mid-1700s in Great Britain, massive amounts of resources have been consumed (Mitchell, 1962), and huge amounts of harmful gasses have been emitted to the environment which resulted in disturbance of the ecosystem and the depletion of the ozone layer in many places of the world.

Concrete is the most widely used material on earth after water mainly due to its widely available ingredients, the cost of manufacture and its durability (Myadaraboina et al., 2014). According to Mehta (Mehta, 2004), for a variety of reasons, the concrete construction industry is not sustainable. First, it consumes huge quantities of virgin materials. Second, the principal binder in concrete is portland cement, the production of which is highly energy intensive and causes

large emissions of greenhouse gases that are implicated in global warming and climate change; each ton of cement produced releases approximately one ton of CO_2 which is causing environmental concerns (Myadaraboina et al., 2014). Current estimates of world production of cement are of the order of 2.5×10^9 ton per year (Kelly and Van Oss, 2008). Worldwide, the cement industry alone is estimated to be responsible for about 7% of all CO_2 generated (Meyer, 2009). Third, many concrete structures suffer from lack of durability which has an adverse effect on the resource productivity of the industry.

However, more than any other industry, the building industry is affected by the ongoing sustainability debate (O'Brien et al., 2011). Sustainable structural engineering follows the basic principle that the energy and resources consumption due to the construction and operation of a structure must be minimized (Müller et al. 2014). Based on this, the current paper aims at minimizing the embodied energy as well as the CO_2 emissions associated with the building of structures through optimizing the concrete section design and the concrete mix design. First, A case study was used to investigate the benefits of using high strength concrete (HSC) for concrete sections design in comparison to normal strength concrete (NSC). The basic benefit would be a decreased area of the concrete cross sections required to sustain a specific load, which typically means decreased concrete material consumption. Secondly, a number of HSC concrete mixes collected from the literature review were investigated to judge their environmental impact. The results from the first and second part were further integrated, compared and analyzed for sustainability.

2. THEORETICAL BACKGROUND

In 1987, the Brundtland Report defined sustainable development as: "the ability of humanity to ensure that it meets the needs of the present generation without compromising the ability of future generations to meet their own needs." (Brundtland, 1987). Starting from this, the structural designer is held responsible for reducing the amounts of concrete material required through efficient concrete design as well as making sure that the concrete mixes designed to achieve different concrete strengths are sustainable in terms of the material consumption, embodied energy and the CO_2 emissions associated with each component of the mix.

Fidjesto and Thorstensen (Fidjesto and Thorstensen, 2012) introduced a three steps approach for improving the sustainability of the construction process. First step involves reducing the volume of concrete required by using concrete with higher strength, which makes it possible to reduce the cross section for building components. To put more emphasis on the role of HSC concrete, it has been advocated by Mehta (Mehta, 2009) that the concrete profession already has the means to make significant reductions in CO_2 without compromising quality – rather with improved quality because the use of appropriately designed high strength concrete materials ensures improved sustainability and long-time serviceability of concrete construction. The second step as stated by Fidjesto and Thorstensen aims at creating new, less polluting concrete technologies. This creates space for research on sustainable concrete, or "green concrete," which can be simply defined as concrete with lower environmental impacts than conventional concrete (Glavind and

Haugaard, 1998). Last but not least, is using a more durable concrete that will have a longer service life.

In an effort to investigate the effect of using HSC for the structural design of a reinforced concrete building, Fidjesto and Thorstensen (Fidjesto and Thorstensen, 2012) designed a 1000 m^2 ground area, four floor building using both high strength concrete (85 MPa) and traditional concrete (35 MPa). The building was traditionally designed as a column/slab/beam structure according to Norwegian Standard (NS 3473). For the conventional floor system, a total concrete volume of

1447.7 m^3 was required when NSC was used in comparison to 1231.1 m^3 for HSC, indicating a saving in the total concrete volume required in the range of around 15%. However, the reduction in column size was referenced as the potential advantage of high strength as the saving in the material requirements for columns was in the range of around 45 to 50%.

Of all the components in concrete, recent studies have confirmed that portland cement being one of the most energy intensive of all industrial manufacturing processes has the highest embodied energy which accounts for over 96% of the embodied energy of the concrete mix (Wilson, 1993; Griffin 2005), and primary source of CO_2 generated by typical commercially produced concrete mixes, being responsible for 74 - 81% of concrete CO_2 emissions (Flower and Sanjayan, 2007). Consequently, cement offers the greatest opportunities for developing sustainable concrete technologies, unlike fine and coarse aggregate for example, as their production and transportation accounts for less than 8% of the energy used in the manufacture of concrete (Griffin, 2005).

One approach for reducing the binder content in the concrete mixture is by optimizing mixture by particle packing and filling the gaps in the concrete microstructure with better gradation of the aggregate so as to decrease the need for binder volume (Fidjesto and Thorstensen, 2012). However, the most effective remedy to solve the problem is to use less portland cement which means to replace as much binder as possible by using additions, such as supplementary cementing materials (SCM) and fillers, especially those that are by-products of industrial processes; as they reduce cement consumption, energy and cost, and to use recycled materials in place of natural resources (Farzadnia et al. ,2011).

Among all mineral admixtures, fly ash has attracted the most attention. Silica fume is another widely used mineral admixture. These supplementary cementitious materials, work in combination with portland cement to improve strength and durability in addition to reducing the CO_2 embodied in concrete by as much as 70% with typical values ranging between 15 and 40% (NRMCA, 2012).

Fly ash, a principal by-product of the coal-fired power plants, is well accepted as a pozzolanic material that may be used either as a component of blended portland cements or as a mineral admixture in concrete (Mehta, 2004). Currently, 50% of fly ash produced globally is stockpiled or placed in a landfill (Sear, 2002) and only 20% of available fly ash is being used in the cement and concrete industry (Malhotra and Mehta, 2005). In commercial practice, the dosage of fly ash is limited to 15 - 20% by mass of the total cementitious material. Usually, this amount has a beneficial effect on the workability and cost economy of concrete but it may not be enough to sufficiently improve the durability to sulfate attack, alkali-silica expansion, and thermal cracking. For this purpose, larger amounts of fly ash, on the order of 25 - 35% are being used (Mehta, 2004).

Fly ash and silica fume both have embodied energies of zero as they are waste products of another industrial process. (Griffin, 2005), However, fly ash must be transported farther that most materials used to manufacture concrete as coal power plants are fewer in number and more isolated from population centers. Even if fly ash is moved 1,000 miles by train, requiring 360 MJ/tonne, this transportation energy is only 5% of the 6,500 MJ/tonne required to produce portland cement (Malin, 1999). Consequently, even when transportation is considered, fly ash has a significantly lower embodied energy than cement.

The demolition and need of disposal of concrete structures, pavements, etc., creates another environmental burden. Construction and demolition debris produces a considerable fraction of solid waste in developed countries. The Environmental Protection Agency (EPA) has estimated that approximately 58% of landfill waste is from construction debris, which a significant portion is concrete and masonry rubble (Rahal, 2007). Therefore, replacing raw aggregate with recycled

aggregate would be advantageous. Recycling aggregate has little reduction in energy use and CO_2 emissions, however, recycled aggregate can significantly decrease the amount of construction debris sent to landfills, and the importance of reducing waste cannot be negated as it is a main component of sustainable concrete (Griffin, 2005).

This paper focuses on an integrated sustainability approach where the HSC is used for the structural design while the optimized HSC concrete mixtures used to achieve such strengths are investigated for sustainability. These approaches could lead to better sustainability results when used individually or better in synergy, so as to reach an optimum scenario having the lowest environmental impact in terms of embodied energy and CO_2 emission.

3. METHODOLOGY

Initially, for the sake of exploring the feasibility of using HSC instead of NSC for the structural design of a concrete building, a case study was introduced. Secondly, a number of HSC concrete mixtures were obtained from an extended search of the literature available on the topic. The concrete mixtures were assessed for their sustainability by investigating their life cycle assessment, using the available data on the environmental impact of different components involved in the concrete mix.

3.1. Case Study

The chosen building is a six storey (21 m height) concrete structure with a floor area of 882 m^2. The structural system of the building is a reinforced concrete skeleton as shown in Figure 1.The slabs were taken as flat slabs with an edge beam, the spans between columns ranges from 3 m to 12 m. For this case study, only columns are considered for the comparison. This based on the fact that normally HSC is feasibly used for structural members in compression such as columns (Kotaem, 2015). It is important to note that columns usually constitute only small volumes of concrete (e.g. 200 - 800 m^3) within one project. i.e. around 20 to 25% of the concrete volumes required for the whole structure (Breitenbücher, 1998). The concrete building was designed according to the Eurocode 2 standards for the design of concrete structures (BS EN 1992-1-1:2004). Figure 2 shows the column and axes plan with column models labelled. The plan is symmetrical half way between axis 5 and axis 6, and therefore the column cross sections are symmetrical vertically. It should be noted that each column model represent a set of columns with similar straining actions obtained from the structural analysis.

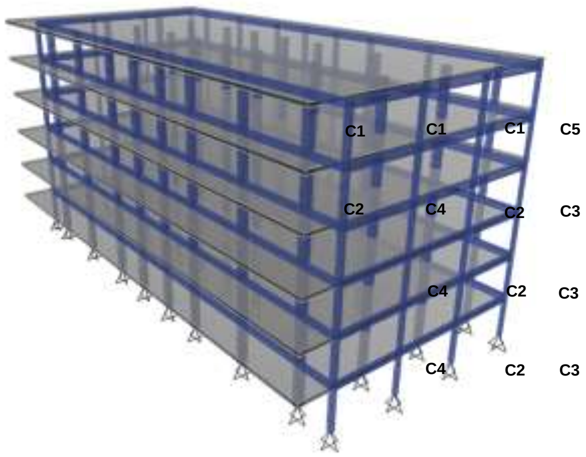

Figure 1: FEA model of the case study

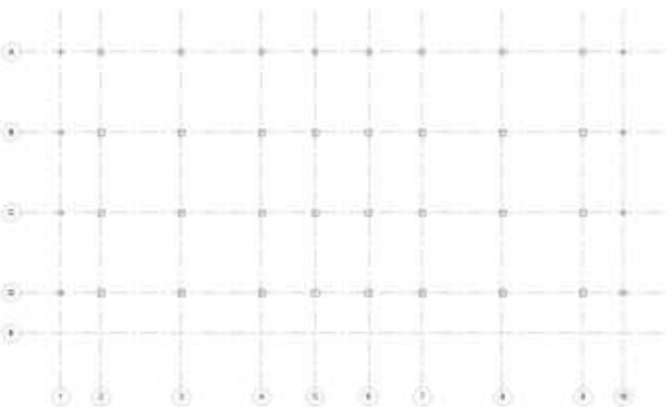

Figure 2: Column and axes plan

3.2. Structural Design

The structural analysis of the case study was performed using finite element analysis software (FEA). The structural design of the columns was carried out using Microsoft Excel models developed for the structural design of concrete cross sections to the Eurocode provisions. Columns were designed initially and then the designed was further refined until the final cross section was achieved so as to able to sustain the applied loads with a capacity ratio of at least 75% ensuring efficient concrete section. The columns were designed so as to sustain the axial load acting on them as well as the biaxial moment as obtained from the structural analysis process. The loads were defined according to the provisions of the Eurocode. The own weight of concrete elements was calculated considering a self-weight of concrete of 25 kN/m^3. The own weight of the concrete elements was considered in the design as dead loads using average values obtained from the preliminary design. Regardless, it is important to note that the loads could be slightly lower when HSC concrete is used instead of NSC since one of the expected outcomes of using HSC is a reduced concrete sections which eventually leads to a decrease in the own weight of the element itself. The floor cover and walls loads were taken as 2kN/m^2 and 3 kN/m^2 simultaneously, and were considered as part of the dead loads. The live load was taken as 4 kN/m^2. The load case considered was (1.35*Dead Load) + (1.5*Live Load).

The horizontal loads, such as earthquake and wind loads were initially investigated, however, were not found to impose excessive loads on the structure when compared to the vertical loads, and therefore were neglected in the analysis for the sake of simplicity. The design value of the modulus of Elasticity (E_s) may be assumed to be 200 GPa. Steel reinforcement of yield strength (f_{yk}) equal to 500 MPa was used in design. The allowable strain in the steel (ε_s) was taken equal to 2.2. The factor for the effective length of all columns was considered to be 0.85.

One main concern of this paper is the saving in concrete area possible when HSC is used. Design wise, the saving in concrete area of a reinforced concrete section is more sound when the amount of steel reinforcement area is fixed (Kotaem, 2015). Therefore, the approach used for all the designed cross section was a fixed area steel - variable area concrete approach (fixed A_s – variable A_c), where the concrete area of the cross section changed along with the change in the concrete strength, while the steel reinforcement area was kept fixed. According to the Eurocode, a concrete with a compressive strength of ≤ 50 MPa is considered NSC, and strength > 50 MPa is considered HSC. All the concrete columns were designed using 30, 60 and 90 MPa concrete strength.

3.3. Concrete Mixes

The key to concrete durability and sustainability, and therefore to high performance, is to enable concrete attain a tight, highly-impermeable pore structure (Griffin, 2005). HSC has a lot to do in that sense. HSC is traditionally composed of cement, coarse aggregate that is much smaller than conventional coarse aggregate ≤ 9.5 mm (ACI Committee 363, 2010), fine aggregate, supplemental cementitious materials (SCM) such as silica fume, fly ash, granulated ground blast furnace slag (GGBFS), metakaolin, and quartz powder, fibers, and HRWR. The addition of the SCMs enhances the mechanical properties of the cement paste by producing secondary hydrates, filling voids, and enhancing rheology (Dili and Santhanam, 2004).

In eco cement, large amounts of Portland cement clinker (up to 70%) are replaced by available mineral additives such as natural pozzolanic materials, sand, limestone, granulated blast furnace slag, fly ash, glass cullet and ceramic waste (Sobolev et al., 2006). A case study by G.C.Isaia (Isaia, 2000) reveals that a reduction of up to 67% of the energy requirements and 80% in the cementing materials cost may be expected when pozzolan additions of up to 50% are used. With 25% of pozzolans added, energy requirements may drop by 33% and cost by 20%.

From the literature review, 17 different concrete mix designs for NSC and for HSC basically, were collected for an extended sustainability analysis. The mixes were chosen so as to convey the required concrete strength for the design of the case study as stated in section 3.2, i.e 30, 60 and 90 MPa. Each mix was chosen so as to have strength greater or equal to the strength required, yet still less than (f_{ck} + 1.65*σ), were σ was taken as 5%. 5 mixes were used for concrete having strength of 30 MPa, 5 mixes for 60 MPa and 7 mixes for 90 MPa. The concrete mixes along with their components are shown in Table 1.

3.4. Sustainability Aspect

The most famous tool for evaluating sustainability is the life cycle assessment (LCA) of the structure. The LCA is a technique for evaluating the environmental footprint of products or processes (Hauschild, 2005). The inventory of life cycle, one phase of the LCA, enables us to quantify the two sustainability indicators, which are the total embodied energy of used construction material and their CO_2 emissions (International Standardization Organization, 2006).

3.4.1. Embodied Energy

Embodied energy is an accounting methodology that aims to find the sum total of non-renewable energy necessary to produce a product or service from raw material extraction, transport, manufacturing, assembly, installation, operations, and, finally, its disassembly, deconstruction, and/or decomposition. Typically, embodied energy is measured as a quantity of the energy per unit of building material, component, or system (Ashley and Lemay, 2008). Embodied energy may be expressed as Mega Joules (MJ) or Giga Joules (GJ) per unit of mass (kg or tonne), area (m^2) or volume (m^3).

3.4.2. Carbon Footprint

Carbon dioxide (CO_2) is one of several greenhouse gases that are believed to contribute to global warming by trapping the sun's radiant energy in our atmosphere. This process is called the greenhouse effect. Other greenhouse gases include water vapour, methane, ozone, and others. CO_2 is measured as the amount of emissions per unit of building material, component, or system (Ashley and Lemay, 2008). CO_2 may be expressed as Kilogram (kg) or Tonne (tonne) per unit of mass (kg or tonne), area (m^2) or volume (m^3).

3.4.3. Environmental Impact

Firstly, the embodied energy and the CO_2 emissions would be assessed for all the 17 concrete mixtures shown in Table 1. The environmental impact resulting from the production of 1 m³ of concrete can be calculated by multiplying the impact resulting from the production of each raw material with the amount of raw material used in the concrete and by summing up the individual impacts. The embodied energy per m³ of the mix (EE) was assessed as defined in equation (1) and the CO_2 emissions per m³ of the mix (CO_2) were calculated as defined in equation (2). For both the equations, q_i is the quantity of the constituent material per m³ of the concrete mix, while e_i and c_i are the embodied energy and the CO_2 emissions simultaneously. In order to assess the embodied energy and CO_2 emissions for each mix, eco-properties for the constituent materials given in Table 2 were used. Thereafter, these data would be further merged with the data from the case study. The embodied energy and the CO_2 emissions for the total volume of concrete required by the case study for each concrete strength used in the design process (30, 60 and 90 MPa), was assessed using equations (3) and (4). The concrete volume (V) required when different concrete strengths used is multiplied by the embodied energy per m³ (EE) of the concrete mix with the corresponding strength as in equation (3), and is multiplied by CO_2 emissions per m³ (CO_2) of the concrete mix with the corresponding strength as in equation (4).

$$EE\ (MJ/m^3) = \sum_{i=1}^{n} q_i\ (kg/m^3) * e_i\ (MJ/kg)$$
(1)

$$CO_2\ (kg/m^3) = \sum_{i=1}^{n} q_i\ (kg/m^3) * c_i\ (kg/kg)$$
(2)

$$Total\ EE\ (GJ) = EE\ (MJ/m^3) * V\ (m^3)$$
(3)

$$Total\ CO_2\ (tonne) = CO_2\ (kg/m^3) * V\ (m^3)$$
(4)

Table 2: Life cycle assessment data of important concrete raw materials

Material	Environmental Impact		(Source/Reference Number)
	Embodied Energy (MJ/kg)	CO_2 Emissions (kg/kg)	
Cement	5.8	0.691	(25) & (11)
Fly Ash	0	0	(54) & (27)
Silica Fume	0	0	(16) & (27)
Coarse aggregate	0.0470	$1.06*10^{-3}$	(25) & (11)
Recycled concrete aggregates	0.0842	$6*10^{-3}$	(11)
Fine aggregate	0.0235	$1.06*10^{-3}$	(11)
Quartz powder	0.8516	$2.34*10^{-2}$	(11)
Water	0	0	(67)
Water reducer	16	0.739	(11)
Superplasticizer	29.15	0.944	(61)

4. RESULTS AND DISCUSSION

4.1. Design of RC Columns

Table 3 shows the concrete dimensions and steel reinforcement details resulting from the structural design of the columns in the case study. It could be seen that the steel reinforcement area (A_s) was kept fixed for all the designed cross sections in each column model, allowing only the concrete cross sectional area (A_c) to change along with the change in the concrete strength (f_{ck}). The steel reinforcement ratio (μ) was optimized in such a way so as to always remain as low as possible, yet satisfy the code minimum reinforcement requirements. Such low steel reinforcement ratio works side to side with the (fixed A_s – variable A_c) approach to allow for maximum benefit from the concrete section which is our current area of interest. Most columns had a capacity ratio of 0.9 or greater, indicating that the concrete sections are working with high efficiency. Table 4 shows the concrete volumes required for the structural columns in each of the three strength scenarios, namely 30, 60 and 90 MPa. It also shows the average saving in concrete volumes achieved along with the increase in the concrete strength. The average saving is calculated by taking the concrete volume required for the 30 MPa concrete strength as the reference point for comparison. It could be seen that in the case of a 60 MPa concrete strength only half the concrete volume would be required in comparison to a 30 MPa concrete. Furthermore, a 90 MPa concrete strength would result in a saving of around 65% in the concrete area and therefore the volume required when compared to a 30 MPa concrete. However, the saving achieved upon going from 60 to 90 MPa is not as high as that achieved upon increasing

the strength from 30 to 60 MPa, even though that the numeric difference between the two strength values in each case is the same, i.e. 30 MPa difference in the strength for both cases. This is due to the fact that some expressions in the Eurocode are adjusted for classes above 50 MPa concrete strength, because the characteristics of HSC are different from NSC.

Table 3: Strucutural columns design details

Column	Straining Actions			Column Design (Variable A_c with f_{ck}, at Fixed A_s)							
	P (kN)	M2 (kN.m)	M3 (kN.m)	f_{ck} (MPa)	b (mm)	h (mm)	A_c (mm^2)	Reinforce-ment	A_s (mm^2)	μ (%)	Capacity ratio
C1	2696.5	54.8	17.6	30	410	410	168100	4 φ 16	804.1	0.48	0.95
				60	300	300	90000	4 φ 16	804.1	0.89	0.93
				90	250	250	62500	4 φ 16	804.1	1.29	0.94
C2	4732.7	32.4	59.5	30	540	540	291600	4 φ 20	1256.4	0.43	0.91
				60	390	390	152100	4 φ 20	1256.4	0.83	0.90
				90	320	320	102400	4 φ 20	1256.4	1.23	0.92
C3	3933.8	31.7	42.4	30	490	490	240100	4 φ 20	1256.4	0.52	0.91
				60	350	350	122500	4 φ 20	1256.4	1.03	0.92
				90	290	290	84100	4 φ 20	1256.4	1.49	0.92
C4	5725.6	35.2	0.9	30	590	590	348100	4 φ 22	1520.2	0.44	0.90
				60	400	400	160000	4 φ 22	1520.2	0.95	0.99
				90	330	330	108900	4 φ 22	1520.2	1.40	0.98
C5	1751.8	40	9	30	340	340	115600	4 φ 12	452.3	0.39	0.95
				60	250	250	62500	4 φ 12	452.3	0.72	0.94
				90	210	210	44100	4 φ 12	452.3	1.03	0.94
C6	893.4	5.4	2.2	30	240	240	57600	4 φ 10	314.1	0.55	0.86
				60	170	170	28900	4 φ 10	314.1	1.09	0.89
				90	150	150	22500	4 φ 10	314.1	1.40	0.78

Table 4: Concrete volumes required and the average saving in concrete quantities

f_{ck} (MPa)	Column	No. of similar columns	Total height of each column (m)	Concrete cross section (mm^2)	Concrete volume (m^3)	Total concrete volume (m^3)	Average saving in concrete quantities (%)
30	C1	8	21	168100	28.241	190.659	0.00
	C2	10		291600	61.236		
	C3	8		240100	40.337		
	C4	6		348100	43.861		
	C5	6		115600	14.566		
	C6	2		57600	2.419		
60	C1	8		90000	15.120	96.890	49.18
	C2	10		152100	31.941		
	C3	8		122500	20.580		
	C4	6		160000	20.160		
	C5	6		62500	7.875		
	C6	2		28900	1.214		
90	C1	8		62500	10.500	66.356	65.20
	C2	10		102400	21.504		
	C3	8		84100	14.129		
	C4	6		108900	13.721		
	C5	6		44100	5.557		
	C6	2		22500	0.945		

4.2. Environmental Impact of Concrete Mixes

Going back to Table 1, the lower part of the table constitutes data about the environmental impact assessment of the concrete mixes collected from the literature review. The embodied energy as well as the CO_2 emissions of each concrete mix was assessed according to section 3.4.3. From the table, mix 6 (60 MPa HSC) is seen to have the lowest environmental impact of all the mixes, with an embodied energy and CO_2 emissions of 950 MJ/m^3 and 85 kg/m^3 simultaneously. Mixes 14 and 16 (93 and 98.9 MPa HSC) seem to have the highest embodied energy of around 3657 MJ/m^3 and the highest CO_2 emissions of 380 kg/m^3. However, the later results are deceiving. A bulk number for the total embodied energy and the CO_2 emissions per m^3 of concrete materials does not provide a fair comparison of the environmental impact of all the concrete mixes. A better assessment would be through associating such environmental impact to the concrete compressive strength offered by the mix. Figure 3 shows the Embodied energy and the CO_2 emissions per unit MPa of the concrete strength offered by the mix, achieved by simply the dividing each of the embodied energy and the CO_2 emissions by the 28 day compressive strength; through this illustration it is obvious that mix number 6 still has the lowest environmental impact with an embodied energy of 15 MJ/m^3/MPa and CO_2 emissions of 1.3 kg/m^3/MPa, while mix number 4 (30 MPa HSC) has the highest environmental impact with an embodied energy of 68.8 MJ/m^3/MPa and CO_2 emissions of 8.0 kg/m^3/MPa. Mix number 6 is an innovative mix where quartz powder was used and is expected to be very dense since small size aggregate was used. Out of coincidence, mix number 4 is a low strength mix usually used in the field and was found recommended on one of the construction practise websites.

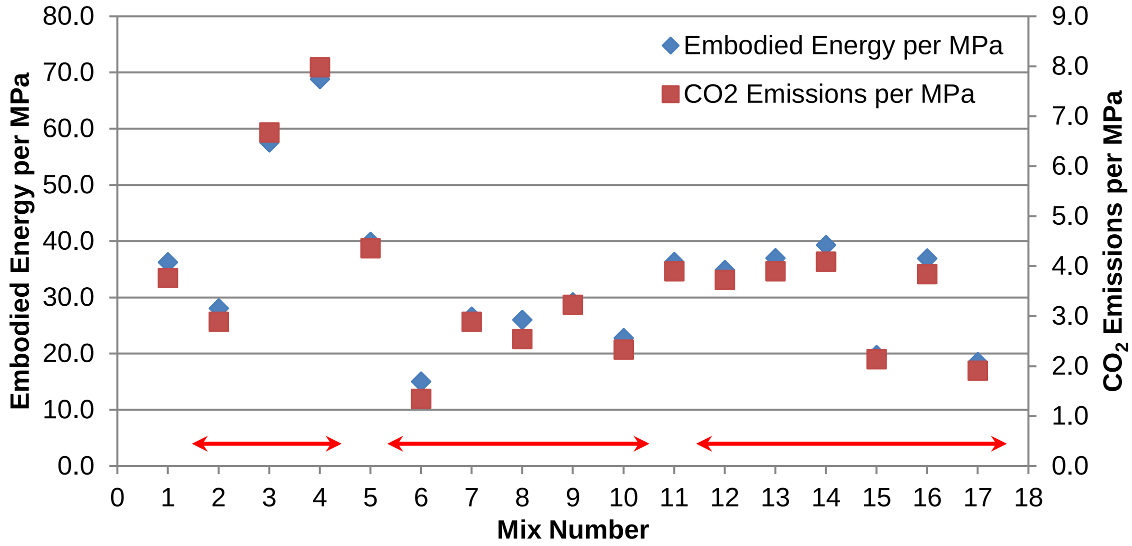

Figure 356: Embodied energy and CO_2 emissions per unit MPa for each concrete mix

4.3. Environmental Impact of Case Study

Finally, the data obtained from using HSC in the concrete design and the sustainability assessment of the different HSC concrete mixtures where put together. As stated earlier in section 3.4.3, the concrete volumes required when the case study was designed using 30, 60 and 90 MPa concrete strengths are investigated for the environmental impact when the appropriate concrete mix for each concrete strength from the mixes in Table 1 was incorporated. This integration of both the approaches, as expected, resulted in the most efficient results as both the benefits of the reduced concrete volumes when HSC was used, and the sustainability optimized HSC concrete mix design initiatives were implemented. Table 5 shows the environmental impact of the columns of the case study designed using 30, 60 and 90 MPa concrete strength, with all

the concrete mixes used appropriately. In Table 5, mix 6 gives the lowest total embodied energy and CO_2 emissions, while mix 4 again has the greatest environmental impact. The case study designed using 30 MPa concrete made with mix 4 (NSC) would use almost 5 times more embodied energy and produce more than 6 times the CO_2 emissions in comparison to designing the columns using a 60 MPa concrete mix having mix 6 (HSC) constituent materials. Such results open the door to even more applications, as 60 MPa concrete is not extremely high and could be possibly extended for use in other concrete elements as beams and slabs rather than such columns which usually represent only 20% of the total concrete volume in a structure. This would result in even better concrete structures in terms of sustainability with lower total environmental impact and less resource consumption.

Table 5: Environmental assessment results for the case study using different concrete mixes

		Mix Number																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
f_{ck} (MPa)	Concrete volume (m^3)	Total Embodied Energy (GJ)																
30	190.7	207.1	184.6	384.3	459.4	273.8	-	-	-	-	-	-	-	-	-	-	-	-
60	96.9	-	-	-	-	-	92.0	168.7	167.4	193.4	156.6	-	-	-	-	-	-	-
90	66.4	-	-	-	-	-	-	-	-	-	-	216.8	213.0	228.1	242.7	128.5	242.5	126.0
f_{ck} (MPa)	Concrete Volume (m^3)	Total CO_2 Emissions (tonne)																
30	190.7	21.5	19.0	44.5	53.2	29.9	-	-	-	-	-	-	-	-	-	-	-	-
60	96.9	-	-	-	-	-	8.3	18.3	16.4	21.4	16.0	-	-	-	-	-	-	-
90	66.4	-	-	-	-	-	-	-	-	-	-	23.3	22.7	24.1	25.2	13.9	25.2	13.0

5. CONCLUSIONS

This research focuses on the use of HSC concrete as a potential solution to the concrete industry sustainability problem. The approach followed comprises two parts; structural design using HSC which leads to material saving, and use of HSC sustainable concrete mixes with low environmental impact.

The obtained results showed that using HSC for the design of structural columns in a case study could lead to material saving as high as 65%. The assessment of different concrete mixes obtained from the literature review for sustainability was carried out. The results showed that a 60 MPa HSC (mix 6) concrete mix optimized for sustainability would have an embodied energy and CO_2 emissions of 950 MJ/m^3 and 85 kg/m^3 simultaneously, in comparison to an embodied energy of 2410 MJ/m^3 and CO_2 emissions of 279 kg/m^3 for a traditionally used 30 MPa NSC (mix 4) concrete mix. Further analysis was carried out by associating the environmental impact to the compressive strength of the concrete mix. The same HSC 60 MPa (mix 6) concrete mix had a low environmental impact with an embodied energy of 15 MJ/m^3/MPa and CO_2 emissions of 1.3 kg/m^3/MPa, while the 30 MPa NSC (mix 4) concrete had a high environmental impact with an embodied energy of 68.8 MJ/m^3/MPa and CO_2 emissions of 8.0 kg/m^3/MPa.

Finally, the data obtained from using HSC in the concrete design and the sustainability assessment of the different concrete mixtures where put together. It could be seen that if the columns of the case study were designed using 30 MPa concrete made with the 30 MPa NSC concrete mix (mix 4), it would use almost 5 times more embodied energy and produce more than 6 times the CO_2 emissions in comparison to designing the columns using a 60 MPa concrete mix having the 60 MPa HSC (mix 6) constituent materials.

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Table 1: Concrete mix constituents, embodied energy and CO_2 emissions for mixes obtained from the literature review

		Mix Number																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
		[Source/Reference Number]																
		(50)	(32)	(49)	(20)	(56)	(54)	(57)	(55)	(57)	(55)	(12)	(12)	(41)	(63)	(22)	(63)	(54)
Constituent Materials (kg/m³)	Cement	155	136	335	400	220	110	264	225	311	225	487	475	500	520	293	520	268.[illegible]
	Fly ash	190	204	0	0	182	0	176	225	207	225	0	59	0	0	44	0	0
	Silica fume	0	0	0	0	0	0	0	0	0	0	47	24	30	100	59	100	0
	Coarse aggregate	1150	1089	1187	1183	1153	1104	1185	994	1185	994	1068	1068	1100	742.5	1292	825	940.1
	Recycled concrete aggregate	0	0	0	0	0	0	0	0	0	0	0	0	0	82.5	0	0	0
	Fine aggregate	850	756	712	635	659	883	665	811	561	835	676	659	700	685	627	685	876.5
	Quartz powder	0	0	0	0	0	168	0	0	0	0	0	0	0	0	0	0	114.3
	Water	120	124	141	172	150	94	136.[illegible]	139	150	141	141.[illegible]	137.[illegible]	135	145	130	145	130.[illegible]
	Water reducer	0	0	0	1.2	0	0	0	0	0	0	0	0	0	0	0	0	0
	Superplasticizer	3.89	3.795	0	0	3.105	3.3	4.75	12.24	4.24	8.4	12.90	13.34	16.1	20	5.54	20	6.2
Max. coarse aggregate size (mm)		19	19	-	20	25	16	-	-	-	-	12.5	12.5	-	1.18	20	1.18	16
W/B – W/C		0.34 – 0.77	0.36 – 0.91	0.42 – 0.42	0.43 – 0.43	0.37 – 0.68	0.33 – 0.68	0.31 – 0.51	0.31 – 0.61	0.29 – 0.48	0.31 – 0.63	0.29 – 0.63	0.29 – 0.63	0.25 – 0.27	0.23 – 0.27	0.36 – 0.44	0.23 – 0.27	0.34 – 0.43
28 days compressive strength (MPa)		30	34.5	35	35	36	63.2	65.5	66.5	68.5	71	90	92	93	93	98	98.9	102.6
Embodied Energy (MJ/m³)		1086	968	2016	2410	1436	950	1741	1728	1996	1616	3267	3210	3437	3657	1936	3654	1898
Embodied Energy per MPa [(MJ/m³)/MPa]		36.2	28.1	57.6	68.8	39.9	15.0	26.6	26.0	29.1	22.8	36.6	34.9	37.0	39.3	19.8	36.9	18.5
CO_2 Emissions (kg/m³)		113	100	233	279	157	85	189	169	221	165	361	343	363	380	210	380	196
CO_2 Emissions per MPa [(kg/m³)/MPa]		3.8	2.9	6.7	8.0	4.4	1.3	2.9	2.5	3.2	2.3	3.9	3.7	3.9	4.1	2.1	3.8	1.9

Design of Funicular Arched Wooden False Work

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Abstract: *Construction of buildings with conventional formwork/falsework systems involves using a lot of wood as shoring which involves an extra cost and reduction of space in the construction site. A new design is presented within this study that involves the use of funicular arched wooden trusses instead of the conventional stringer-shore structural system. A closed form solution for the truss was formulated in order to calculate the straining actions and deflections. A parametric study was performed using the closed form solution to study the variations of the straining actions and deflections within the members while changing the truss span. The weights of the proposed trusses were compared to the weights of conventional formwork in order to judge the economical soundness of the new design.*

Keywords: Construction Engineering; Formwork Design; Funicular Arches; Structural Engineering; Wood;

1. INTRODUCTION

Most of concrete slabs are cast in place which creates a necessity for temporary support. Formwork supported by falsework constitutes this temporary structural system that supports the freshly poured concrete. The design of typical formwork/falsework systems involves the use of plyform or plywood to support the concrete slab while secondary wooden beams called joists transfer the load from the plyform to the main beams that are called stringers. Each stringer is typically supported on two or more shores as they could be simply supported or composed of multiple spans (Peurifoy & Oberlender, 2011). The shores could be either made of wood, steel or aluminum. In large projects, steel shores are more frequently used than job-fabricated wooden shores for supporting formwork for concrete beams and slabs. Most of those steel shores are patented and made available and adjustable over a wide range of lengths, for most of them; adjustments in length can be made in small increments and more durable but with an initial cost that is higher than that of wooden shores (Bennett & D'Alessio, 1996).

The use of patented trusses instead of stringers is a common practice that has been applied using wooden trusses with steel props or steel trusses. The advantage of such a system is mainly in the increase in span that enables fast assembly and reduction of amount of shoring (PERI, 2015). However, the entire commercially-available truss forms are typical trusses with constant depths which makes them not that cost saving in terms of their material cost in addition to the fact that they are patented that creates an additional initial cost.

Semi-circular, horse-shoe and parabolic arches made of stones or bricks have been used by ancient civilizations in Levant, Greece, Rome and transferred to gothic and Islamic civilizations (Wikimedia Foundation, Inc., 2016). However it was only within the last two hundred years where trusses having arched shapes were constructed. Unlike regular trusses with constant depths, funicular arched trusses through their parabolic shape have a major advantage in terms of minimizing the axial forces within its diagonal and upper chord members (Leet, Uang, & Gilbert, 2006). Hence, funicular arched trusses are more structurally sound in terms of having less axial forces and lower deflection and could typically cover larger spans. Due to that they are typically used in long-span bridge construction (Darwish, et al., 2015). However, till this moment funicular arched trusses were not used in formwork/falsework design.

The current study focuses on proposing the design of a funicular wooden truss that minimizes the forces within its members and hence minimizes the mid-span deflection and the needed cross-sectional area of each member. This newly proposed temporary structure is replacing the use of four spans of stringers with five shores supporting them by one single truss. Within the study, the variation of forces within each type of members is studied with changing the span. Also this variation is compared to the variation in the straining actions of typical stringer-shore designs upon changing their spans.

2. MODEL

2.1. Structure Description

The truss proposed in the study is made of thirty wooden members. As shown in **Error! Reference source not found.**, eight of these members are horizontal members (covering eight equal bays) on which the formwork is supported; eight are vertical transferring the load to the lower eight chord members that form the arched shape while six are diagonal members.

According to (Leet, Uang, & Gilbert, 2006), the arch is considered funicular if it is hinged at its two supports, with an intermediate hinge in its mid-point and its shape obeys a certain parabolic equation which is:

$y = -4hx^2/L^2$

Where x and y are the horizontal and vertical coordinates (measured from the mid-point of the arch), h is the arch height and L is the arch span. Once an arch is satisfying such conditions and subjected to a uniformly distributed vertical load, it is proven that the bending moments and shear forces within this arch are zero's (Leet, Uang, & Gilbert, 2006). Such behavior is reflected in a funicular arched truss in the fact that the diagonal and upper horizontal members are all zero members and the loads are transferred through the vertical members to the lower arched chords that carry large compressive axial forces. As the upper members are equidistant having zero axial forces, the members covering eight bays where considered to be two main members with each of them covering four bays and connected to each other at the intermediate hinge at the mid-point (top) of the arch. This is done to reduce the bending moments within these members that are resulting from them acting as beams carrying the uniform load and transferring it to the vertical members. Consequently, the maximum bending moment within each horizontal member is:

$M_u = wa^2/9$

Where M_u is the maximum bending moment, w is the distributed load and “a” is the length of each bay (which is equal to L/8).

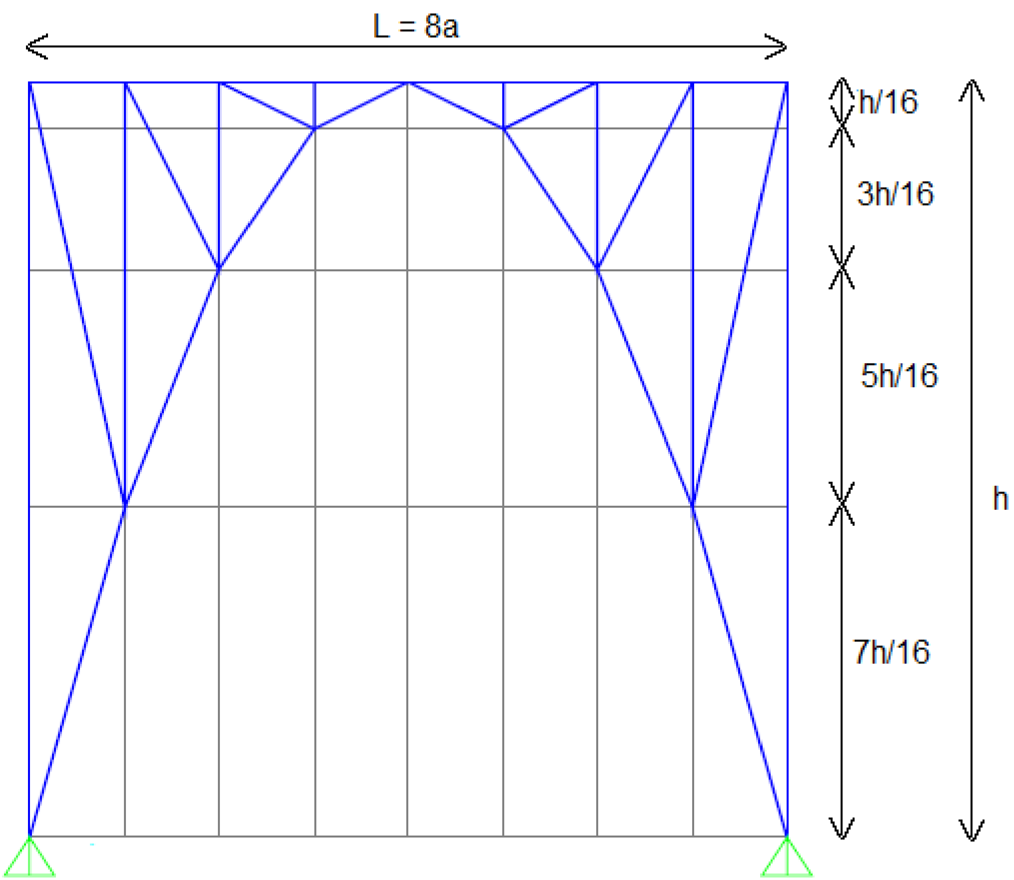

Figure 1: The proposed funicular arched truss false work.

On solving this funicular truss using the method of joints it was proven that the upper horizontal members and the six diagonal members are all zero members. It was also proven that the axial force for the each of two exterior vertical members is $P_{vext} = -wa/2$.

While the axial force for each of the six internal vertical members is $P_{vint} = -wa$

On the other hand, the axial forces in the eight lower chord members forming the arch shape were found to be satisfying one general equation which is:

$P_{ij} = -wL_{ij}L/h$

Where P_{ij} is the axial force within the member connecting nodes I and j, L_{ij} is the length of the member, L is the truss span and h is the truss height.

Furthermore, in order to also cover the deflection criteria in designing this proposed falsework/formwork system, the maximum deflection had to be calculated. The concept of virtual work was utilized in order to calculate the mid-span deflection (at the location of the intermediate hinge). A vertical unit load (called Q) was applied at the point at which the deflection needs to be calculated. The system is solved producing the axial force (F_Q) within each member. These axial forces will be used together with the original axial forces (F_P) to produce the mid-span deflection (Δ) using the following relationship:

$\Delta = \Sigma F_P F_Q/(EA)$

Where E is the modulus of elasticity and A is the cross-sectional area of each member of the truss (Leet, Uang, & Gilbert, 2006).

2.2. Validation

The closed form solution described in the previous sub-section has been validated using the finite element software SAP2000 (Computers and Sturctures Inc., 2016). The validation was performed for a truss having a height of 3.2 m and a span of 3.2 m (corresponding to a 0.8 m bay). The applied distributed load representing the load of the freshly poured concrete was 22500 N. The axial forces in the truss members outputted by SAP2000 are shown in **Error! Reference source not found.**.

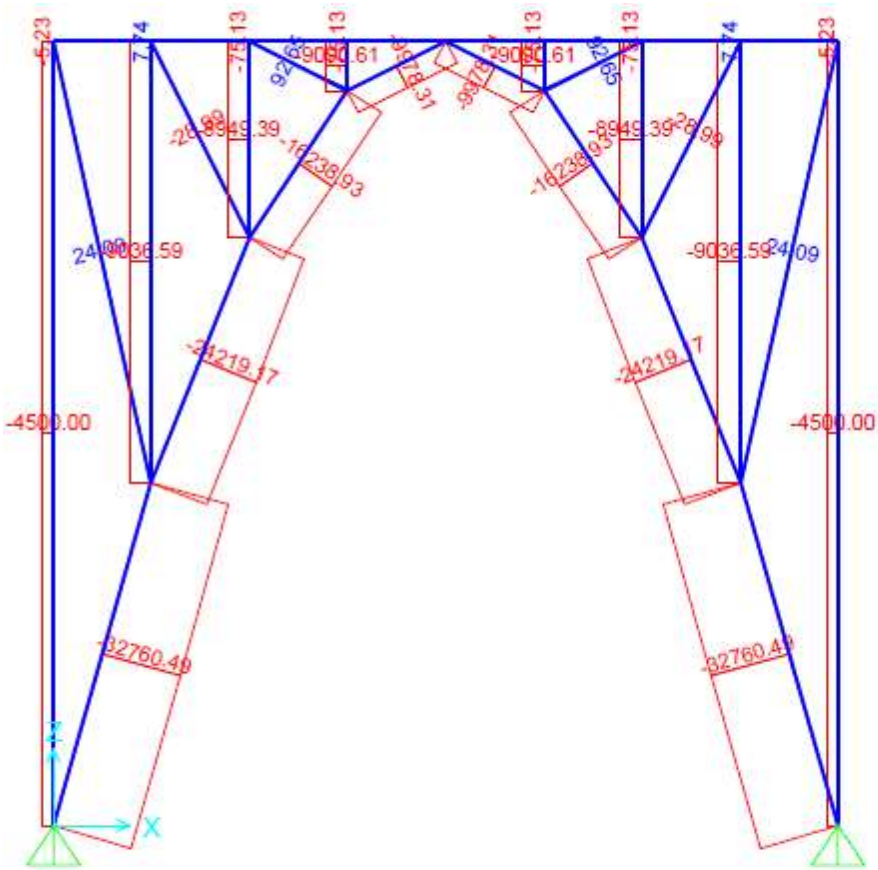

Figure 2: The axial forces in the truss members outputted by SAP2000.

The major aspect that could be noticed is that the diagonal and upper horizontal members had negligible axial forces that were within the order of few Newtons which is extremely low when compared to the forces within other members. This agrees with the fact that according to the closed form solution these members are zero members and the small forces produced by SAP2000 are only due to the approximate numerical methods that its solver utilizes. On the other hand, the axial forces within the inner vertical members are 9000 N as produced by the closed form solution while it is 9036 N on using SAP2000 with a difference of only 0.4% between the two figures. A similar behaviour could be seen when comparing the axial forces within the lower chord members using the closed form solution to their counterparts using SAP2000 as the difference between the two were ranging from 0 to 0.8%.

Accordingly, the closed form solution is considered to be valid as the differences between its outputted axial forces and their counterparts outputted by SAP2000 are negligible. Consequently, the closed form solution could be used to analyse different trusses of that same shape however different dimensions which is the parametric study described in the coming section.

3. PARAMETRIC STUDY

3.1. Structural Analysis and Design

The type of wood chosen for construction of the falsework was Douglas-fir larch that has a unit mass of 470 kg/m^3, a modulus of elasticity of 13 GPa and a strength of 50 MPa as specified by (Beer & Johnston, 1992). The section size and shape of the different members varied according to their locations and the straining actions within each of them. The six diagonal members were chosen to have a squared cross-section of only 20 mm x 20 mm as they are all zero members with no axial forces acting within them. The eight horizontal members also have no axial forces within them however they have bending moments due to the distributed loads acting on them, hence these members were all chosen as rectangular members designed to resist bending stresses. On the other hand the eight lower chords and the eight vertical members had only axial compressive forces within them and hence they were all chosen to have squared cross-sections in order to have the same buckling capacity about each of the two local axes and designed to resist compressive forces.

In addition to satisfying the strength criteria, the trusses were also designed to satisfy the deflection criteria. According to (Peurifoy & Oberlender, 2011) the maximum deflection should never exceed L/360 for architectural concrete. Hence, this value was used as the maximum allowable deflection that should not be exceeded.

On the other hand, the soundness of this design was checked by performing a parametric study. Within this study the span was varied from 3.2 m (lower bound of the study) to 6 m (upper bound of the study) with increments of 0.4 m. Hence, eight different trusses with eight different spans were studied while keeping the height to be 3.2 m for all the trusses under study as practically speaking the clear floor height in most of regular buildings is between 3 m and 3.4 m and the variation in this figure is not that significant. For each truss the soundness of the design was judged by comparing it to a typical conventional falsework system made of the same type of wood and subjected to the same loads. The total volume of the wood used in each arched truss was calculated and compared to the total volume of wood used to construct conventional stringers and shores covering the same span.

3.2. Results

Eight different funicular arched trusses were designed. All the members under compression were designed to withstand Euler buckling; this applies to the lower chords and the verticals members. The first lower cords (from right and left hand sides) are the ones facing the largest compression forces and hence were designed to have the largest cross-sections. The variation of the axial compression within these members is presented in Figure on which also the axial capacity of the designed members is plotted. The axial buckling capacity is function of the material, cross-section and member length, hence for the range of spans between 3.2 m and 5.2 m the capacity was simply decreasing with the increase in the member length (due to increase in span) until being just slightly more than the axial force as for these spans the member cross-section was kept to be 60 mm x 60 mm. On the other hand, for arches with spans of 5.6 m and 6 m, the member cross-section had to be increased to be 70 mm x 70 mm which explains the sudden jump in the axial capacity. It is also worth to note that on comparing the axial compression forces within the members under study for the different spans to the axial capacity, they were all less than the axial capacities showing that the designed members were safely designed.

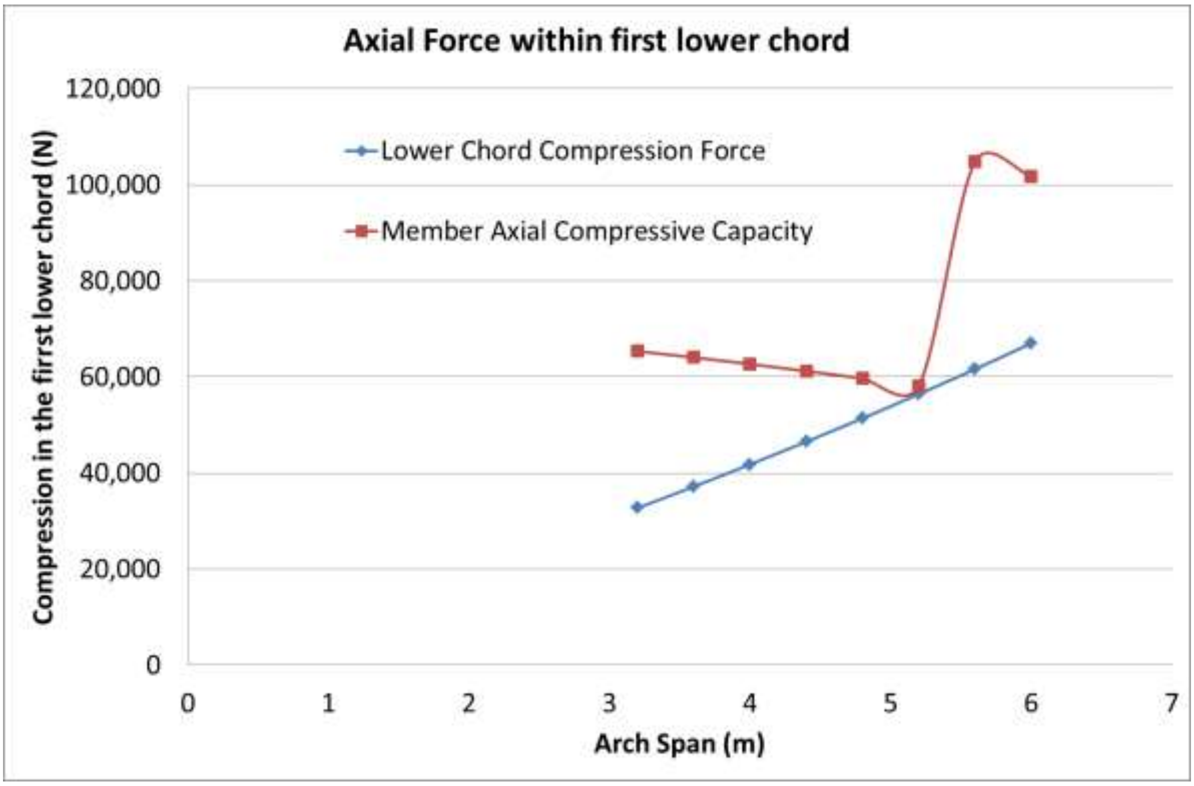

Figure 3: The Variation of the axial force and the member capacity with different spans.

The variation of the mid-span deflection was also affected by the sudden change in the member cross-sections that happened at a span length of 5.2 m and 5.6 m as shown in Figure . It could be clearly seen that the deflection was increasing with the span length however it dropped at a span lengths of 5.2 m and 5.6 m as several members had an increase in their cross-section starting from these spans. It is also worth to note that on comparing the mid-span deflections for the different spans to the maximum allowable

(L/360), they were all less than the maximum allowable deflections showing that the designed funicular arched trusses were all abiding by the deflection criteria.

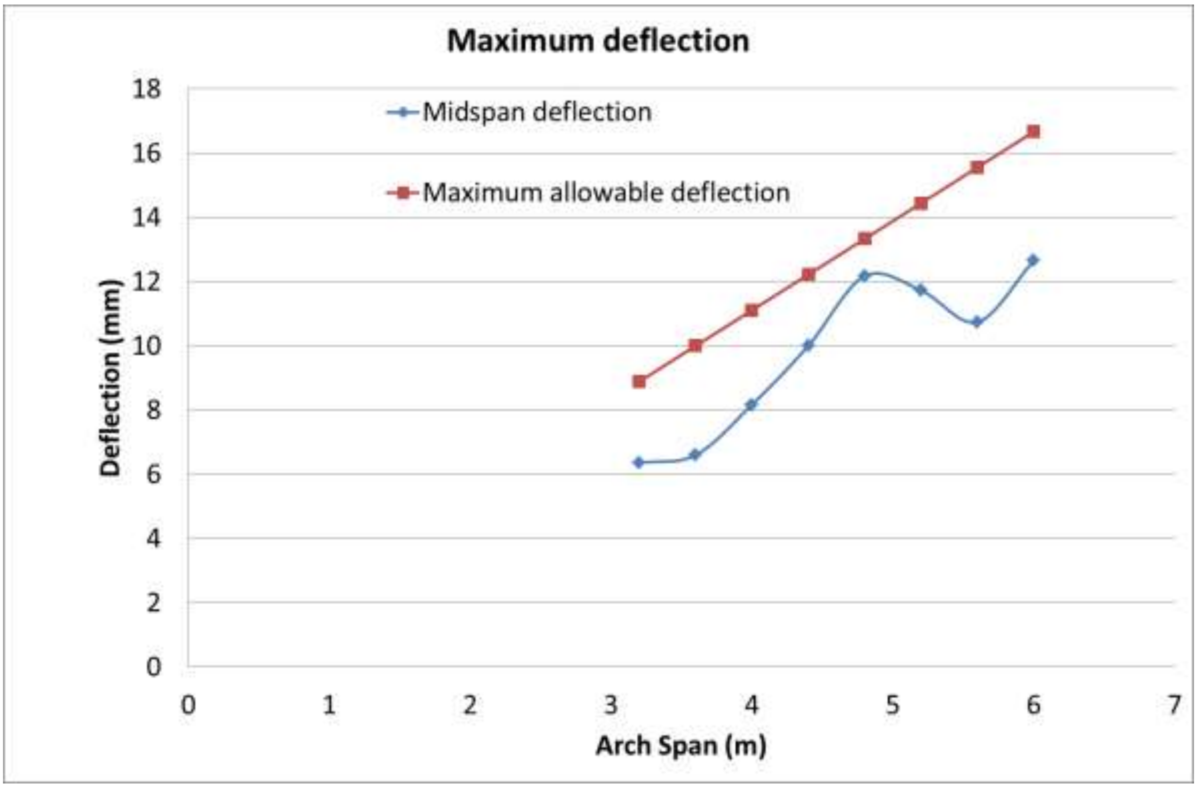

Figure 4: The Variation of the mid-span deflection and the maximum allowable deflection with different spans.

After designing each of the eight arched trusses corresponding to the eight different spans, the volume of all the members was calculated and consequently, the total weight of each truss was calculated and compared to the weight of the stringers and shores that would have been alternatively used to carry the same load if a conventional wooden formwork system would have been designed using the same kind of wood. The results presented in Figure show that for all spans, the weights of the newly proposed funicular arched trusses are always significantly less than those of the regular false work systems. Furthermore, the results shown in Table 5 show that the reduction in the weight of the false work is ranging between 35% and 56% with an average of 46%. This significant reduction in weight means that there is an expected significant reduction in the material cost of the false work wood and a significant reduction in the transportation cost (whether too the site or within it) as this cost is function of the volume and weight of the transported wood which have been significantly reduced.

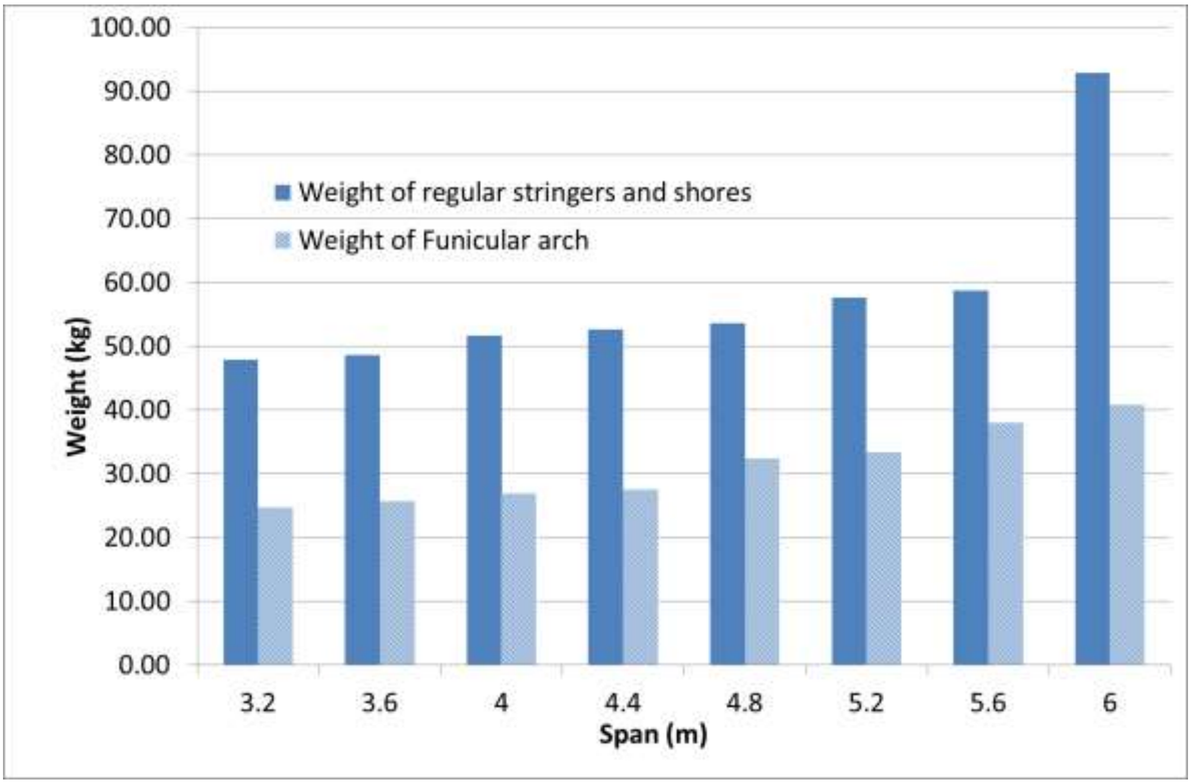

Figure 5: The variation in weights of regular system versus the funicular arched truss for different spans.

Table 5: The percentage reduction in weight

Span (m)	Weight of Regular Stringers and Shores (kg)	Weight of Proposed Funicular Arched Truss (kg)	Percentage reduction in weight
3.2	47.94	24.65	49%
3.6	48.65	25.63	47%
4	51.70	26.90	48%
4.4	52.64	27.52	48%
4.8	53.58	32.35	40%
5.2	57.58	33.31	42%
5.6	58.75	37.96	35%
6	92.83	40.73	56%

4. CONCLUSIONS

According to the results presented in the previous subsection the following conclusions could be drawn:

- The closed form solution and the finite element model produced nearly the same results with very minor differences proving that the results of the closed form solution are valid.
- Increasing the span of the funicular arched truss false work significantly increases the forces within its members creating a need for stiffer members for larger spans; this was most significant in the lower chord members.

- Consequently, increasing the span of the funicular arched truss false work significantly increases the total weight of the funicular arched truss members.
- On comparing the total weight of the funicular arched truss members to that of the conventional stringer-shore falsework system made of the same type of wood, the newly proposed design proved to save 35 – 56 % of the weight of the wood that would have been used to construct conventional stringers and shores reflecting an average savings of 46% in the material costs of falsework.

According to the drawn conclusions the author recommends performing the following research:

- Full-scale modelling of the proposed design needs to be performed.
- The details of the connections between the different truss members need to be studied.
- The response of the proposed design under wind loads need to be studied.
- A cost analysis needs to be performed in order to compare the cost-effectiveness of the proposed design to that of the patented systems readily available in the market.

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Theme III

Energy Efficiency & Renewable Technologies

Impact of Dusty Weather on Power Output of Solar Cells on Commercial Roof-top PV Systems in Egypt

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Abstract: *The dust effect on multi-crystalline PV module was investigated for outdoor conditions. The PV module performance has been tested under the deposition dust. The aim of the conducted experiment is to identify the effect of dust on the voltage and output power of PV modules. According to the obtained results, a drop of PV module's output power is observed during dusty days with an average drop in performance of 29%. This was found to be in-line with the findings in the literature. The significance of this study is that it affirms the previous findings in the literature regarding the significant impact of dusty and other pollutants on the performance of PV Modules, as well as it identifies this as a major challenges facing the development of and growth of PV Panels in Egypt considering its unique weather conditions. As such, the imperative for developing an optimum frequency of cleaning and maintaining PV panels specifically for Egypt is identified due to the frequency of days with high levels of dust, low levels of visibility, and a severe lack of rain.*

Keywords: PV Panels; Dust; Solar Efficiency; Commercial Solar Power

1. INTRODUCTION

Solar energy has been emerging as one of the most promising sources of clean, renewable energy sources in the world. The reasons for solar energy's attractiveness — and, in specific, the attractiveness of solar energy produced by photovoltaic (PV) panels — mainly revolves around the durability, flexibility, versatility, low maintenance, and long lifetime of such PV panels. From these points, PV panels have been ideal for establishing both on- and off-grid solutions for a variety of scenarios.

However, in order to understand the limitations of the majority of commercially available PV panels, a variety of factors still need to be considered; namely, the various external factors including temperature, dust, intensity of solar radiation, and hours of available sunlight. The main focus of this paper will be to better understand the impact of dust and dusty weather on the performance of commercial, roof-top PV panels in Egypt. The main objective of this research is to study the effect of dust on the efficiency of PV panels in the region on three types of photovoltaic modules in order to investigate the potential of these systems under the climate of Cairo.

2. Literature Review

There is very little in the literature that researches the impact of dustiness on PV panels, especially recently using more modern technology; however, there are some studies to consider. In a pioneering study on the impact of dust on PV systems, a degradation in performance of up to 4.7% was recorded with an average loss in incident solar radiation < 1% (M. C. Hottel and B. B. Woertz 1942). Furthermore, in a study near Riyadh in Saudi Arabia, it was indicated that a 32% reduction in performance had occurred after eight months under desert conditions in the area (Salim et al. 1988). In a similar study, a 17% decline in PV power was demonstrated due to dust deposition on PV modules in Kuwait (Wakim 1981). In another study, it was reported that the dirt on PV modules caused a 2% of power reduction as compared to clean PV modules. However, a power decrease of about 11.5% was then reported in a PV module exposed for only 72 hours in Riyadh, Saudi Arabia (Sayigh et al. 1985).

In addition, the effect of a dusty sand layer on beam light transmittance on a PV module glazing surface has been investigated by Al-Hasan experimentally and mathematically and found a negative impact (Al-Hasan 1998). When the European Union has started funding projects in the Mediterranean areas, it was mentioned in their guidelines on integrating of Photovoltaics in the Mediterranean area that there are some factors which contributed in PV balance of system (BOS), factors are listed with their contribution percentages as: temperature effect 5%, inverters losses 9%, shading 3%, mismatching 3%, reflection 3%, resistance 1%, and dust with 2%. These percentages are listed according to the projects survey made in the region (FOSTErinMED 2011).

Different researches and scientists have been working on the performance evaluation of photovoltaic system under different climates. The availability of power supply will give a good chance to involve the populations of such remote areas, increase their knowledge and make them familiar with the daily life of modern society (Adiyabat et al. 2006). Furthermore, in this study, the effect of dust accumulation on the tilted glass plates revealed a reduction in plate-transmittance ranging from 64% to 17%, for tilt angles ranging from 0° to 60° respectively after 38 days of exposure. A reduction of 30% in useful energy gain was observed by the horizontal collector after three days of dust accumulation.

In another study, the reported experiment showed that the deposition of fine dust particles on the cover of PV modules significantly affects the performance of these modules (Goossens & Van Kerschaever 1999), and it revealed that dust accumulation caused a 32% reduction in the performance of solar PV within a period of eight months. Nearby, in Kuwait City, a study recorded a reduction in PV power by 17% due to sand accumulation after six days (Wakim 1981). This study has also indicated that the influence of dust on PV performance would be higher in spring and summer as compared to that in autumn and winter.

In another study, the actual performance of five identical pairs of roof-top PV panels were experimentally evaluated while operating in the urban environment of Athens (from the atmospheric air pollution point of view) (Kaldellis & Kokala 2010). Then, the study experimentally investigated and modelled the effect of three types of dust (red soil, limestone, and ash). The impacts of dust accumulation, humidity level and the air velocity have been elaborated separately and the impact of each on the other has been clarified (Mekhilef et al. 2012). Another study in a working paper was made in Egypt by GUC and Arab Organization for industrialization during 2011 for one farm 600 Kw located in Saker Quraysh area. The study has acted as the drop in power due to the dust accumulation on the PV, for three periods as daily cleaning, two months cleaning and year clearing. The power dropt respectively as: 0.001%, 25% and 35%. But the study didn't indicate the type of each module.

Moreover, sand and dust particle accumulation on PV modules in dry regions have been numerically modelled and analysed (Beattie et al. 2012). The study indicated that the formation of particle clusters is an important effect that strongly influences the reduction in electrical power output. In addendum, Monto and Rohit have reviewed the current status of research in studying the impact of dust on PV and they identified challenges and have recommended further pertinent research. Based on the exhaustive literature study a recommendation table has been developed to guide in the identifying appropriate cleaning/maintenance cycle for PV systems in response to the prevalent climatic and environmental conditions (Mani & Pillai 2010).

For the impact of dust in the Sahara of Libya, a study was conducted experimenting the results of a heavy layer of dust accumulating on a module array during the period of February to May of 2012. And has resulted in a total reduction in output power by 3-4% that was recovered through washing the modules (Mohamed & Hasan 2012). In this study, the frequency for cleaning solar cells was established for various climates. The results for the was Mediterranean climate – for which temperature ranges from 10^o to 40^o C, annual precipitation is around 42 cm and with a latitude range of 30^o to 50^o North and South – were found to be a cleaning once every week or 2 weeks depending upon the rate of dust accumulation on the surface and in some areas daily cleaning may be beneficial to increase the system's overall efficiency (Mohamed & Hasan 2012). In Saudi Arabia, a study was conducted for ten months from February to December of 2012 and concluded that the higher the dust density, the less amount of solar radiation gets transmitted through the module glass cover to the solar cells (Adinoyi & Said 2013).

3. System Specifications

Experimental PV systems were installed in the aforementioned region with a total capacity of 4.5 KW energy.

3.1. System Description

The system consists of three different types of PV: Thin Film (produced by Tenten First Solar), Polycrystalline (produced by Canadian Solar), and mono-crystalline (produced by Solar World) photovoltaic modules. The parameters of each photovoltaic PV module generates 1400W on peak power; open short circuits current of the module is 4.7A and open circuit voltage is 18V. Every module consists of number of cells and is connected in series to feed sunny island convertor. Systems were placed in the following coordinates: 30.153°N/31.431°E. The systems were placed at an elevation of 120m above sea-level. A detailed description of the modules is provided (see Table 6: Specifications of PV modules) as well as a block diagram of the system (see

Figure 57: Block Diagram for the PV System (source: Data Sheet of the Modules)

Table 6: Specifications of PV modules

Type	Watt/Unit	No. of Units	Total Watts	Length (mm)	Width (mm)	Height (mm)	Weight (kg)	Area of 1 Module (m^2)	Total Area (m^2)
Thin Film Layer (First Solar)	70	21	1,680	1,200	600	7	11	0.7	17.3
Mono-Crystalline (Solar Wind)	175	8	1,400	1,610	810	34	15	1.3	10.4
Poly-Crystalline (CSI)	235	7	1,645	1,638	982	40	20	1.6	11.3

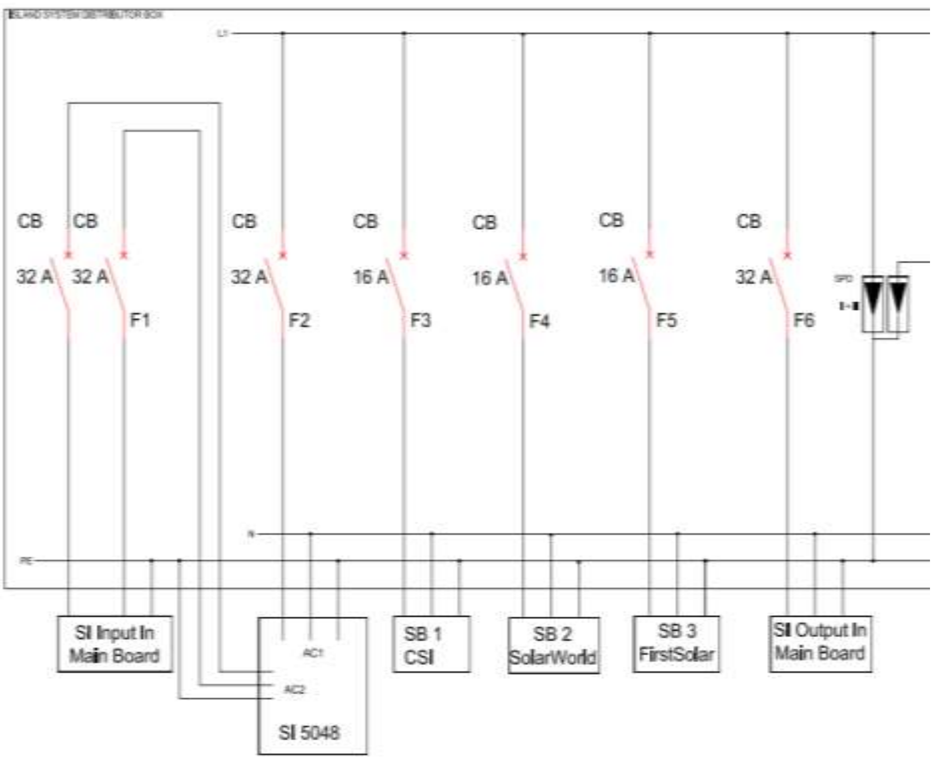

Figure 57: Block Diagram for the PV System (source: Data Sheet of the Modules)

3.2. SMA data log system specifications:

- PV system power: 4.515 KW_p
- **Modules:** CSI Poly crystalline, SW Mono crystalline and FS Thin film respectively.
- **Communication System:** Sunny WebBox
- **Inverter Type:** Three Sunny Boy 1700 invertor types
- **AC/AC Inverter Type:** Sunny Island 5048 single phase
- **Sensors:** Sunny Sensor Box measuring both ambient and module temperatures
- **Commissioning date:** October 2013.

3.3. System Models:

It was observed that beside the dust which settled on the solar PV modules, there is also atmospheric dust that scatters the solar radiation, reducing the amount of direct solar radiation reaching the light transmitting element of the solar modules. Since the primary objective of the study was to investigate the effect of accumulated dust on the performance of the PV modules,

Measurements for maximum power was recorded around noon on cloudless days, with radiation intensity being 800 W m^{-2} or greater. The main parameters on which is based the calculation of a PV system are the conversion efficiency under standard conditions (η_{stc}) and the kilowatt peak (KW_p). the first is defined as the efficiency of the photovoltaic module that produces electric current in standard conditions, which are incident solar radiation 1000 W/m^2, air temperature equal 25ºC and sunlight spectrum equivalent to 1.5AM (air mass). The efficiency n_{stc} is given by the following equation (1):

$$n_{stc} = \frac{P_{max}}{G.A_{mod}} \quad (1)$$

In equation (1), P_{max} is the electric power of the module in Watts, G is the irradiance incident on the module (1000 W/m^2), and A_{mod} is the total area of the module. Furthermore, The KW_p is defined as the amount of panels needed to produce 1 KW power under standard condition. To quantify the KW_p it is necessary to determine its surface. The equation to determine the needed area is provided using the following equation (2):

$$A_{KW_p} = \frac{P_{max}}{G.n_{stc}} \quad (2)$$

In equation (2), KW_p is reached, P_{max} is equal to 1 KW while under standard conditions, solar radiation is equal to 1 KW/m^2, thus equation (3) can be written:

$$m^2 = \frac{1}{n_{stc}} \quad (3)$$

In equation (3), units are not requested. It's purpose of the equation is to demonstrate that the area in m^2 of 1 KW_p of panels is equal to the inverse ratio of the standard condition efficiency. The average energy yield for the system according to the different types of energy losses is formulated as:

$$E_{sys} = P_{array\_STC}.f_{man}.f_{dirt}.f_{temp}.H_{tilt}.n_{pv\_inv}.n_{inv}.n_{inv\_sb} \quad (4)$$

Where E_{sys} is the average yearly energy output of the PV array, in watt-hours, P_{array_STC} is the rated output power of the array under standard test conditions in watts, f_{man} is the dimensionless de-rating factor for the manufacturing tolerance f_{dirt} is the dimensionless de-rating factor for the dirt, f_{temp} is the dimensionless temperature de-rating factor, H_{tilt} is the monthly irradiation value (KWh/m^2) for one year for the selected site, η_{pv_inv} is the efficiency of the subsystem (cables) between the PV array and the inverter, η_{inv} is the dimensionless efficiency of the inverter, and η_{inv_sb} is the efficiency of the subsystem (cables) between the inverter the inverter and the Switchboard.

4. Research methodology

The experiment investigated the effect of dust on the three modules during complete year and has focused on the dusty days for the period between January, 2015 and June, 2015. The climate parameters and weather records have been taken for certain days where the weather was unstable with strong dusty wind covering the area with the PV panels. The monitoring data has been recoded day by day to compare the output of the modules on these dusty, wind days with the regular output. Also, the experiment investigates the effect of sand on the module performance by leaving the cells unclean on normal days (without dusty wind) and see the effect of cleaning on the performance. The ways of cleaning have varied between three kinds: with wet towel, with dry towel and with Detergents for glass. Figure 1, is the PV installed on the roof of Faculty of Engineering, Heliopolis University. Commissioning date the 2nd of October, 2013. The experiments were performed in Heliopolis University, Cairo

5. Experimental System Configuration

5.1. Description of the Experiment

The dusty days have been recorded manually with monitoring the data of the ambient temperature, module temperature and the production power for the whole system. Because of the obfuscate vision in these dusty days, the Meteorological Authority was forced to close some marine ports. Table 2 shows the wind speed in m/s in the dusty days, the power yield in this day by Kwh and the energy produced one day after and one day before the target days

Table 7: Records of Dusty Days:

Date	Wind Speed (m/s)	Average Daily Power Yield per Month	Power Yield on the Dusty Day	Power Yield One Day After
06 January, 2015	11 m/s (normal 4.1)	15.82	16.75	5.32
10 February, 2015	10 m/s (normal 5.1)	16.57	15.41	6.10
18 February, 2015	11 m/s (normal 5.1)	16.57	14.80	2.53
08 March, 2015	11 m/s (normal 5.7)	16.57	18.74	11.02
26 March, 2015	09 m/s (normal 5.7)	21.00	21.87	14.15
31 March, 2015	09 m/s (normal 5.7)	21.00	22.25	19.70
10 April, 2015	10 m/s (normal 4.6)	22.93	19.01	8.49
28 April, 2015	10 m/s (normal 4.6)	22.93	23.04	٢٢,٠٩
13 May, 2015	10 m/s (normal 4.6)	21.92	20.13	18.41
27 May, 2015	8.8 m/s (normal 4.5)	21.92	14.82	13.5
27 June, 2015	7.7 m/s (normal 4.7)	21.59	21.30	٢٠,٢٨
09 September, 2015	5.0 m/s	20.44	9.50	17.90

6. Analysis

To analyse the potential impact of dusty weather on the solar panels, the average power yield of the month on non-dusty days was compared to the average power yield on dusty days for that month. However, since the sample size for individual months was very small (most months having only one or two dusty days), inferential analyses such as the Student's t-test were not considered to give accurate or useful results.

Table 8: Wilcoxon Rank Sum Test of Dusty and Non-Dusty Days (Two-Tailed)

Month	Average, Non-Dusty Day Power Yield (KWh)	Average Dusty Power Yield (KWh)	Difference	Percentage of Loss	p-Value
January	16.61	8.46	8.15	49%	0.055[a]
February	17.71	9.71	8.00	45%	0.015[b]
March	21.71	16.45	5.26	24%	0.033[b]
April	23.65	18.29	5.36	23%	0.044[b]
May	22.56	17.62	4.94	22%	0.006[c]
June	21.70	19.91	1.79	8%	0.105
July	21.92	N/a	N/a	N/a	N/a
August	21.88	N/a	N/a	N/a	N/a
September	20.44	13.31	7.13	35%	0.044[b]
Average	20.91	13.31	5.805	29%	N/a

a: significant at $p < 0.1$; b: significant at $p < 0.05$; c: significant at $p < 0.01$

As the number of incidences were very small, it was determined that non-parametric statistical technique of the Wilcoxon Rank Sum technique be used to determine if there is a significant difference between power output in the individual months. The results are seen in Table 8: Wilcoxon Rank Sum Test of Dusty and Non-Dusty Days.

As it can be seen, a significant difference in power output can be seen in the months of February, March, April, May, and September at the 95% Confidence Level (P < 0.05). In the other months, the lack of a statistical significance can be a result of the very small sample size per month.

To get a better measure of the impact of dusty days and to allow for more generalizable results, the total power output for normal days over the duration of the study was compared with the power output of the panels during the dusty days using a Student’s t-Test. The results can be seen in Table 9: Student's t-Test of Dusty and Non-Dusty Days (One-Tailed).

Table 9: Student's t-Test of Dusty and Non-Dusty Days (One-Tailed)

t-Value	Df	Lower 95% CI	Upper 95% CI	Non-Dusty Days Mean	Dusty Days Mean	p-Value
4.682	23.617	3.946	N/a	21.007	14.786	0.000

As it can be seen in Table 4, the power output during dusty days is significantly less than the power output during non-dusty days with high statistical significance and confidence (P < 0.01).

7. Conclusion

As a result of the experiments conducted, the study confirms the results of the studies reviewed in the Literature Review. Indeed, dusty days and the layers of dust that settles have a significant impact on the power output, even considering the various, modern PV panel technologies utilized in the study with output drops of up to 49%. This study thus affirms the necessity of developing a system of constant cleaning, especially following particularly dusty days. This is because the impact of the dusty weather is not only limited to the day that had a high degree of particles and pollutants in the air, but also all preceding days in which the panels are not cleaned. This is especially important as power output for PV panels with a layer of dust can decline even further than the power output for days with significant levels of dust in the air. The implications of this study implies the issue that not only that PV panels cannot be left without any level of maintenance, but also that the level of cleaning and maintenance may exceed the amount needed for PV panels elsewhere in the world. This could significantly undercut the natural advantage Egypt holds in terms of solar power production due to its high level of solar irradiation, high percentage of sunny days, and so on by reducing the output of the panels far more frequently than other nations in the region. Thus, it is recommended that future research in Egypt be conducted to identify optimal levels and frequencies of cleaning and maintenance in order to limit this negative outcome.

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Designing with Daylight in Residential Buildings

A Case Study in New Cairo

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Abstract *Daylight is counted as a vital factor in any architectural space that its consideration carefully in the preliminary design stage achieves user comfort. Moreover, good daylight design includes preventing excessive sunlight from entering and heating the space and good daylight distribution, which could be achieved by using shading systems. Consequently, this decreases the energy consumption rates of buildings, especially in Cairo. Achieving this level of careful design needs deep investigations performed by computer simulations. Conversely, daylight is not commonly used and considered in buildings in Egypt. Therefore, this study presents an intensive brute force investigation of designing with daylight for a four-floor building in Cairo. The study inspected the potential of using simple louver shading systems for a residential building in Cairo. In detail, the study was constructed on two consecutive phases. The two phases examined 1620 different configurations. The first phase focused on the visual comfort in the spaces, while the second phase concerned about ordering the successful cases from the first phase with respect to their energy performance. In addition, visual comfort was evaluated referring to LEED V4 standard and through the new improved IES metrics sDA and ASE. Furthermore, all the configurations were carried out using Grasshopper, which is a parametric modelling plugin for Rhinoceros 3D. Besides, the simulation was processed through DIVA 3.0 for Rhino that uses Radiance, DAYSIM and EnergyPlus simulation engines. Finally, a comparative analysis was carried out to conclude the effect of shading over the whole building through DesignBuilder software.*

Keywords: Energy Efficiency, Natural Daylighting, and Shading Systems

1. Introduction

Environmental and energy problems occupy nowadays the highest concern, as challenge number one facing the world. Therefore, man has no choice but to diminish energy consumption rates. As population and energy concerns increase, the demand for low energy practices are urgently needed. (Cheung *et. al*, 2005)

Globally, the request of achieving an energy efficient building is increasingly taking part, rising the attention to the importance of restoring and utilizing daylight in buildings. Daylighting has many advantages in improving the building design, as the design and well distribution of natural daylight in the space improves the visual comfort and reduces the need for artificial electric lighting. (Mikler *et al*. 2008) Artificial lighting is considered as an easily obtained method, which many building designers use it rather than going through the exhaustive process of daylighting design. In addition, artificial lighting has many disadvantages as the excessive utilizing of artificial light reflects on the energy consumption of the building. Besides, daylighting is also valued for its aesthetic possibilities and its ability to fulfil human needs (Lechner, 2014)

2. Literature review

In the context of Egypt, the last 60 years witnessed neglecting the utilization local suitable environmental techniques due to westernization. Rarely, passive design strategies such as solar shading, orientation, thermal mass, natural lighting and ventilation are used. (Abdel-Razek, 1998) (El Araby, 2002)

During 2008, residential buildings in Egypt occupied the major consumeption of energy recording 47% of the total electrical energy production. Besides, electricity consumption for residential buildings is expected to reach 35% growth yearly in the future, based on the 10% yearly increase from 1998 to 2008. In addition, cooling energy revealed to be the major sector in a building’s energy consumption achieving 67% of the total energy consumption of the unit. (Mourtada, 2009) During 2012, it was reported that buildings including residential and commercial sectors consumed 40% of the total energy of the world and about half of all that electricity could be saved by daylighting. (EIA, 2012) These high rates of energy consumption in buildings require interactions from different responsible parties as architects, governments and building’s owners.

Building energy consumption rate is highly affected by the façade design and the daylighting system utilized. A daylighting system is structured on several components that contribute in its performance, such as façade openings, glazing materials and the attached shading devices, which have a high impact on the daylight distribution and the energy consumption due to solar heat gain. (Lau *et. al*, 2016)

Glazed areas and windows allow the access of solar gains, which leads to overheating in hot climates. In climates that are characterized by high temperatures, high solar gains result in high internal temperatures and the increase of discomfort hours. All these factors affect negatively on the cooling loads of buildings resulting the increase of energy consumption by buildings.

Solar shading is the strategy of reducing heat gains into the space by preventing the solar radiation incidence in the indoor environment. Besides, solar shading is considered as a simple and inexpensive passive strategy, which could be highly effective and efficient in a clear sky and dry climate. In other words, controlling the amount of light distributed inside the room and preventing direct sunlight from penetrating diminishes heat gain inside the space. Careful design is required to achieve the balance between the visual comfort levels and the thermal comfort levels, which needs studying all the effective parameters and different configurations. Solar shading techniques include external shading as awnings, louvers and overhangs and internal shadings include blinds and curtains. During a long time, architects applied internal shading techniques neglecting external shading, but many studies reported that external shading is more effective, as it prevents direct sunrays from entering the space. While, internal shading works after they have already penetrated the space resulting higher heat gains. (Kim *et.al*, 2012) (Olgyay, 1992)

One of the external shading techniques that is widely used today is the louver shading system. It provides a non-expensive solar protection method for buildings and improves daylight distribution inside the interior space. Many studies investigated the potential of using louvers on daylight and thermal performance. A study investigated the performance of a louver shading device finding that the effective parameters of a louver shading system is the louver inclination angle, window to wall ratio and number of louvers. However other studies used vertical fins in the east and west orientations, Palmero & Oliveira revealed the positive effect of installing a horizontal louver system in a vertical layout on the east and west facades in Cairo's climate. (Palmero & Oliveira, 2010)

Wong and Li studied the effectiveness of a simple horizontal shading device on cooling load for East and West windows of residential buildings. The study resulted 2.62–3.24% energy savings by applying the shading device with 30cm depth, while recorded 5.85–7.06% savings in the case of 60cm depth. (Wong & Li, 2007) Gouri Datta concluded that the optimization of a louver system design is carried out annually. (Datta, 2001)

As a result, many techniques were developed to enable daylighting design for buildings considering its main principle. One of these techniques is computer simulation, which overcame previous drawbacks and was used in many researches to investigate daylighting performance coupled with energy analysis. (Malkawi, 2010) Also, Loutzenhiser stated that building energy simulation programs can be very effective in design decisions by carrying out parametric studies for the daylight design process. (Loutzenhiser *et. al*, 2007)

Locally, Egypt is characterized by the chaotic and major use of repetitive prototypes of housing units in several locations with no consideration of the orientation and surrounding environments as shown in Figure 1. Consequently, this causes massive problems especially in daylighting, which is considered as one of the major factors of its availability is orientation. However, daylighting design requires careful study and implementation, as daylighting principles is to reach maximum visual comfort coupled with minimum cooling loads in the space.

Recently, many studies investigated solar shading effect on energy consumption of buildings. However, no studies examined solar shading design carefully for each space in the building. The careful design is expected to be more effective in the balance between visual comfort and thermal performance. Therefore, the study aims to investigate the potential of designing a daylight system for each space in a selected repetitive housing prototype building located in Cairo. In other words, the study considered the investigation for the user comfort internally in the space, while neglecting any external comfort factors, such as the view. Referring to the literature, the horizontal louver system using a vertical layout appeared to be suitable for East and West orientations coupled with its positive effect in daylight distribution inside the space. The prototypical condition of the addressed case study endorses unitization and simplicity in the approached solutions. Consequently, the horizontal louver system in a vertical layout was used for the investigation. The study approached the research aim in a different method than previous studies. In other words, the study adopted a brute force methodology by studying the case intensively on each architectural space of the building. Besides, the study assessed the daylight adequacy using the new approved IES metrics (Heschong *et.al.* 2012) and complying with LEED V4 that wasn't used for assessment in the previous mentioned studies. Finally, the study was processed through different soft-wares using same simulation engines to result a comparative analysis of the exact saving effect achieved by a shading system on the whole building energy consumption.

3. Research methodology

Based on the previous literature, the study was structured on two phases using a parametric simulation process to investigate the potential of designing a daylight system. First, phase one studies the visual comfort that results from different proposed configurations of the horizontal louver system coupled with different WWRs. The second phase studies the thermal energy performance of the successful configurations from the first phase. Last, the improvement caused by applying the system was investigated through a whole building simulation, as a comparison of the cooling load of the base-case building and the cooling load after applying the daylight shading system was carried out.

The evaluation criteria of phase one was based on LEED V4 minimum requirements using the IES approved metrics; Spatial Daylight Autonomy (sDA 300/50%) and Annual Sunlight Exposure (ASE 1000/250hr) (IES, 2012). The LEED V4 require minimum values of 55% for the sDA metric and no more than 10% of ASE values (USGBC, 2014) (Heschong *et.al.* 2012). In addition, the methodology of selecting a reference building was based on several factors. First, the building typology which is residential. Second, the building was selected to be a repetitive prototype, so the findings of the study could be applied to the similar buildings of the same prototype. The reference project for the case study of this research was selected to be in the 5th settlement of New Cairo city as shown in Figure 2. The masterplan of the selected reference project consisting three zones of land plots around 300 m^2, and the plots have different orientations in all the orientation axes as shown in Figure 3. Hence, a statistical study for the masterplan was carried out, and It was found that the east oriented buildings are the major land piercings of the masterplan. Therefore, the conducted study was carried out on the east oriented buildings, that consists of ground floor, two typical floors and last floor.

Based on the methodology, the simulation soft-wares were selected. Phase one and phase two of the simulation were processed using Grasshopper 3D and DIVA 3.0 for Rhino, which is a simulation interface that couples daylight simulation engines and thermal energy simulation engine; Radiance, DAYSIM and Energy Plus respectively. DesignBuilder was selected as a software for the comparative analysis for several factors. First, for the non-capability of performing a multi-zone simulation on DIVA 3.0. Second, DesignBuilder uses the same simulation engines used by DIVA 3.0.

In detail, a complete urban cell was modelled using grasshopper 3D to be similar to the reality and to consider the shading effect of adjacent buildings. Additionally, rooms of the building were classified into two types; two fenestration rooms and one fenestration rooms and annotated as shown in Figure 4. In other words, the similar rooms in the same orientation were simulated once, while any difference in room dimensions, orientation and floor number required a specific simulation for the specific room.

Several parameters were studied in this investigation as illustrated in in Table 2 and visualized in Figure 5. The design parameters were a result of the literature findings, as the louver rotation angle was recommended for its effectivity. The number of louvers was studied to investigate the effect increasing number of louvers on the performance, while WWR was a studied parameter with a range from 30% to 70%. While, the limitation of the investigated solution required a constant depth for the louver, as high depth results a structure limitation and increases the cost. In addition, the primitive design characteristics of the louver were determined from the previous studies and illustrated in Table 1. Also, the Radiance simulation parameters for the used Metrics are as shown in Table 3. The successful configurations were simulated from the scope of energy consumption to conclude the optimum louver design for the building.

The total energy consumption was used for evaluation and selection of the optimum cases, which includes cooling and lighting load. Finally, last part of the simulation concerns about finding the total effect of the applied optimum cases. This part was carried out by a comparative analysis between the two cases; building before shading and building after shading. The required cooling load was used for the comparison between the two cases.

Table 1: primitive design characteristics of the louver system

Side Extension	30 cm
Depth	60 cm
Distance Between Louvers	60 cm

Table 2: Different studied parameters

Parameter	Range	Step
Window to wall ratio	30% - 70%	10%
Number of Horizontal Louvers	1-3	1
Louver Angle	0^o - 45^o	15^o

Table 3: Simulation parameters of Radiance

Required Metric	Ambient Bounces	Ambient Divisions	Ambient Sampling	Ambient Accuracy	Ambient Resolution
sDA	6	1000	20	0.1	300
ASE	0	1000	20	0.1	300
Analysis nodes	Distance between analysis nodes = 0.3m				

4. Discussion and conclusion

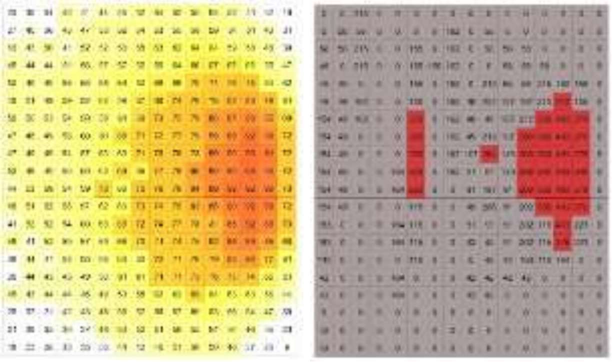
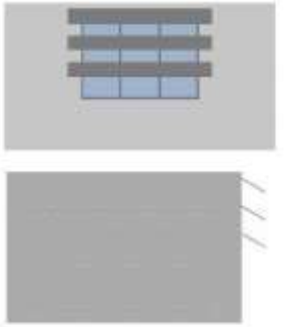
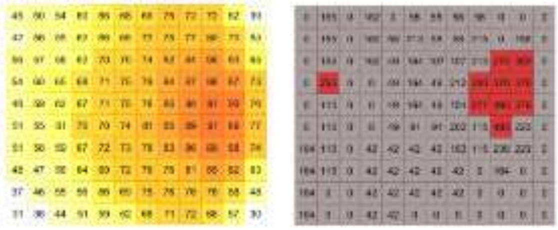
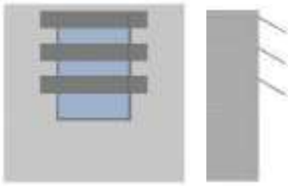
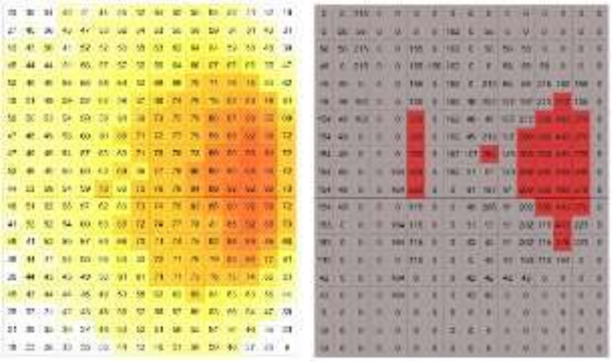
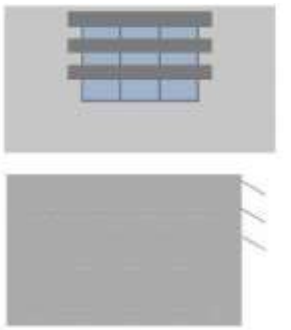
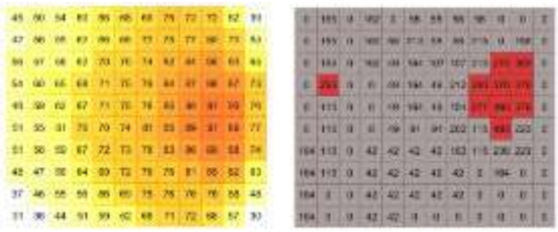
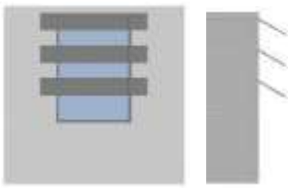
Rooms of One Fenestration

First, this category is defined as the rooms having one opening in its perimeter, so this opening is the main fenestration. Therefore, this requires studying its different WWRs effect on the internal daylight and the thermal performance. The incapability of investigating two windows as parameters led to neglecting secondary windows in the ground floor living space, as fenestrations were ordered upon their priority. In other words, facing windows were studied, while side windows were not considered. The 1st category study was conducted through 600 simulation configuration. Cases were evaluated to comply with LEED V4 requirements.

Table 4: Optimum configurations for rooms of one fenestration

Room Name	Floor Number	WWR (%)	Louver Angle (º)	Number of Louvers	sDA (%)	ASE (%)	Total Cooling (kWh)
G-L	Ground	30	30	3	72	10	66.4
A1-B1	Typical	30	30	3	89	8	83.1
	Last	30	30	3	91	8	83.0
A1-B2	Typical	30	30	3	66	4	76.0
	Last	30	30	3	66	4	76.2
B-B1 & A2-B1	Ground	50	15	3	61	0	115.5
	Typical	30	0	3	75	4	101.6
	Last	50	45	3	65	4	95.5
B-B2 & A2-B2	Ground	50	0	3	57	0	117.7
	Typical	30	0	3	55	1	94.1
	Last	40	30	3	55	7	84.1

Table 5: 2D visualization of the successful configurations

Room		Daylight Metric (sDA, ASE)	Other Views
G-L	Ground Floor		
A1-B1	Typical Floor		
Room		**Daylight Metric (sDA, ASE)**	**Other Views**
G-L	Ground Floor		
A1-B1	Typical Floor		

In addition, optimum configurations of the successful cases that balance between daylight and thermal performance were summarized in Table 4, where it appears that all successful cases had three louvers, besides the major successful WWR was 30%. Furthermore, examples of the successful cases were illustrated in Table 5, which shows the different metrics sDA and ASE visualizations coupled with the room and louver 2D views. Furtherly, accepted cases were simulated for phase two. Finally, daylight design in the first category of rooms provides the internal spaces with visual comfort levels coupled with adequate daylight, which complies with LEED V4 requirements.

Rooms of Two Fenestrations

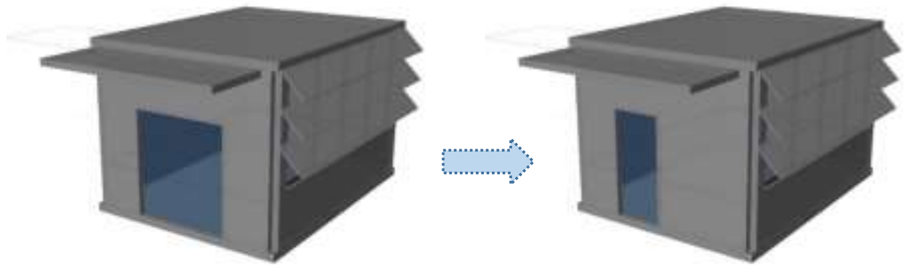
Second, this category contains the rest of the rooms having more than one fenestration, but not as two parameters. In other words, fenestrations in these rooms are characterized by being one fixed as the balcony opening that was considered as a constant component, while the main fenestration was considered as a variable for studying the WWR parameter.

Moreover, the configurations of the parameters for best results were summarized in Table 6. Additionally, not all the rooms achieved accepted cases by the LEED V4, as the ASE values were more than 10%. Therefore further investigations were conducted for these configurations in order to achieve accepted cases.

Table 6: Optimum configurations for rooms of two fenestrations

Room Name	Floor Number	WWR (%)	Louver Angle (º)	Number of Louvers	sDA (%)	ASE (%)	Total Cooling (kWh/m^2)
A1-L	Typical	30	45	3	99	20	115.9
	Last	30	45	3	99	20	115.8
A2-L	Typical	30	30	3	100	17	158.1
	Last	30	30	3	100	34	157.7
B-B3	Ground	40	30	1	95	9	115.5
	Typical	40	0	3	100	18	146.5
	Last	40	45	3	100	33	119.2
B-L	Typical	30	45	3	69	10	117.7
	Last	30	45	3	68	10	94.1

Through observing the results of each room with the different parameters, it was found that despite the change of the studied parameters doesn’t result a change in the ASE level. This could be explained that the solar shading has reached its maximum effect in blocking direct sunrays, while the fixed fenestration (balcony entrance) is the effective in that case. Therefore, simulation in this stage was carried out once more on the best cases, but with half area of the former balcony entrance as shown in Figure 6.



As per expectations, the decrease in the balcony entrance area resulted better performance, lower ASE values and more accepted cases. However, some configurations didn't achieve the minimum ASE requirements. Despite the failure of some configurations to comply with LEED V4 requirements, the total cooling load decreased by decreasing the area of balcony entrance. In addition, all the optimum achieved results of the case of two fenestration rooms were summarized in Table 7. Generally, the majority of the cases required three louvers, besides best WWR ranged from to 30% to 50%.

Table 7: Optimum configurations for rooms of two fenestrations after decreasing balcony area.

Room Name	Floor Number	WWR (%)	Louver Angle (°)	Number of Louvers	sDA (%)	ASE (%)	Total Cooling (kWh/m^2)
A1-L	Typical	30	45	3	100	20	96.8
	Last	30	45	3	100	20	96.7
A2-L	Typical	30	30	3	81	10	141.7
	Last	30	30	3	98	17	145.3
B-B3	Ground	40	30	1	95	9	115.5
	Typical	40	0	3	95	7	141.9
	Last	40	45	3	94	17	118.1
B-L	Typical	30	45	3	69	10	117.7
	Last	30	45	3	68	10	94.1

In conclusion, it can be noticed the high effect of ASE levels on the required cooling loads as diminishing the ASE levels directly decreased the required cooling load of each space. While in the cases that ASE didn't decrease, the decreasing of WWR gives higher U-value for the building envelope leading to diminishing of heat gains internally. Different metrics sDA and ASE visualizations coupled with the room and louver 2D views were illustrated for the optimum achieved configurations in Table 8. Finally, a closer observation for the effect of modifying the balcony area appears in the ASE values illustrated in Table 9.

Table 8: Optimum configurations for rooms of two fenestrations

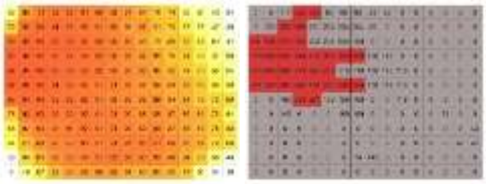
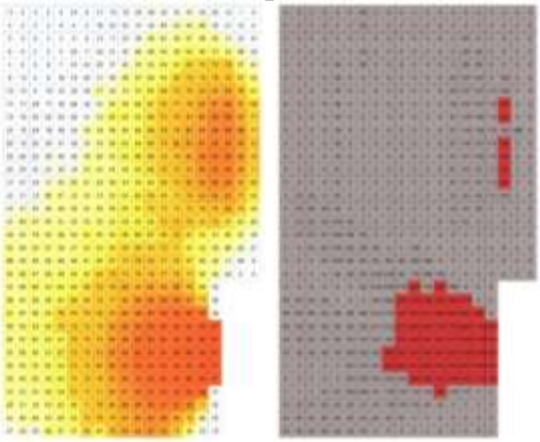
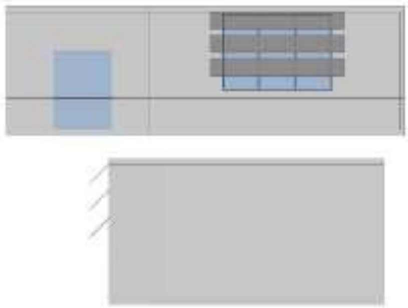
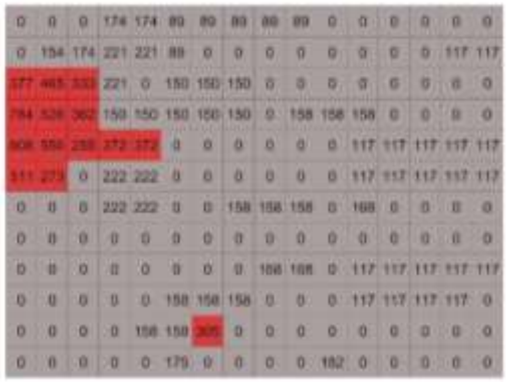
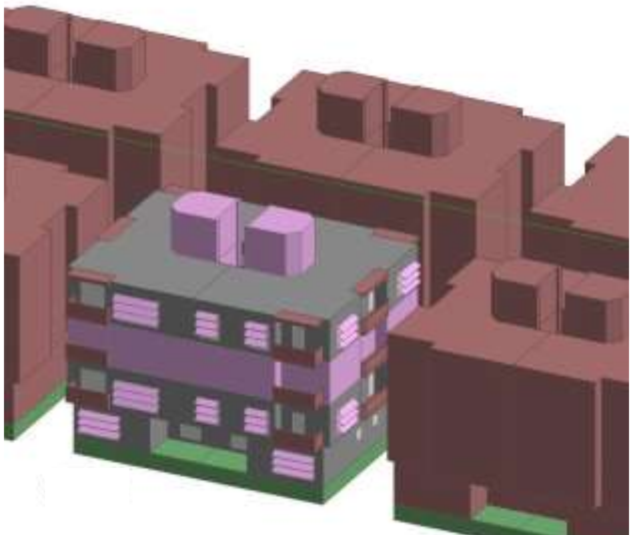
Room	Daylight Metric (sDA, ASE)	Other Views
Last Floor		
Typical Floor		

Table 9: The effect of changing the balcony area on the ASE values

	Before Decreasing Balcony Area	After Decreasing Balcony Area
ASE Metric		
ASE Valu	18% (Not within the accepted range)	7% within the accepted range

Comparative Performance



In order to evaluate solar shading effect of the whole building, a similar 3D model was created and modeled including the surrounding buildings in DesignBuilder. The surrounding buildings were in the form of adiabatic components to facilitate modeling data and save simulation time. After reaching adequate daylight inside most of the spaces, the simulation results and successful configurations were inputted to Design-Builder to study the effect of shading elements on the whole building through calculating the required cooling load.

Figure 7. shows the application and modelling of the optimum concluded configurations in the prior part of the study. In addition, the louver systems were modelled as standard components in Design-Builder. Design Builder simulated the required cooling load of the whole building revealing the positivity and high effect of shading on the whole building.

The results of phase three showed that solar shading is an effective strategy and has high impact on energy efficiency. Moreover, the effect of window shading was relative to the floor number. In other words, louver shading was effective on the last floor by 700 – 800 kWh, while on the lower typical floor by nearly 400-450 kWh and on the ground floor by about 200 kWh. Furthermore, the overall effect of shading on the whole building reached 10.64% saving about 4190 kWh as shown in Figure 8.

5. CONCLUSION

This research investigated the potential of using daylight in architectural design and giving its careful consideration. Furthermore, the study tackled the main objective through a brute force simulation process that included 1620 different configurations. The study was performed on a repetitive prototype in Cairo. In addition, the study revealed that in the case of east oriented prototypes in this project, applying louver shading sytems would achieve a high impact of reducing required cooling load of the units coupled with high levels of visual comfort in most of the spaces. Consequently, this leads to energy consumption diminish and the increase of the thermal comfort hours coupled with adequate daylight in the space. In general, the study concluded the importance of using a shading system and using deep investigations in designing and configuring it. Besides, it revealed the high impact that can be obtained in diminishing the energy of a repetitive prototype if applied on the similar buildings. However, not all the configurations achieved optimum performance. Therefore, further research is recommended for the unsuccessful spaces. Besides, other shading types can be integrated with the louver system as vertical fins. Also, more parameters can be investigated to reach the optimum configuration. Finally, designing with daylight is a critical objective that should be considered in designing residential buildings in Cairo and can effectively be an approach for solving the energy problem of buildings.

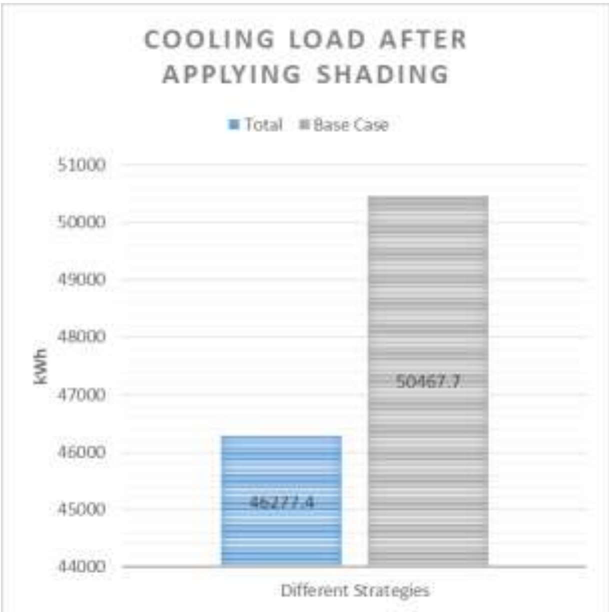


Figure 8: Total cooling load reduction resulted after applying louver system.
Source (DesignBuilder, 2015)

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Reducing the Energy Consumption with Responsive Architecture in the Hot Arid Regions

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Abstract *Designing buildings which are sustainable and can reduce the energy consumption is such an architectural turn. Historically, buildings were designed paying attention to the surrounding environmental conditions, using natural materials and creating comfortable indoor environment. Along with the technological development, buildings were designed depending on the technical systems to maintain the interior comfort which leads to the increasing of energy consumption and pollution of the environment. One of the most important methods of saving energy in a building is carefully designing its façade. Building's façade is one of the most significant contributors to the energy budget as well as the comfort parameters of a building.*

The aim of the paper is proving that responsive façades reduce the energy consumption of buildings and thus reduce the carbon emissions and the environmental pollution. At first, the paper will briefly describe responsive architecture and its types. Then, a comparative analysis between four different types of the responsive façades will be applied on a selected building in Egypt in order to prove that responsive façades reduce the energy consumption. The comparative analysis will also result in determining the most efficient type in reducing the energy consumption based on a computer simulation of grasshopper programs, Ladybug and Honeybee plugins. At the end, the paper will suggest some recommendations for the architects in order to improve the responsive architecture in Egypt.

Keywords: Responsive Architecture; Rotating Responsive Façade; Shifting Responsive Façade; Folding Responsive Façade and Diaphragm Responsive Façade.

1. INTRODUCTION

The building sector plays a great role in the non-renewable energy consumption resulting in polluting the environment, emitting greenhouse gasses and changing the climate. In order to achieve a sustainable society, the energy consumed by buildings needs to be reduced. The Intergovernmental Panel on Climate Change in 2007 stated that the building sector consumes energy more than the transportation and the industrial sectors. It also stated that, building sector is one of the sectors which large amount of energy can be saved from (IPCC, 2007). Improvements in the materials and the mechanical systems installed have made it possible to increase the buildings efficiency and decrease the energy consumption (Modin, H., 2014).

Building's main purpose is protecting the occupancies from the external surrounding environment and achieving comfortable indoor environment. Throughout history, this was possible by applying the passive techniques such as thermal mass, solar insulation, shading and natural ventilation. The building was designed to deal with the environmental alteration surrounding it (Modin, H., 2014). Nowadays, large number of buildings are designed without taking into considerations the surrounding environmental conditions. The development of building technology results in designing buildings which depend on additional systems during large periods of the year. Intensive HVAC (Heating, ventilation and air conditioning) system is used to reduce the unwanted conditions and to maintain a comfortable indoor environment. The HVAC system consumes about 58 percent of the energy used in buildings, as shown in figure (1). (International Energy Agency (IEA), 2014).

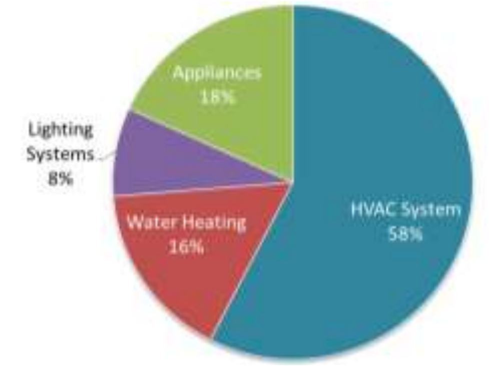


Figure (1): Energy Consumption in Building Sector (International Energy Agency (IEA)), 2014

The building envelope, which is the outer skin of the building, is the layer of maximum thermal exchange between the indoor and the outdoor environment. The building envelope is subjected to cyclic changes in the exterior climate through day and night and seasonal periods. As a result, the building envelope should be designed to be a great potential for energy saving and react with these alterations. (Addington M. and Schodek, D., 2005)

Moving elements are not a recent phenomenon in the building sector. The developments in the field of robotics and electronics have made it possible for the architectural elements to move, and to respond easily to the alteration of the external surrounding environment. The possibilities of responsive materials and responsive building envelopes can play a great role in the reduction of the energy consumed by HVAC systems for heating and cooling spaces (Modin, H., 2014).

2. RESPONSIVE ARCHITECTURE

Contemporary architecture has introduced kinetic movements as a process of self-adaptation and responsiveness. According to Tristan d'Estree Sterk, responsive architecture is defined as *"a class of architecture or building with the objective of physically reconfiguring themselves to meet changing needs with variable mobility, location or geometry"* (Sterk, T., 2005). Responsive architecture is the architecture which has the ability to change its properties and flexibly control the different parameters of a building envelope, in order to adapt to the alteration of the external climatic environment so as to maintain the indoor comfort. The changes can be introduced by several ways, such as the use of moving elements in the façade or the chemical changes in the properties of the façade material (Modin, H., 2014).

Two types of responsive architecture are (1) responsiveness to weather and climate and (2) responsiveness to human interaction. Responsiveness to weather and climate can respond and adapt to the surrounding weather and environment in order to increase the building performance and reduce the entered solar radiation. This can be achieved through two techniques, either by changing the geometric pattern or changing the properties of the material used (Meagher, M., 2015). Changing the geometric pattern is changing the fragments and the orientation of the patterns on the façade. The building is divided into patterns which change their location in order to reduce the solar radiation entering the building, as shown in figure (2), (Modin, H., 2014). Changing the material's properties is changing the chemical properties of the material which the façade is made out of due to certain conditions such as exposing to high solar radiation. The aim of this process is to reduce the solar radiation entering the building, as shown in figure (3),(Kolarevic B., and Parlac V., 2015). Responsiveness to human interaction is responding the building to the movement of the human body. The aim is to form an interactive tool which grape the attention of the users moving around the building, as shown in figure (4), (Studio

Figure (2): Institute of the Arab World, Paris (Modin, H., 2014)

Figure (3): Media TIC Building in Barcelona (Kolarevic B., & Parlac V., 2015)

Figure (4): Aperture Wall (The Future of Things Website, 2015)

In changing the geometric patterns, the parts and components of the building's façade alter in different movement to form different geometry. The types of movement are (1) rotating type, (2) shifting type, (3) folding type and (4) diaphragm type, as shown in figure (5). (N. Gondrie, & G. Gooskens, 2013).

The responsive façade system composed of a sensor, a processor and an actuator (Addington M., & Schodek, D., 2005). The Sensor reads data in the surrounding medium and sends this data as an input data to the processor), as shown in figure (6). The processor takes a decision according to the predefined logic and then sends a signal to the actuator. The actuator is the part of the system which is responsible for converting the processed data into a mechanical or chemical action (Modin, H., 2014).

The scope of the paper is investigating the four different movements of changing geometric patterns in responsiveness to weather and climate type, as shown in figure (7).

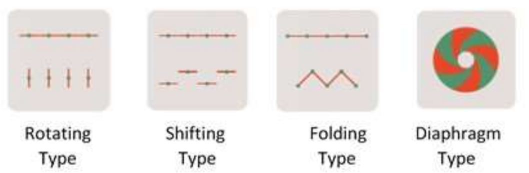


Figure (5): Types of Movement of Macro Level (N. Gondrie, & G. Gooskens, 2013)

Figure (6): The Responsive Façade System (Modin, H., 2014)

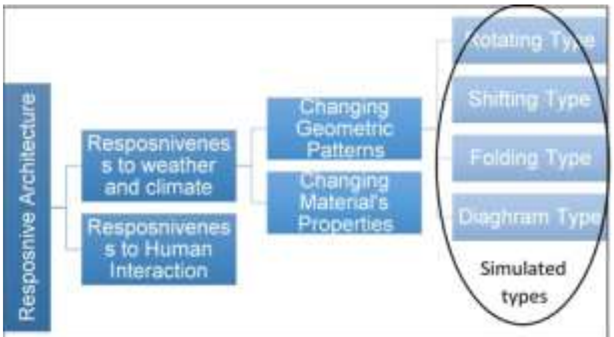


Figure (7): Types of Responsive Façades applied as modified conditions of D-Building (Author, 2016)

3. INTERNATIONAL RESPONSIVE FAÇADES

The following is a comparative analysis between two international buildings which used responsiveness to weather and climate type in the façades.

Table (1): Comparative Analysis between Two International Responsive Façades (Author, 2016)

<table>
<tr><th colspan="2"></th><th colspan="2">Al Bahr Towers, United Arab Emirates</th><th colspan="2">Q1 Building , Germany</th></tr>
<tr><td rowspan="6">Responsive Façade's Mechanism</td><td>Responsive Façade's Mission</td><td></td><td colspan="2">Preventing the direct sun rays from entering the buildings during working hours</td><td></td></tr>
<tr><td>Type</td><td colspan="2">Folding Type</td><td colspan="2">Rotating Type</td></tr>
<tr><td>Form</td><td colspan="2">Each Unit composed of 6 triangular forms or origami umbrellas</td><td colspan="2">Horizontal metal “feathers” and vertical stainless steel stalks. The horizontal Metal varies from trapezoids to triangles and rectangles.</td></tr>
<tr><td>Movement</td><td colspan="2">Unfold/fold to respond to the sun’s path and the surrounding environment</td><td colspan="2">Rotate around its axis to respond to the sun’s path and the surrounding environment</td></tr>
<tr><td>Location of Responsive Units</td><td colspan="2">They are covering only the East, South and West Zones, while the north zone is not covered as the sun hits it before and after the working hours</td><td colspan="2">The four facades contain responsive units. Only three facades rotate (west, east and south facades), as the north façade is not exposed to solar rays.</td></tr>
<tr><td>Responsive Units’ Program</td><td colspan="2">Simulates the movement of the sun and correspondingly moves the responsive units automatically</td><td colspan="2">Adapts the responsive units automatically according to the hours along the day</td></tr>
<tr><td rowspan="4">Effect of the Responsive Façade</td><td>Solar Gain</td><td colspan="2">50% reduction</td><td colspan="2">30 % reduction</td></tr>
<tr><td>energy consumption</td><td colspan="2">20% reduction</td><td colspan="2">30 % reduction</td></tr>
<tr><td>carbon emission</td><td colspan="2">20% reduction</td><td colspan="2">27 % reduction</td></tr>
<tr><td>Natural Light</td><td colspan="4">Better natural lighted spaces due to permitting natural diffused light entering the building which affects the health of the users positively.</td></tr>
</table>

4. RESPONSIVE CASE STUDY IN EGYPT

4.1. Selected Building in Egypt

The criteria is the selection of a random building located in an arid region, Egypt, which has a fully glazed system façade. The chosen building, shown in figure (8), is an educational building called D-Building located in the German University Campus in Cairo. The D-Building is used by 3 departments which are Architecture and Urban Design department, Civil Engineering department and Applied Arts department. The building is located in New Cairo city, Cairo, the capital of Egypt. It is located in the Campus of the German University in Cairo, behind Arabella Compound and the calcified woods protected area, as shown in Figure (9).

Figure (8): D-Building in the German University in Cairo (Author, 2016)

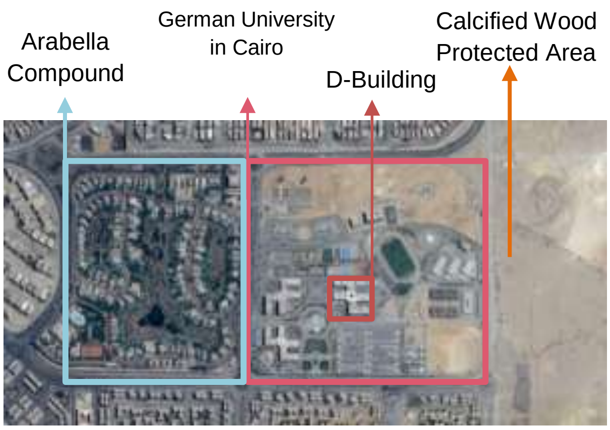


Figure (9): Location of the D-Building (Author, 2016)

4.2. Building's Energy Simulation

4.2.1. Points of Simulation

<u>Types of Energy Simulated</u>

Buildings consume large amounts of energy in order to achieve a comfortable indoor environment which can be accomplished by HVAC system. The HVAC system depends on the cooling and heating energies (Consumer Energy System, 2016). As a result, the paper will simulate the selected building according to the cooling and heating energies, trying to prove that the responsive façades reduce the cooling and heating energies and thus reduce the energy consumption.

<u>Simulations' Days</u>

The cooling and heating loads are affected by the solar radiation. As Shown in figure (10), the intensity of the solar radiation is affected by the length of the day. As a result, the selected days for the simulation are the longest and the shortest days of the solar radiation in Cairo, Egypt. December 21st is the shortest day in Cairo with 10:13 hours of daylight, while June 20th is the longest day with 14:05 hours of daylight (Weather Spark, 2015).

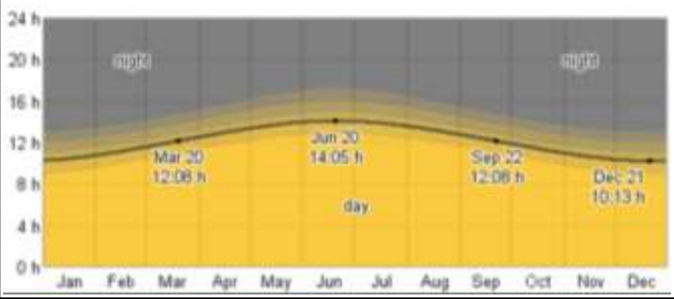


Figure (10): Daily Hours of Daylight and Twilight in Egypt (Weather Spark, 2015).

Selection of the Simulated Period of Time

The simulation period of time is the hours during which the building is exposed to solar radiation which is starting from 7:00am till 19:00 pm. After calculating the solar radiation hourly from 7:00am till 19:00, as shown in table (2). It is revealed that the minimum solar radiation are at the early beginning of the day (7:00 am till 9:00 am) and at the end of the day (17:00pm till 19:00pm), while the maximum solar radiation is at the middle of the day (12:00pm till 14:00pm). As a result, the cooling and heating energies will be calculated along 9 specific periods of time, as follows:

- 07:00am till 09:00am - 09:00am till 10:00am
- 10:00am till 11:00am -11:00am till 12:00pm
- 12:00pm till 14:00pm -14:00pm till 15:00pm
- 15:00pm till 16:00pm - 16:00pm till 17:00pm
- 17:00pm till 19:00pm

Table (2): Hourly Solar Radiation on D-Building from 7:00am till 19:00pm
Source: Author

Period of Time		Solar Radiation	
Starting Time	Ending Time	June	December
7:00am	8:00am	1890.5	46
8:00am	9:00am	2830.6	535.4
9:00am	10:00am	3637.9	1364.7
10:00am	11:00am	4182.5	2523.5
11:00am	12:00pm	4296.6	3976.9
12:00pm	13:00pm	4411.1	4858.9
13:00pm	14:00pm	4620.1	4971.98
14:00pm	15:00pm	4763.3	3953.6
15:00pm	16:00pm	4574.3	3085.6
16:00pm	17:00pm	3993.1	1574.6
17:00pm	18:00pm	3154.6	0
18:00pm	19:00pm	1339.1	0

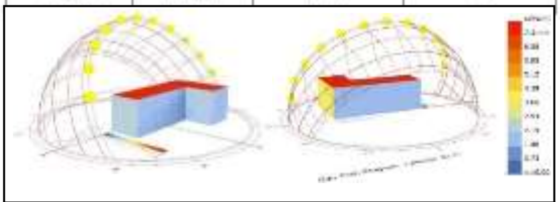


Figure (11): Solar Radiation Analysis in 20th of June from 7:00 till 19:00 (Author, 2016)

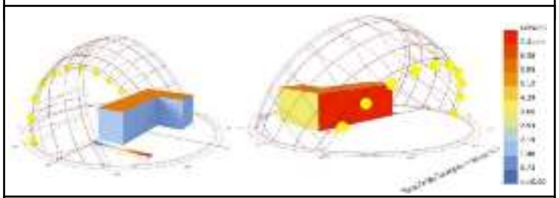


Figure (12): Solar Radiation Analysis in 21st of December from 7:00 till 19:00 (Author, 2016)

Selection of Simulated Building's Façade

Solar radiation Analyses were carried out using Ladybug and Honeybee plugins. As shown in Figure (11), the west façade is the most façade exposed to solar radiation during 20th of June with 3.66 KWh/m2. As shown in Figure (12), the south façade is the most façade exposed to solar radiation during 21st of December with 7.31 KWh/m2. As a result, the south façade is exposed to solar radiation more than the west façade. Thus, the paper will simulate the responsive façades on the south façade of the D-Building.

4.2.2. Simulation of the Building's Existing Condition

Figure (13): South Façade (Author, 2016)

The existing condition of the D-Building is the current state which is the full glazed façade without any responsive façade, as shown in figure (13). The simulation will be carried out in two steps which are cooling and heating energy. The two Energies will be simulated in two periods of times which are 20th of June and 21st of December. The heating energy in the 20th of June is zero and the cooling energy in the 21st of December is also zero. The followings are the cooling energy in the 20th of June and the heating energy in the 21st of December:

Table (3): Cooling and Heating Energies of the Existing Condition (Author, 2016)

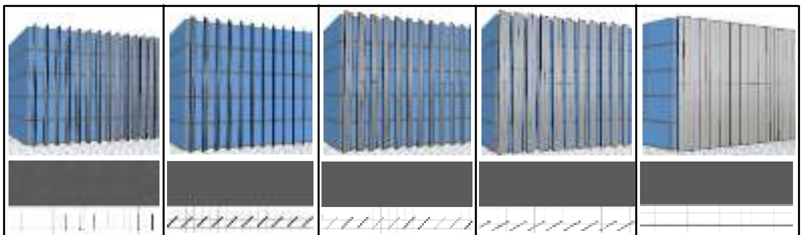
Hours	20th of June	21st of December
	Cooling Load (KWh)	**Heating Load (KWh)**
7:00AM till 9:00 AM	19.5	464.9
9:00AM till 10:00 AM	267.7	86.3
10:00AM till 11:00 AM	516.3	57.9
11:00AM till 12:00 PM	504.4	21.6
12:00PM till 14:00 PM	1049.4	26.5
14:00PM till 15:00 PM	652.7	9.8
15:00PM till 16:00 PM	749.2	8.7
16:00PM till 17:00 PM	803.2	9.1
17:00PM till 19:00 PM	1336.5	28.4
Total Cooling Load / day	5898.9	713.3

4.2.3. Simulation of the Building's Modified Conditions

The modified conditions of the D-Building are the four different types of the changing the geometric patterns of the façade which are (1) Rotating Type, (2) Shifting Type, (3) Folding Type and (4) Diaphragm Type.

<u>Rotating Responsive Façade</u>

The unit of the rotating responsive façade rotates around its axis. There are two types of rotation which are the vertical and horizontal rotation mechanism. The vertical rotating responsive façade rotates around the z-axis, while the horizontal type rotates around the x-axis. The rotation of the units starts the rotation from 7:00am till 19:00pm in 5 different angles. The five rotation angles are 90º, 60º, 45º, 30º and 0º, as shown in figure (14). The units rotate by an angle 90º at the early evening (7:00am till 9:00 am) and at the ending of the day (17:00pm till 19:00pm) in order to enter the solar radiation and to allow the view surrounding the building. The units rotate till they reach 0º at the middle of the day (12:00pm till 14:00pm) in order to block the high intensity of the solar radiation, as shown in table (4).



90º	60	45º	30º	0º
7:00am to 9:00am	9:00am to 10:00am	10:00am to 11:00am	11:00am to 12:00pm	12:00pm to 14:00pm
17:00pm to 19:00pm	16:00pm to 17:00pm	15:00pm to 16:00pm	14:00pm to 15:00pm	

Figure (14): Rotational Angle of the Rotating Responsive Façade (Author, 2016)

Table (4): Cooling and Heating Energies of the Vertical and Horizontal Rotating Responsive Façade (Author, 2016)

Hours	Angle of Rotation	Vertical Rotating Responsive Façade		Horizontal Rotating Responsive Façade	
		20^{th} of June	21^{st} of December	20^{th} of June	21^{st} of December
		Cooling Load (KWh)	Heating Load (KWh)	Cooling Load (KWh)	Heating Load (KWh)
7:00AM till 9:00 AM	90^{o}	0.16	421	0.15	424
9:00AM till 10:00 AM	60^{o}	59	79	58	82
10:00AM till 11:00 AM	45^{o}	155	65	152	68
11:00AM till 12:00 PM	30^{o}	319	37	318	39
12:00PM till 14:00 PM	0^{o}	757	51	757	41
14:00PM till 15:00 PM	30^{o}	508	15	504	16
15:00PM till 16:00 PM	45^{o}	608	14	604	14
16:00PM till 17:00 PM	60^{o}	666	14	662	14
17:00PM till 19:00 PM	90^{o}	1119	44	1122	45
Total Cooling Load / day		4191.16	740	4177.45	743

<u>Shifting Responsive Façade</u>

The units of the shifting responsive façade move in the y-axis and change their location taking into consideration the location of the other parts. The vertical and the horizontal shifting responsive façades differ in orientation of the units, however they move in the same direction. The shifting responsive façade moves on the y-axis starting from 7:00am till 19:00pm in 5 different movements. The shifting façade has two different types of units. The first type is the units which are static, while the second type is the units which move on the y-axis. The five movements of the units are 1m, 0.75m, 0.5m, 0.25m and 0m away from the static units, as shown in figure (15).

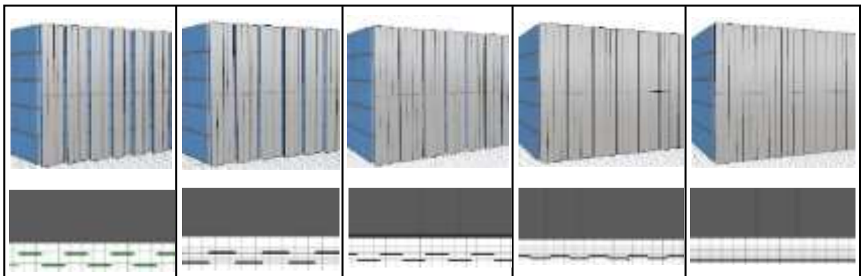
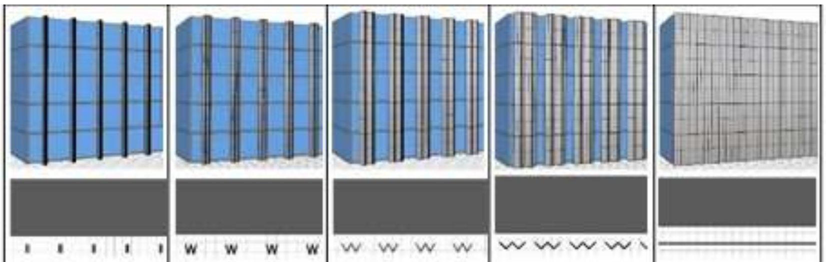


Table (5): Cooling and Heating Energies of the Vertical and Horizontal Shifting Responsive Façade (Author, 2016

Hours	Angle of Rotation	Vertical Shifting Responsive Façade		Horizontal Shifting Responsive Façade	
		20th of June	21st of December	20th of June	21st of December
		Cooling Load (KWh)	Heating Load (KWh)	Cooling Load (KWh)	Heating Load (KWh)
7:00AM till 9:00 AM	1m	0.12	426	0.15	424
9:00AM till 10:00 AM	0.75m	57	81	58	80
10:00AM till 11:00 AM	0.5m	151	67	153	65
11:00AM till 12:00 PM	0.25m	315	39	315	36
12:00PM till 14:00 PM	0m	757	45	757	40
14:00PM till 15:00 PM	0.25m	500	16	500	16
15:00PM till 16:00 PM	0.5m	597	14	597	14
16:00PM till 17:00 PM	0.75m	657	14	656	14
17:00PM till 19:00 PM	1m	1104	48	1103	45
Total Cooling Load / day		4138.12	750	4139.15	734

<u>Folding Responsive Façade</u>

The units of the folding responsive façade move by the folding technique and change their location taking into consideration the location of the other parts. The vertical and the horizontal shifting responsive façades differ in orientation of the units, however they fold with the same angles. The folding responsive façade folds starting from 7:00am till 19:00pm in 5 different angles which are 90 º, 60 º, 45 º, 30 º and 0 º, as shown in figure (16).



90 º	60 º	45 º	30 º	0 º
7:00am till 9:00am	9:00am till 10:00am	10:00am till 11:00am	11:00am till 12:00pm	12:00pm till 14:00 pm
17:00pm till 19:00pm	16:00pm till 17:00pm	15:00pm till 16:00pm	14:00pm till 15:00pm	

Figure (16): The 5 Angles of the Folding Responsive Façade (Author, 2016)

Table (6): Cooling and Heating Energies of the Vertical and Horizontal Folding Responsive Façade (Author, 2016)

Hours	Angle of Rotation	Vertical Folding Responsive Façade		Horizontal Folding Responsive Façade	
		20th of June	21st of December	20th of June	21st of December
		Cooling Load (KWh)	Heating Load (KWh)	Cooling Load (KWh)	Heating Load (KWh)
7:00AM till 9:00 AM	90 ⁰	0.145	427.33	0.13	427.33
9:00AM till 10:00 AM	60 ⁰	57.75	82.45	58.07	82.45
10:00AM till 11:00 AM	45 ⁰	153.58	68.38	153.5	68.38
11:00AM till 12:00 PM	30 ⁰	316.9	38.87	317.7	38.87
12:00PM till 14:00 PM	0 ⁰	757.81	51.05	758.77	51.05
14:00PM till 15:00 PM	30 ⁰	503.1	16.19	504.17	16.19
15:00PM till 16:00 PM	45 ⁰	604.43	13.96	602.7	13.96
16:00PM till 17:00 PM	60 ⁰	663.89	14.4	666.16	14.4
17:00PM till 19:00 PM	90 ⁰	1122.122	49.47	1120.15	49.47
Total Cooling Load / day		4179.727	762.1	4181.35	758.754

<u>Diaphragm Responsive Façade</u>

The building's aperture opens and closes in a circular technique in order to control the entrance of the solar radiation inside the building. The diaphragm responsive façade opens and closes in a circular technique starting from 7:00am till 19:00pm in 5 different radiuses which are 1m, 0.75m, 0.5m, 0.25m and 0m , as shown in figure (17).

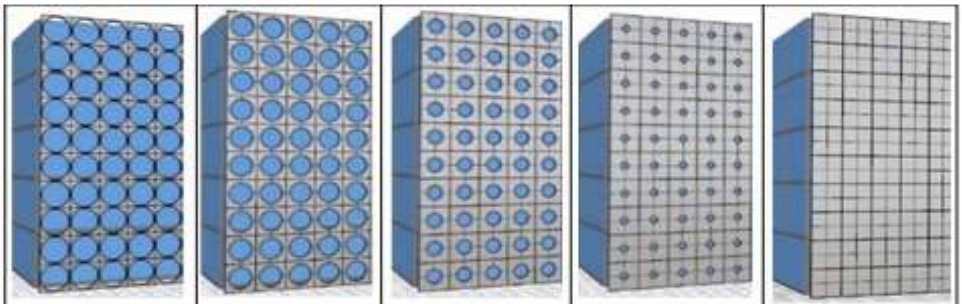


Figure (17): The 5 Radiuses of the Diaphragm Responsive Façade (Author, 2016)

Table (7): Cooling and Heating Energies of the Diaphragm Responsive Façade (Author, 2016)

Hours	Movement	20th of June Cooling Load (KWh)	21st of December Heating Load (KWh)
7:00AM till 9:00 AM	90 ^{0}	0.13	428.049
9:00AM till 10:00 AM	60 ^{0}	56.49	83.2
10:00AM till 11:00 AM	45 ^{0}	150.42	70.27
11:00AM till 12:00 PM	30 ^{0}	313.79	41.12
12:00PM till 14:00 PM	0 ^{0}	757.9	51.15
14:00PM till 15:00 PM	30 ^{0}	499.45	16.3
15:00PM till 16:00 PM	45 ^{0}	599.74	13.77
16:00PM till 17:00 PM	60 ^{0}	659.78	14.32
17:00PM till 19:00 PM	90 ^{0}	1114.39	51.79
Total Cooling Load / day		4546.812	769.96

4.2.4. Comparison between the Five Building's Conditions

Total Cooling and Heating Energy consumed in the two Days

	Rotating Responsive Façade		Shifting Responsive Façade		Folding Responsive Façade		Diaphragm Responsive Façade
	Vertical	Horizontal	Vertical	Horizontal	Vertical	Horizontal	
Total Cooling & Heating Loads (KWh)	4931.16	4920.45	4888.12	4873.15	4941.83	4940.104	4922.056
Cooling & Heating decreased Loads	1681.04	1691.75	1724.08	1739.05	1670.37	1672.09	1690.14
% Decreased	25.42	25.59	26.07%	$\boxed{26.30\%}$	25.26%	25.29%	25.56%

5. CONCLUSION

Numbers of simulations are carried out in order to prove that the responsive façades can reduce the energy consumed by buildings. A comparative Analysis is held between the energy consumed by the building in its existing condition and the four different modified types of the changing geometric patterns. The four modified types are the rotating, shifting, folding and diaphragm types. They change their geometric patterns according to the alteration of the surrounding weather and climate. As the HVAC aspect is the most aspect in the building sector in consuming the energy, the comparative analysis was carried out between the cooling and the heating. The objectives of the comparative analysis are to determine the most efficient type from the four types in reducing the energy consumption and the percentage of the reduction. The numbers of simulations are carried out using the Grasshopper program, Ladybug and Honeybee Plugins program. Diva plugin is also used to recalculate the energies as a sort of checking the results.

The rotating, shifting and folding types are investigated in both the horizontal and the vertical orientation. The diaphragm type is investigated in only one orientation as there isn’t any difference between the vertical and the horizontal movement due to its circular movement. The followings are the concluded points from the comparison between the horizontal and the vertical movement of each type:

- <u>Rotating Responsive Façade:</u>
- The horizontal rotating façade reduces energy more than the vertical rotating façade by a difference of 0.17%.
- The horizontal rotating responsive façade reduces the energy consumption by 25.59%.

- <u>Shifting Responsive Façade:</u>
- The horizontal shifting façade reduces energy more than the vertical rotating façade by a difference of 0.23%.
- The horizontal shifting responsive façade reduces the energy consumption by 26.3%.

- <u>Folding Responsive Façade:</u>
- The difference between the energy reduced by the horizontal and the vertical movement of the folding responsive façade is 0.03% which is nearly 0%. As a result, there is no difference between the horizontal and the vertical folding façade in reducing the energy consumption.
- The folding responsive façade reduces the energy consumption by 25.29%.

- <u>Diaphragm Responsive Façade:</u>
- The diaphragm responsive façade reduces the energy consumption by 25.56%.

The following is the arrangement of the four types of the changing geometric patterns according to the most efficient type in reducing the energy consumption in the building sector:

1. Horizontal Shifting Responsive Type
2. Horizontal Rotating Responsive Type
3. Diaphragm Responsive Type
4. Folding Responsive Type

The result of the paper is proving that responsive architecture reduces the energy consumed in the building sector by a percentage of 25-27. The shifting responsive type applied on an educational building in Cairo on the south façade reduces the energy consumed better that the rotating, folding or diaphragm type.

Recommendations for Architects

In order to improve the application of responsive architecture in Egypt, architects should take care of the followings in the building's three stages:

In the Design Stage

- The selection of the façade where the responsive architecture will be applied on.
- The selection of the exact hour and the corresponding rotation angle or moving distance.
- The orientation of responsive façade, whether it is vertical or horizontal.

In the Implementation Stage

- The components of the system which can be easily replaced if there is any failure to avoid the problem occurred in the Arab World Institute building.
- The mechanism of movement which should not be a complicated movement in order to avoid the system's failure.

In the Operation Stage

- The system's maintenance should be done on time in order to avoid the failure of any part of the system to avoid the problem occurred in the Arab World Institute building.

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Reducing Carbon Emissions in Egypt's Building Sector

The Ecological Case for Bearing Walls

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Abstract: *Buildings are the main cause for global CO_2 emissions (USGB, 2008). Almost half of their lifetime emissions are caused during the production process of the utilized building materials and the transportation to the construction site – so called grey or embodied energy (Adams, 2006). This paper adds an ecological point for the use of load-bearing walls. It demonstrates that bearing walls ought to become the preferred construction method, particularly for residential buildings of one to three stories, as this technique renders superior ecological qualities, i.e. saving CO_2 emissions, and facilitates financial advantages, while also improving the thermal comfort within the building.*

The Egyptian construction industry relies heavily on the method of skeleton construction. This technique has become the predominant way of constructing buildings taller than a few floors, although an abundance of historic examples proves the lasting qualities of bearing walls (the world's highest brick building is the tower of St. Martin Church in Landshut, Germany, with a height of 130 m). Undoubtedly, skeleton construction is very adaptable and enables easy extensions upwards. Yet, also small houses with merely one or two stories (detached or row houses) are increasingly constructed in this very energy intensive way. A typical two-story family home produces 438 tons of CO_2. 92% are caused by the reinforced concrete in the structural slabs, beams and foundations (73% concrete and 19% steel) and only 8% by the bricks. Shifting the construction to the method of bearing walls can dramatically reduce the emissions per home to 183 tons of CO_2. This technique relies on masoned walls that carry slabs for the ceiling. It reduces construction costs by saving expensive steel. In addition, the thick brick walls improve the building shell, thereby lowering the energy demand for cooling and air-conditioning systems.

This paper demonstrates the possible reductions of building related prime energy consumption and carbon emissions through a shift in construction standards towards load-bearing walls. It shows also that economic feasibility is given due to reductions in construction and operation costs. Despite these financial incentives, a wide behavioral change has not yet taken place within the Egyptian society, implying that additional (social, cultural and political) factors need to be considered as well. This paper therefore elaborates on prevailing impediments and aims to encourage a switch in the Egyptian building sector to the bearing wall method.

Keywords: bearing wall, CO2 emissions, embodied energy, cost reduction

1. INTRODUCTION

When standing under the remains of the vaulted magazines of the Ramesseum in Luxor, one cannot help but wonder how these structures have survived the passing of millennia. Made entirely from mud bricks, the vaults have withstood the destructive elements of wind, sand, heat, and water surprisingly well (El-Derby & Elyamani, 2016; Emery, 2011). It is striking that the ancient Egyptians were capable of devising such enduring buildings with so little technical support, while contemporary architects and urban planners are struggling to find suitable solutions for Egypt's unfolding housing crisis (Sims, 2015, pp.117ff).

Figure 58: Storage vaults of the Ramesseum in Luxor Photo: Shelbyrrot

The Ramesseum was erected as the memorial temple of Pharaoh Ramesses II in the 13th century BC, i.e. about 3300 years ago (El-Derby & Elyamani, 2016, p. 299). In Egypt's dynastic history, sacral buildings were typically accompanied by spacious magazines to store the goods needed for the temple's daily operations (Emery, 2011, p.2). They were roofed with long vaults, with the Ramesseum being the best-preserved and best-known example (Emery, 2011, p.5)

The case of the Ramesseum vividly demonstrates the distinguished qualities of bearing wall constructions and brick buildings. It shows that bearing walls allow for a diverse variety of architectural elements - including, for example, vaults and domes - and render formidable endurance and stability. Regrettably, the knowledge about the qualities of bearing walls has largely disappeared from modern building practices in Egypt. Hassan Fathy described the benefits of vernacular architecture, including adobe construction, which is entirely based on bearing walls, already in 1969. However, his demonstration site of New Gourna had little substantial impact beyond the academic debate and barely affected the realities of the built environment. On the contrary, it can be observed that the vast majority of construction projects across Egypt are nowadays based on the skeleton method: frames of reinforced concrete form the structure of the building, which is subsequently filled in with burnt bricks. Although load-bearing walls provide a cheaper and ecologically less harmful alternative to most standard types of construction, the utilization of this building technique is hampered by widespread concerns about its static integrity, ignorance of its superior performance and socio-cultural reservations.

Against this backdrop, this paper aims to strengthen the ecological component of the discourse on bearing wall constructions (Al-Damarany, 2008). It reveals that buildings erected with bearing walls produce significantly less CO2 than comparable structures that are based on the skeleton method. In addition, it illustrates that bearing walls provide better indoor climate conditions due to the increased wall thickness, which in turn decreases the need for air-conditioning in hot arid climates such as Egypt's. The paper further demonstrates that these ecological advantages of bearing walls are accompanied by considerable financial incentives, as they heavily save on steel and concrete, the costliest components of skeleton buildings.

2. THE EGYPTIAN BUILDING SECTOR

To understand the persistent rejection of load-bearing walls by wide parts of the Egyptian society, it is imperative to consider an interplay of social, economic and political conditions. This chapter outlines several factors, which all have an influence on the prevailing building realities in Egypt.

2.1. User needs and perception

It is a cultural norm in Egypt to buy and own the used living spaces. This trend is currently magnified by the weak performance of the Egyptian Pound (Reuters, 2016). The house or apartment is the main living space for the Egyptian family and it is common to share it with multiple generations. The place has to be affordable and provide financial security for the future. In dense cities, the next generation of a family often builds on top of existing structures, extending the building vertically. Therefore, the building or apartment has to be stable and adjustable. The flexibility of the skeleton method permits house owners to easily change walls or extend the building with additional floors, allowing other family members to live in the same building.

2.2. Energy efficiency

In recent years, demand for energy efficient houses in Egypt has increased. The main reason for this new trend is the rising electricity price throughout the region (Cockburn et al, 2015). Furthermore, Egypt is extremely volatile to climate change (Nett at al., 2015). The augmented temperature peaks in summer force people to install air-conditioning systems to avoid health issues. Dropping prices make such systems affordable to a wide range of customers. However, air-conditioners cause dramatic peaks in electricity demand, especially in the early evening hours, forcing state authorities to shut down entire districts to avoid nationwide blackouts (Ibrahim, 2014). Consequently, the government has begun to discourage excessive power consumption by increasing prices and cutting subsidies for electricity. The dominant usage of the skeleton method aggravates the issues, because the thin brick layers that fill in the concrete frameworks exhibit low thermal resistance and thermal capacity.

2.3. Load-bearing walls: virtues and preoccupations

The most commonly used argument against bearing wall structures refers to the safety of the buildings (Al-Damarany, 2008). They do not include steel reinforcements, which are widely regarded as a necessary structural support. However, it has been argued repeatedly that load-bearing walls have not only proven to be as safe as skeleton buildings, but also have a longer life span (Al-Damarany, 2008). The former vice president of the International Union of Architects, Dr. Salah Zaki, points out that New York and Chicago have proven the stability of the bearing wall structure by the longevity of their 10-15 story buildings from the turn of the 19th century (Al-Damarany, 2008). For example, the Monadnock Block in

Chicago reaches 16 stories high and has been standing safely since 1893 (Understand Building Construction, 2016).

The restricted versatility of bearing wall structures is also depicted as a problem in regards to architectural design, as it puts a limit to wide openings or spans and requires thick walls, which reduce floor space. Thus, the argument goes, skeleton structures are necessary to enable certain architectural styles. However, load-bearing walls with a thickness of only 35 cm on the ground floor allow for buildings of up to six stories (Geist et al, 1984). Furthermore, Egypt's prevailing climate specifically calls for narrow openings and thick walls to maintain comfortable room climates. Consequently, the bearing wall method is particularly suitable for the requirements of Egypt's cities and other settlements.

2.4. Historic forerunners and contemporary examples

One of the modern pioneers of bearing walls was Hassan Fathy, as can be seen is his work around Egypt, including the Al-Harini Villa in Giza and the Alaa al-din Mostafa House in Idfu (Serageldin, 2007, p.26). One of Fathy's non-residential buildings is the Fares School in Upper Egypt (Steele, 1997, p.194). Other well-known load-bearing structures in Egypt include the Deir Al-Samaan Monastery next to Elephantine Island (Steele, 1997, p.27) and the Abdeen Palace in Cairo (Al-Damarany, 2008).

El Gouna Mosque is a contemporary example for load-bearing structures in Egypt. It was built around 1992 and is architecturally based on Hassan Fathy's design, including domes and vaults with spans of up to 5 m (see figure 2 and 3). Currently, the mosque is undergoing an extension due to an increase in worshipers. While the enlargement follows the original design, it adds more cross vaults and enlarges the interior openings, whose width and height are increased from 1.8 to 2 m and from 1 to 2.5 m, respectively (El-Dahan, 2016).

Figure 2: El Gouna Mosque, interior
Photo: Hend El-Dahan

Figure 3: El Gouna Mosque, exterior
Photo: Hend El-Dahan

2.5. Political factors

The strong representation of the construction industry in the political environment is considered to be another decisive factor behind the reluctant application of bearing wall structures in Egypt. Hassan Fathy faced such adversities as early as 1948. At that time, Osman Ahmad Osman, who owned one of the biggest construction conglomerates in Egypt, contained Fathy's work through his political influence, because an increased utilization of mud bricks and bearing wall structures would have threatened the steel and concrete industries (Steele, 1997, p.91). More recently, Abu Hashema's Egyptian steel company

(Ahmad, 2014), and Ahmad Ezz's Ezz steel company (Al Jazeera, 2011) have resembled Osman's case. Their political involvement and strongly rooted industries might be one of the reasons why load-bearing structures are far less frequent than skeleton structures.

2.6. Regulatory requirements

The Egyptian building code was introduced in 2003 to define the minimum standards for new residential buildings of new urban communities. The standard stipulates minimum performance values for windows and surfaces, thermal comfort boundaries as well as performance ratings for air-conditioning systems. Furthermore, the required building stability is defined according to specific seismic zones, as shown in figure 4. The use of masonry for bearing wall constructions is permitted in all zones with a Peak Ground Acceleration (PGA) of less than 0.2 m/s², which is the case for almost the whole of Egypt. Nonetheless, load-bearing walls are widely considered to be structurally unsound and thus unsuitable for the local construction market.

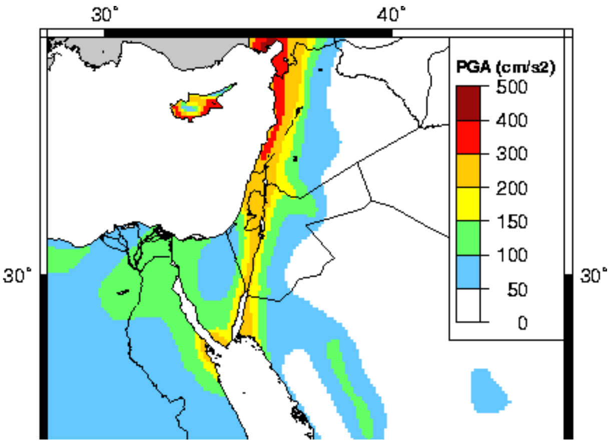

Figure 59: Seismic hazardousness around the Red Sea
Source: Bosse et al.

Further requirements by law are given for the energetic building quality. It is rated by the Overall Thermal Transfer Value (OTTV), which describes the heat losses or gains of a building through its total envelope area. This value includes gains through transmission, radiation and ventilation and should not exceed 30 W/m² in hot arid climates like Egypt (Hanna et al, 2004). Furthermore, the Green Pyramid Rating System (GPRS) was introduced in 2010, which was intended to establish an equivalent to the LEED standard for Egypt. Unfortunately, the building code and GPRS display serious contradictions with each other (Ayyad et al., 2012) and with construction reality.

For example, the building code requires that the u-value of a wall should be below $u_w \leq 1.0$ W/m²K, respectively below $u_g \leq 0.5$ W/m²K for windows in the region of Cairo (Hanna, 2013). Typical hollow red bricks, as commonly used in Egypt, have a thermal conductivity of $\Lambda_{brick} = 0.6$ W/mK (Attia et al., 2012). To fulfill the prescription of the building code, an uninsulated wall that is constructed with red bricks would have to render a thickness of 0.6 m. In reality, however, only a single brick layer of around 0.2 m is typically used for wall constructions by this creating a u-value of $u_w = 2$ W/m²K. Compact buildings that rely on bricks to fulfill the energetic requirements of the building code would make skeleton constructions with reinforced concrete obsolete.

2.7. Current situation in Egypt

The building sector in Egypt is dominated by the use of single layered brick walls in reinforced skeleton frames – even for two-story family houses (see figure 5) –, although this construction method is undesirable in terms of thermal performance and energy efficiency. Yet, load-bearing walls still face formidable obstacles on the Egyptian construction market, despite their proven virtues and durability. This trend is rooted in the perception that skeleton structures are more flexible, quicker and more reliable. In addition, the national construction sector has an immanent interest in endorsing the skeleton method, as it is more profitable for the industry. In conclusion, presenting the benefits of bearing walls is ever more important in order to overcome existing preoccupations and push towards a more environmentally friendly building practice, which reduces CO_2 emissions and costs.

Figure 60: Construction site of a single family house in El Gouna
Photo: Christoph Banhardt

3. METHODOLOGY

To quantify the environmental and economic benefits of load-bearing walls over the skeleton method, the material demands of a typical building are established. The required amounts of materials can be linked to embedded CO_2 emissions and costs. The differences in thermal comfort can be obtained by simulating the different building envelopes that result from the two building techniques. This chapter outlines the underlying methodology of this approach.

3.1. Carbon footprint calculations

The following calculations are based on a typical single-family house with a floor space of 250 m², as it is commonly found across the entire MENA region. Its frequent appearance in gated communities, new towns and holiday destinations makes it a representative case study for many areas in Egypt and beyond. Such a villa (see figure 6) has the additional benefit of being rather uncomplicated with regards to bearing walls, as it features limited architectural or structural challenges. Subsequently, it is used to estimate the ecological impact and economic implications of the two building styles under investigation, i.e. bearing walls and the skeleton method.

For the representative single-family house, an average amount of 2.6 m³ of steel, 167 m³ of concrete (the used cement is considered to be "Portland") and 160 m³ of bricks is needed if it is carried out as a skeleton construction. In comparison, if the same building is erected with bearing walls (including domes and vaults), an average amount of 286 m³ of bricks and 62 m³ of concrete is used. These amounts are calculated based on an average bill of quantities for the reinforced steel, concrete and brick elements in both structural systems (Radwan, 2013).

Figure 62: Villa in El Gouna, based on bearing walls
Photo: Hend El-Dahan

Building materials consume energy throughout their entire production chain and thereby produce CO2. This includes the extraction and transportation of raw materials, the production process, packaging, and the shipping of the finished product. The sum of the "embodied" or "hidden" energy required for the above steps is commonly referred to as grey energy (Trachte, 2013).

The assumed CO_2 emissions of the building materials are provided in CO_2 equivalent (CO_{2eq}), implying that other emissions are also considered, such as methane or chlorofluorocarbons. For this purpose, the equivalent global warming potential of each emitted greenhouse gas is calculated and used as a multiplier to establish comparable values. The emissions of construction materials, as utilized for the following calculations, are as follows (Burk 2011):

Bricks: 0.14 $kgCO_{2eq}/kg$ | Concrete: 0.8 $kgCO_{2eq}/kg$ | Steel: 4 $kgCO_{2eq}/kg$

These emissions are based on US American statistical data, since Egyptian values are unattainable. They might underestimate real local emissions, especially for energy intensive products, like concrete and steel, due to the relative inefficiency of electricity production in Egypt and the predominant reliance on oil and coal.

4. RESULTS

4.1. Carbon emissions

The upcoming calculations are based on the following densities of building materials (The Engineering Toolbox, 2016):

Bricks: 1,600 kg/m^3 | Concrete: 2,400 kg/m3 | Steel: 7,800 kg/m^3

The following equation is used to calculate the emission $E_{material}$ of each material i in tons of CO_{2eq}:

$$E_{material,i} = V_i * \varrho_i * f_i$$

The Volume V [m³] of each material is multiplied with its density ϱ [kg/m³] and its emissions factor f [$kgCO_{2eq}/kg_{material}$]. Accordingly, the skeleton structure main elements emit 438 tCO_{2eq} per villa, while the bearing wall structure emits only 183 tCO_{2eq}, saving 58% of the CO_2 emissions. In the case of a bearing wall structure with reinforced concrete slabs (see figure 6), the required steel increases the emission of the building. In this case, the bearing wall still saves 30% of CO_2 emissions (278 tCO_{2eq}) compared to the skeleton structure. The reinforced slabs in the bearing wall structure are usually used to allow more versatility in the spans, height and forms of the buildings. Table 1 summarizes these results.

Table 1: Carbon emissions of representative villa with alternative building methods

Material	Density	Amount for skeleton method	Amount for bearing wall method	Emission factor	Emissions of skeleton method	Emissions of bearing wall method
Steel	7,800 kg/m^3	2.6 m^3	-	4 $kgCO_{2eq}/kg$	81 tCO_{2eq}	-
Concrete	2,400 kg/m^3	167 m^3	62 m^3	0.8 $kgCO_{2eq}/kg$	321 tCO_{2eq}	119 tCO_{2eq}
Bricks	1,600 kg/m^3	160 m^3	286 m^3	0.14 $kgCO_{2eq}/kg$	36 tCO_{2eq}	64 tCO_{2eq}
Total emissions					**438 tCO_{2eq}**	**183 tCO_{2eq}**

4.2. Thermal Improvements

The overall u-value of an outer wall, constructed by a single layer of bricks (0.24m) with a thermal conductivity of 0.68 W/mK, is 1.98 W/m^{2}K. Increasing the wall thickness, by adding a second bricklayer (to 0.48 m), the u-value is reduced by more than 57% to 1.14 W/m^{2}K. Constructing with an air gap between both layers reduces the u-value even further to 0.95 W/m^{2}K. This technique fulfills the requirements of the building code, as discussed in chapter 2. The calculations are made according to u-value computations for external walls, considering a thermal resistance on the exterior wall surface of R_{ext} = 0.04 mK/W and an interior wall surface resistance of R_{int} = 0.13 mK/W. Furthermore, the increased thermal capacity can help to shift and lower the peak electricity demand across the national grid in the early evening hours. Ongoing research indicates that sub-cooling of a room in the daytime allows its walls to "store coldness", which can be released in the early night hours, thereby reducing the demand for the use of air-conditioning systems (Banhardt et al, 2015).

4.3. Construction costs

The construction costs of bearing wall structures are said to be only half of skeleton structures (Al-Damarany, 2008). This presumption can be assessed by financial calculations for both construction methods, determining the difference in building costs. The assumed local average prices for building materials are as follows (Acros News, 2016):

Bricks: 540 EGP/m³ | Concrete: 700 EGP/t | Steel: 6,000 EGP/t

The following equations are used to calculate the costs *C* of each material:

$$C_{steel\ and\ concrete} = amount\ [m^3] * density\ [t/m^3]\ /\ price\ [EGP/t]$$

$$C_{bricks} = amount\ [m^3]\ /\ price\ [EGP/m^3]$$

Accordingly, a standard villa costs 473,430 EGP with the skeleton method and 258,600 EGP with bearing walls, resulting in a cost reduction of more than 45%. When adding reinforced concrete to the slabs of the bearing wall structure, costs increase to 353,625, still causing a 25% cost reduction in comparison to the skeleton structure. Table 2 summarizes these results.

Table 2: Construction costs of representative villa with alternative building methods

Material	**Amount for skeleton method**	**Amount for bearing wall method**	**Price per unit**	**Costs of skeleton method**	**Costs of bearing wall method**
Steel	20.28 t	-	5,250 EGP/t	106,470 EGP	-
Concrete	400.8 t	148.8 t	700 EGP/t	280,560 EGP	104,160 EGP
Bricks	160 m³	286 m³	540 EGP/m³	86,400 EGP	154,440 EGP
Total costs				**473,430 EGP**	**258,600 EGP**

5. SUMMARY AND CONCLUSIONS

The previous calculations illustrate that a switch in the construction method of a single-family house from a skeleton frame to load-bearing walls can reduce carbon emissions by 255 tCO_{2eq}, i.e. almost 60%. In a small town like El Gouna, 88 buildings were erected in 2014. Constructing them with load-bearing walls would have prevented the emission of 20,400 tCO_{2eq}. This, in turn, would have reduced the town's annual emissions of 2014 by close to 10% (Banhardt & Hartenstein, 2016). The superior thermal performance of the bearing walls also would have saved future emissions by reducing the need for air-conditioning.

In terms of construction costs, this paper depicts that a typical villa can be constructed for 214,830 EGP less when utilizing bearing walls rather than skeleton frames, saving 45%. For El Gouna, this would have implied a total saving potential of 18,905,040 EGP. In addition, inhabitants would benefit from lower energy bills due to the reduction in cooling demands.

Despite the portrayed advantages of bearing walls over the skeleton method, a widespread utilization of this building approach is hampered by its bad reputation, especially due to misconceptions with regards to structural soundness in the case of earthquakes. To rectify this situation, a targeted marketing campaign could create awareness about the bearing wall method and its ecological and economic advantages. Referencing existing buildings, such as the early American high-rises, the works by Hassan Fathy or even the impressive remains of the Ramesseum, could help to reduce the remaining prejudices and create trust in the longevity of this outstanding building technique.

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The Design of the Optimal Light Shelf in Educational Setting

Simulation vs. Optimization in assessing daylight performance

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Abstract: *There has been an increasing challenge on architects to design buildings that meet diverse range of performance criteria; and hence, achieve high levels of efficiency in terms of their environmental performance of buildings. This, however, requires new approaches in problem-solving to inform the design process. Particularly, if there is a need to satisfy many criteria to achieve an optimized behavior of the system. This paper investigates two approaches of simulation and optimization as the means to integrate the computer as a tool in the design process. While computer simulation tools are useful for measuring accurate performance, yet they have drawbacks. Simulation tools evaluate one solution on a case-by-case basis. Thus, it is arguably a time-consuming process, where architects feed in a limited number of solutions aiming to find an optimized solution. This approach, therefore, eliminates a larger number of potential solutions that could enrich the design process at an early stage of the design process. To overcome these constraints, a computer optimization approach is emerged yielding promising results using Genetic Algorithms (GAs), where the computer is considered the solution-generator and performance-driven force. GAs generate and evaluate solutions using a simulation tool in an algorithm offering an optimal or near-optimal solution. GAs are effective in solving complex problems, defining criteria between multiple objectives and are, thus, less time-consuming. The aim of the paper is to explore potentials of simulation and optimization approaches, and further define the criteria needed to help determine the suitable approach for assessing environmental performance in buildings according to the architectural problem in question. The findings of the paper will feed into the second phase of the research to enable the application of optimization approach to optimize daylighting performance in educational buildings.*

Keywords: Daylighting, Light Shelf, Environmental Design, Simulation, Building Optimization

6. INTRODUCTION

Design problems in architecture are neither linear nor static problems. They are, rather, iterative and dynamic processes that are continuously in change. Thus, there are many possible solutions as a result of the interaction between various variables, which may sometimes behave oppositely to each other. The challenge is to find the optimum design alternative that yields the highest performance level in a relatively short time (Jones, 2009; Chutarat, 2001).

Daylight is the science of admitting and introducing natural light to space. Natural light comes from two sources; the sun as direct light and the sky as diffused light that enters the building through windows (Mardaljevic et al., 2009). In a daylit working environment, the usual distribution patterns of daylight affects areas near to windows much more than areas deeper far from windows. The former areas become overlit, while the latter areas become underlit which then would require artificial lighting (EFA, 2014). Accordingly, in a square shaped classrooms there is a need to further improve the range of daylight distribution patterns to be more uniform and provide the required levels of light to the students in the middle of the room.

The aim of daylight is not only about admitting adequate illumination levels in space, but rather preventing direct sunlight and controlling how much light is entered. Direct sunlight exposure causes serious inconveniences to the users of the space. First, the overlit area becomes much more illuminated than the required for performing task. Second, the areas exposed to direct sunlight are more susceptible to cause glare which discomforts users. Third, the accompanied overheating due to the continuous exposure of direct sunlight on façade increases the indoor temperature, which consequently increases the cooling demands. Therefore, there is a need for a more holistic approach to integrate the use of shading concepts with daylighting in order to maximize the benefits of natural light while eliminating the downsides (Garcia-Hansen, 2006; Ander, 2014).

1. LITERATURE REVIEW

1.1. Daylight in Educational Facility

Natural light proved to significantly contribute to the psychological health and biological processes of human beings. In an educational setting in particular, daylight improves the performance and productivity of students and employees. However, it is difficult to daylit classrooms due to the deep depth of classroom and the different tasks performed in it (Bruin-Hordijk and Groot, 2010; Rea, 2000).

There are many systems for the design of daylight in educational buildings. Classrooms are designed to receive daylight through sidelight systems; from strip linear continuous windows to floor-to-ceiling window system. The strip fenestration system using long horizontal windows in walls was adopted in the architecture studio in Oporto in Portugal in 1996 (Caldas and Norford, 2001). The use of continuous windows, as opposed to conventional windows was also supported by Al-Mohaisen and Khattab (2006), as it arguably provides uniform daylight distribution. Another study conducted on nine different classes and opening configurations by Bruin-Hordij and Groot (2010) concluded that classroom with two sidelight fenestrations has the best daylight performance.

1.2. Problem Under Study

The problem under study is how to reach the optimal configuration and position of a shading device to maximize useful daylighting and shading performance. Shading devices appear to have a complex behaviour due to interactions between contradictory requirements. In a typical horizontal overhang, as the length of device increases in order to provide for shading, there is a decrease in the daylighting availability inside and thus an increase in the demand for artificial lighting leading to increased energy demands. On the other hand, when the length of shading device decreases, there is an increase in the natural lighting but there is smaller shading performance, and thus, an increase in the overlit areas exposed to direct sunlight, leading to glare and overheating. This, in turns, raises indoor temperature and consequently more cooling loads would be needed. Several research work was conducted in order to introduce and evaluate daylight systems in conjunction with shading, lighting and glare (Torres and Sakamoto, 2007; Gonzalez and Fiorito, 2015; Chutarat, 2001; Gadelhak 2013).

1.3. Problem Formulation

Among the various types of the shading devices, few devices can arguably improve daylight in the back of a room. Light shelf is a typical horizontal overhang that divides the window opening vertically into two parts; upper part for the clerestory window and lower part for the viewer window. It is usually installed in the façade which has the highest sun exposure. Light shelf functions, therefore, as both: shading and light redirecting device (Gadelhak, 2013; A.G.S, 2000).

(1) Shading device: it is extended outwards to shade the viewer window and block direct sunlight and prevent overheating.

(2) Light Redirecting device: it reflects the incident daylight to the ceiling and further again to the back of space for deeper illumination.

In addition to the use of shading elements, this research suggests the use of self-shading as a second strategy in an integrated approach with shading devices, in a way to enhance the global shading performance of the building. Building self-shading techniques are achieved by using several strategies that include tilting facades; recessing or protruding façade parts. This is to reduce the surface area of building skin exposed to direct solar radiation and, thus, decrease the solar heat gain transferred (O'conner, 1997).

1.4. Simulation vs. Optimization Approaches

There has been many ways to integrate computational and advanced tools in the decision making of design process at an early stage (Caldas and Norford, 2002). This paper discusses the process, potentials and limitations of the two approaches; simulation and optimization. Further, it defines the criteria needed to help determine the suitable approach for assessing environmental performance in buildings according to the problem in question.

1.4.1. Simulation Approach

Simulation is a trial and error mechanism (Wagdy and Shalaby, 2013), which first starts when architect models and generates an initial solution based on specific case by case (Caldas and Norford, 2002). The next step is preparing this model to go into simulation process where many input data are fed into the model such as, surface materials; analysis grid; location and orientation of the building; weather climate; simulation type and output; and simulation period. The process then runs the simulation experiment (Carson and Maria, 1997) and displays the results for the given solution. The last step is the architect's decision whether to terminate the process and select the tested solution as the most convenient solution, or to make modifications manually to the design solution and to further reiterate the simulation processes and so forth (Wagdy and Shalaby, 2013).

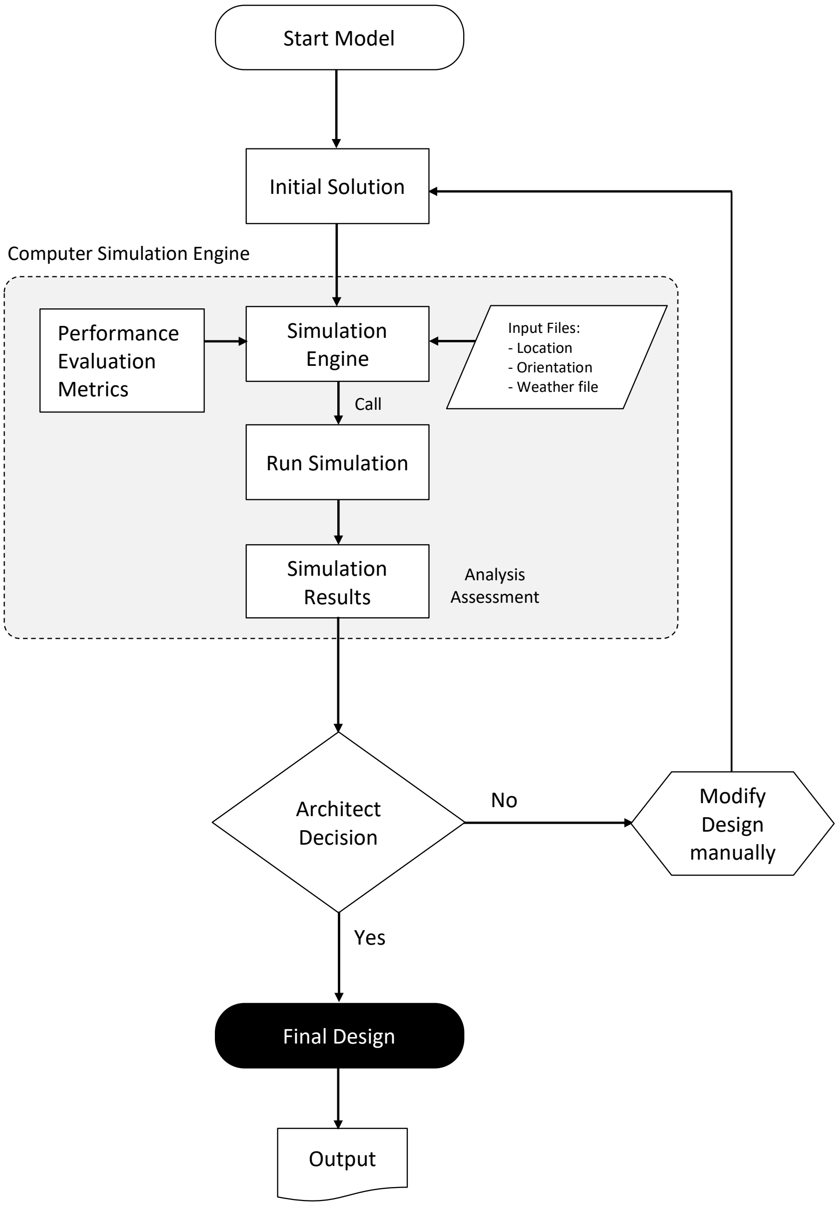

Figure 1: Logic Flow chart for the integration of simulation process into design process. (adapted from Carson and Maria, 1997; Hong et al. 2000; Morbitzer, 2003)

1.4.2. Optimization Approach

Optimization starts the same way as the simulation approach, generating an initial solution model. Similarly, the model proceeds in the simulation experiment to further yield the results of the initial design solution. The next step is the coupling between the simulation program and optimization algorithm (Nguyen, Reiter and Rigo, 2014). The algorithm contains an objective function which the architect would be aiming to either maximize or minimize. The simulation results then feed into the optimization algorithm to evaluate the extent to which the performance of the solution is meeting the objective. Having the solution scored the highest performance, the process will be automatically terminated providing the architect with the optimal or near optimal solution. Otherwise when the solution does not satisfy the objective performance, it goes back from the start feeding into the initial model.

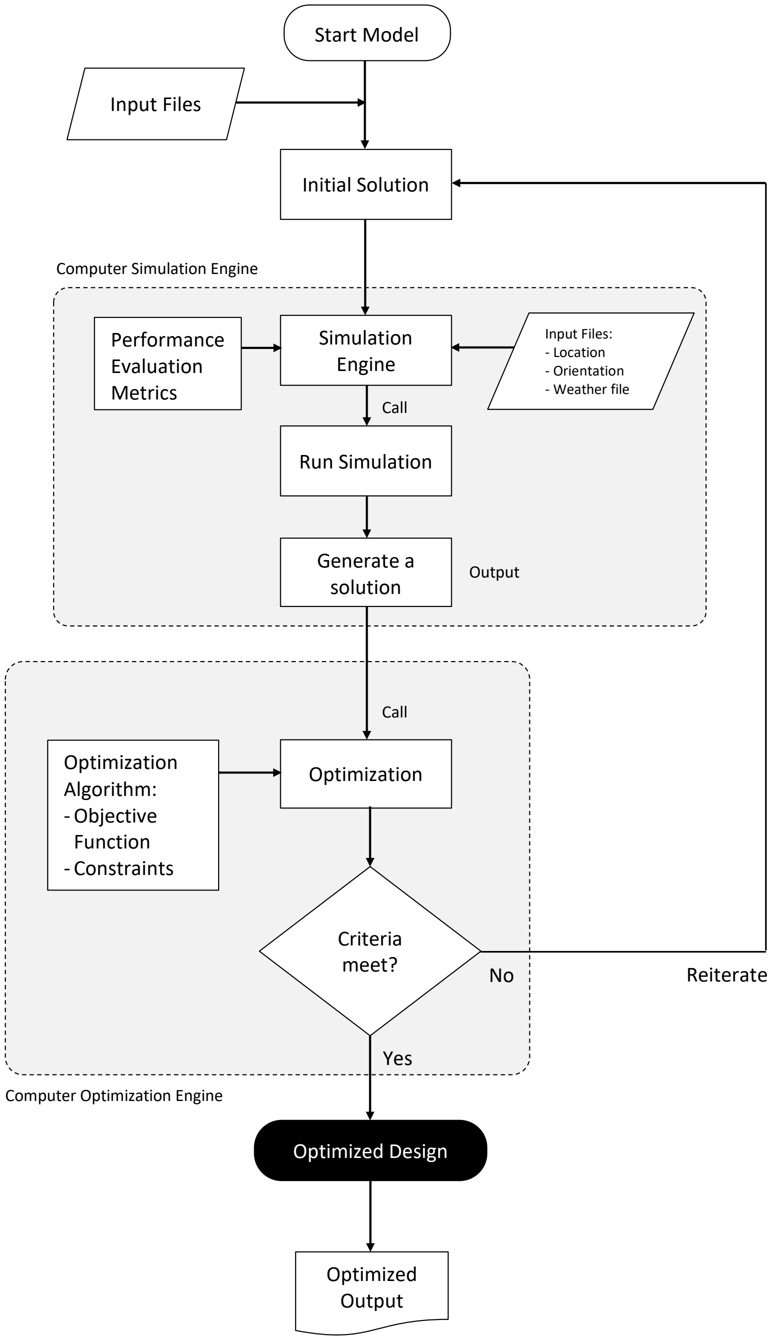

Figure 2: Logic Flow chart for the integration of optimization process into design process. (adapted from Andersen et al. 2008; Wagdy and Shalaby, 2013; Charron and Athienitis, 2006)Selection Criteria of the Approach

In order to be able to evaluate or determine whether simulation or optimization better serves the design process, there is a need to explore the potentials for both approaches. Table 2, lists the different evaluation criteria to allow define potentials for using simulation vs. optimization. The criteria relate to the problem under study in the following aspects; problem size, variables, constraints, objective function, and design solution.

1.4.2.1. Problem Size

The design problem is usually defined by three main components, namely; variables, constraints and objective function (Radford and Gero, 1980). The problem becomes more complex when the number and type of variables increase (Alaimi and Wright, 2014). Thus, increasing in the number of possible solutions, which consequently leads to an increase in the total number of simulations required to find the optimum solution. Multiple variables and solutions for the design of light shelf can be shown in the next section in Table 1.

1.4.2.2. Variables: numbers and types

The variables are the parameters that control the design solution. Any change in the characteristics and encoded values of one variable will be followed by an instantaneous change in the whole design solution. As the number of variables increases, there is an increase in the dimensions of the solution search space size. In the aforementioned problem, there are eight variables most related to the design of light shelf, room surface reflectance, and glazing type, as listed in Table 1. Variables related to light shelf are shown in Figure 3.

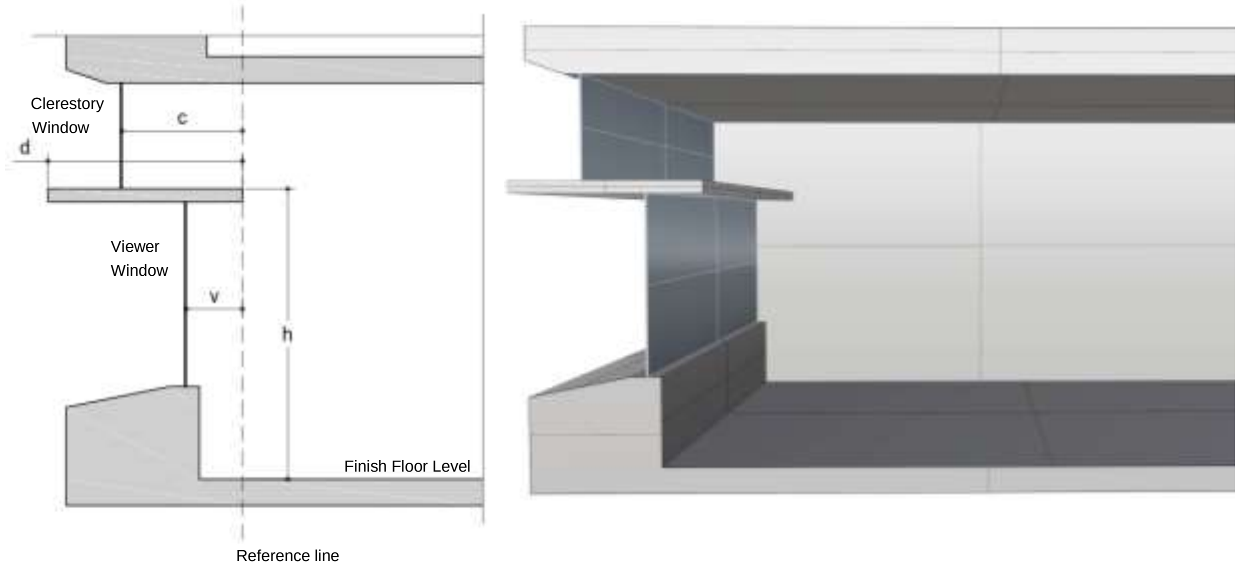

Figure 3: Light shelf variables in cross sectional view and perspective showing the classroom interior.

where d: depth of light shelf from reference line;
h: height of light shelf from finish floor line;
v: position of viewer window from reference line;
c: position of clerestory window from reference line.

Table 1: Problem Variables (adapted from Chutarat, 2001)

Aspect	Variable No.	Variable / Dimension	Abr.	Variable Type	Upper Bound	Lower Bound	Increment Step	No. of Solutions
Light shelf	1	Depth of light shelf from reference line (m.)	d	Continuous	0.20	1.60	0.20	8
	2	Height of light shelf from finish floor line (m.)	h	Continuous	1.80	2.20	0.10	5
	3	Position of Viewer window (and recess of wall) (m.)	v	Continuous	0.10	1.20	0.10	12
	4	Position of Clerestory window (m.)	c	Continuous	0.10	1.20	0.10	12
Room Surface Reflectance	5	Ceiling Reflectance	R_c	Continuous	0.00	1.00	0.20	6
	6	Wall Reflectance	R_w	Continuous	0.00	1.00	0.20	6
	7	Floor Reflectance	R_f	Continuous	0.00	1.00	0.20	6
Glazing	8	Type of Glazing	T	Discrete	0: single	1: double	-	2

In reference to a problem studied by Tuhus-Dubrow and Krarti (2009), a problem which had an overall number of 256 solutions was categorized as a small-size problems, while a large-size problem would have an overall number of solutions that exceeds 20,200,000. In this respect, the total number of possible solutions can be enumerated using Equation (1), by the multiplication of all numbers of solutions in each variable in Table 1. ThFis results in 2,488,320 solutions, which is the same number of simulations required to cover all design possibilities. Total number of possible solutions can be calculated according to the following formula:

$$N_T = N_1 \times N_2 \times \ldots N_i \times \ldots N_n \,, \qquad 1 \leq i \leq n \tag{1}$$

where N_T is the total number of possible solutions; N_i is the number of solution for variable i; and n is the total number of variables.

In addition to the nature of variables which contains three types; continuous, discrete, and mixed-type (Chutarat, 2001). Continuous variables are defined between intervals of two values, for example the height of light shelf can be expressed as; 1.80 m. ≤ height ≤ 2.20 m. in an increment step of 0.10 m. On the other hand, discrete variables have limited number of options, such as type of glazing will either be single or double-glazed type. Therefore, it is a problem with large number of mixed-type variables results in categorizing it in large-size problems.

1.4.2.3. Constraints

Constraints constitute the boundary conditions that should not to be exceeded by the relevant variables. These can be classified into three groups; box constraints, selection constraints, and functional constraints (Wang, Rivard and Zmeureanu, 2006). Box constraints are defined as upper and lower intervals for continuous variables; e.g. the possible variation of the depth of shading devices is limited by 0.20 m and 1.60 m as defined upper and lower bounds respectively. Selection constraints are applied to discrete variables, e.g. the types of glazing and walls. Functional constraints are used to relate design variables and derived variables together. The variables discussed in the section above consist of seven continuous variables, and one discrete variable. The boundary constraints of such variables are shown in Table 1.

1.4.2.4. Objective Function

Since the purpose of the process is to reach the optimum design configuration for the light shelf that will enable maximum useful daylight availability in space, then there must be a specific function linked to the different variables and fed into the process. This function resembles a quantified goal of optimization to measure the extent to which the performance of a design solution reaches the highest performance while satisfying constraints (Chutarat, 2001). The objective function in the research is the proportion of the average light measured annually in classroom to the total lighting requirement level by daylight (Torres and Sakamoto, 2007). Since the daylight illuminance on the horizontal work plane in educational drawing classes considered was 500lx according to daylight standards (Rea, 2000; ESCLDC, 2008). The objective function can be expressed as:

$$Maximize: \quad F(x) = \frac{E(av)\ lx}{500\ lx} = \frac{\sum_h^H \sum_s^S E(ho)\ lx}{\mathrm{H}\times\mathrm{S}\times 500\ lx} \tag{2}$$

where *E(av)* is the annual average daylight illuminance for all sensors in classroom; *E(ho)* is the measured daylight illuminance on the working plane, for a certain hour and sensor; and *H, S* are the number of hours and sensors, respectively, when $h = 1$ and $s = 1$.

1.4.2.5. Design Solutions

There are large number of design solutions in total to the problem under study that occur as a result of the interaction between the different variables. This results in a multi-dimensional search space (Jones, 2009). In this context, there are eight dimensions in the search space that corresponds to eight variables (Table 1).

In an automated procedure, the simulation is coupled in an optimization algorithm where the computer directs the search with probability to find and generate the optimum or near optimum solutions. Similarly, the characteristics of the generated succeeding solution is dependent on its counterpart of the preceding solution. Hence, when the process is automated, solutions developed to a higher fitness solutions, are always derived from the initial solutions (Caldas and Norford, 2002).

Table 2: Evaluation criteria for the use of simulation and optimization processes.

No.	Aspect	Criterion	Simulation Process	Optimization Process
1	Purpose	Process	Architect evaluates design alternatives through the process	Architect uses computer to find the optimal or near-optimal design solution
2	Problem	Problem Size	N/A	Small-size problem (256 simulations) and Large-size problem (20,275,200 simulations)
3	Variable	No. of Variables	Small number of variables	Small and large number of variables
		Type of Variable	Continuous / discrete / mixed-type	Continuous / discrete / mixed-type
4	Constraint	Link to Variable	N/A	Constraints are linked to variable according to type of variable
		Type of Constraint	N/A	Box / Selection / functional constraint
5	Objective Function	Objective Function	N/A (it is not a problem-solving method)	Specific objective function is fed into optimization (it is a problem-solving method)
		Number of Objectives	One objective	One or multiple objectives
		Link to Variable	N/A	Objective function is linked to the variables
6	Solution	No. of Solutions	Evaluate one specific solution on a case-by-case basis	Generate number of possible solutions
		Probability of Solution	Architect predicts the optimal solution	Computer directs the search with probability to reach the optimal solution
		Search Space	Search space is small with few dimensions	Search space is large with multiple dimensions
		Derived Solutions	Initial solution is modified manually by designer	Initial solution automatically drives the performance of the succeeding solutions
7	Simulation	No. of Simulations	Large number of simulations required in order to cover all solutions	Small number of simulations required in order to find the optimal solution
8	Design Stage	-	An early design stage	An intermediate design stage
9	Time of Process	-	More time to simulate all number of design solutions	Less time to simulate few design solutions

2. DISCUSSION AND CONCLUSION

It is argued that computer simulation is one of the fundamental processes that significantly contributes to evaluating solutions to the design problem. While adopting a trial and error procedure where simulation informs the architect with the performance of the anticipated solution to either manually accept or reiterate the simulation for further solutions. This, however, may bear several obstacles in comparison to optimization approach. Therefore, as the complexity of design increases, simulation becomes less useful (Tsangrassoulis et al. 2005). Simulation evaluates one specific solution, while optimization generates and evaluates derivative solutions until it reaches the most efficient solution in terms of measured performance aspects. In this context, simulation is a time-consuming process, while optimization shortens the process to find the optimum or near-optimum results.

In light of the above, it may be concluded that optimization is more suitable to reach the optimal configuration of light shelf in terms of daylight performance. These results will feed into the second part of the research that will introduce the different optimization tools, and define the most suitable search method and optimization algorithm in order to maximize daylight performance.

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Green Classroom Toolbox™

Adapting Schools and Students for Climate Change through Sustainable Architecture

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Abstract: *Existing educational spaces are problematic. They approximately consume 30% of electricity, generate 35% of waste, use 8% of water resources, and are responsible for 20% of greenhouse gas (GHC) and CO2 emissions. While the new construction sector of the building industry has benefited from green building strategies to produce high performance sustainable schools, existing classrooms, however, have been largely ignored. This problem is magnified in the USA due to the large number of existing educational spaces, generally a product of the past 30-50 years, that are energy and environmentally unconscious. This paper describes a research project to generate evidence-based design guidelines for retrofitting schools based on field studies, parametric simulations, and meta-analysis. The guidelines were developed from a triple bottom-line approach linking retrofit strategies to their impact on people, profit, and planet. Specifically, the guidelines were developed to aid architects and engineers in green retrofits of existing schools for optimized energy consumption while enhancing students' health and academic performance. The results of reduced energy consumption of most school typologies by 60-75% is further analysed with regards to an extensive meta-analysis of more than 300 prior studies related to the impacts of the best retrofit strategies researched on students' performance and health. One of the significant targets of this project is to link green retrofit strategies with sustainability curriculum and educational outcomes. The main idea is to develop a model where the retrofitted green classroom becomes the best learning tool and an open text-book for student learning and behaviour change. Though this project was developed for the USA context, the model and methods are generalizable to other locations and countries. The hope is to provide a decision support tool for practitioners and school principals that would help them prioritize and evaluate green classroom retrofit strategies in a comprehensive way.*

Keywords: Evidence-Based Design, 21st Century School Environments, Deep-Energy Retrofits, Sustainable Education, Occupants Health & Performance.

1. INTRODUCTION

Going green with new schools is a good idea, but what about billion square feet of existing public schools, 40 percent of which have 15 million students in poor environmental conditions worse than most prisons? These questions are at the heart of the Green Classroom Toolbox™ Project that received the American Institute of Architects (AIA) research award for 2008 and AIA Upjohn Award 2011. Currently, there is a great opportunity to impact the construction boom in schools and educational buildings. Building high-performance schools is reported to be the fastest growing sector of the building industry (McGraw-Hill, 2011), with a projected increase of 65% in the next five years. It is expected to capture 27.4% of the commercial market construction, topping the other market sectors in both value and number of projects. For the building industry professionals, 24% of architecture and engineering firms report that school buildings represent more than 75-100% of their projects (Figure 1).

Although green schools provide a range of benefits, there is a current gap in information regarding their energy and CO2 performance, as well as their impact on sick days, operations and maintenance, life cost, social inequity, and educational enrichment. The lack of evidence-based design guidelines for this building sector could lead to a devastating missed opportunity in directing that building momentum in the most effective way. In addition, there is a need to connect both deep-energy building retrofits and new construction of school buildings to sustainability education and creating open-text books of building experience and performance to create a change in the way school facilities are designed and built to educate future generation.

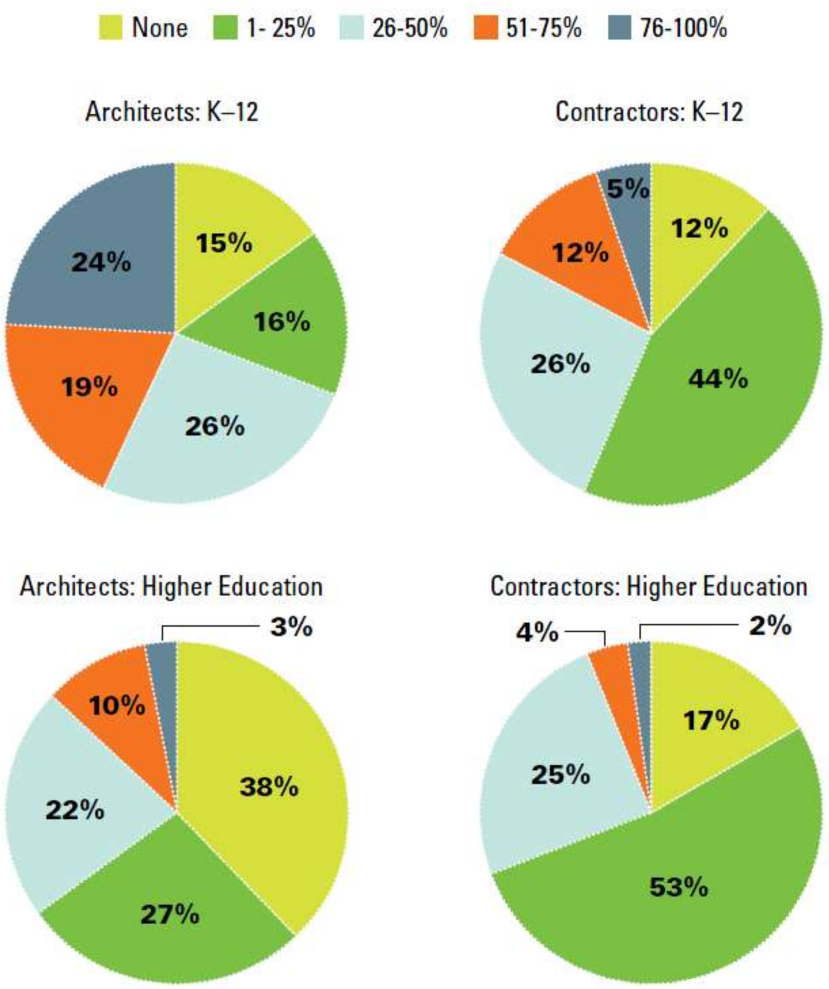

Figure 2: School projects as a percentage of total projects commissioned (source: New and Retrofit Green Schools - Smart Market Report, Mc-Graw-Hill Construction, 2013).

2. OPPORTUNITIES WITH K-12 SCHOOL CLASSROOMS

Based on a national review of 30 green schools, a study by Capital E (Kats, 2006) reported that green schools cost less than 2% more than conventional schools - or about $3 per square foot ($3/ft2) - but provide financial benefits that are 20 times as large. Kats also pointed out the lack of documented studies that evaluate and compare different scenarios for green retrofitting existing schools in terms of how well and how cost effectively they enhance student learning, reduce health and operational costs, and, ultimately, increase school quality and competitiveness. This gap in the existing literature was the main driver for the Green Classroom Toolbox (GCT) research project, which focuses on the impact of green retrofit scenarios for classrooms on the triple bottom line of, people, planet, and profit (Elkington, 1997).

2.1. Research Design

This interdisciplinary project targets the research problem by developing actionable green classroom retrofit guidelines. As reported by Ahrentzen (2006), the design and building professions have not established an agenda for organizing, disseminating, and advancing the state of knowledge on how good design is best employed to create long-term economic and social value. Typically, examples of "best practices" provide little evidence or criteria for what make them "best." For this reason, tools were developed and tested based on a deductive approach. First, in a collaborative effort between academia and local building professional organizations, a base-line survey was conducted to identify the best school green retrofit scenarios. This effort resulted in a check list of best practices of classroom retrofits collected from interviews and focus groups with designers, facility managers, and school principals. Second, this list of best practices was systematically evaluated using the triple bottom line scenario (Elkington, 1997). The practices were tested for their energy and carbon effects as well as their impact on occupants' health and well-being.

2.2. Literature review

According to the US General Accounting Office, almost two-thirds of schools in the US have building systems that are in need of extensive repair or replacement (Kats, 2006). Likewise, a published document by the American Federation of Teachers notes low IAQ in nearly 15 thousand schools (Schneider, 2002). Despite the large body of research linking health and productivity issues with specific building design attributes, empirical studies looking at these issues in schools have been limited and have failed to acknowledge linkages between specific design strategies and occupant outcomes. This limits the relevant data available to understand and quantify the benefits of high-performance, healthy design in schools in general and retrofits in particular.

The project is supported by an extensive review conducted by the Center for Building Performance at Carnegie Mellon University, Building Investment Decision Support (BIDS) program and Capital E (Kats, 2003 & 2006). The BIDS program reviewed over 1,500 studies that investigated the relationship between building systems, such as lighting, ventilation, and thermal control, and occupants' outcomes, such as productivity and health (Loftness et al., 2002). In addition, this analysis included data from a study conducted by William Fisk (2000) linking health and productivity gains of building occupants to better indoor environments and energy efficiency. In addition, a separate meta-analysis was conducted by the author of more than 150 studies that link indoor environmental quality and comfort issues to occupants' performance in green buildings (see Elzeyadi, 2002; 2008).

This project conceptualized the school environment from a place-based experience perspective. This conceptualization (figure 3) relies on the general assumption that any environment is composed of "people" and "buildings" on the macro-scale as well as "buildings" and the overall "environment" on the mega-scale. It is important to acknowledge that "people" in a school setting is composed of students, faculty, and staff. However, this investigation focused on the student portion of schools' population in the framework outlined below. This framework grows out of a perspective that treats students and their school environments as interdependent elements of a system. This systems epistemology rests on the idea that the environment is an organic structure; it has parts that are connected to each other by complex interactions in a way that smaller parts of the system can be identified; the components can be dissected into sub-systems of independent variables (sub-systems), mediational variables (mechanisms), and outcomes (products) as described in more details in Figure 2.

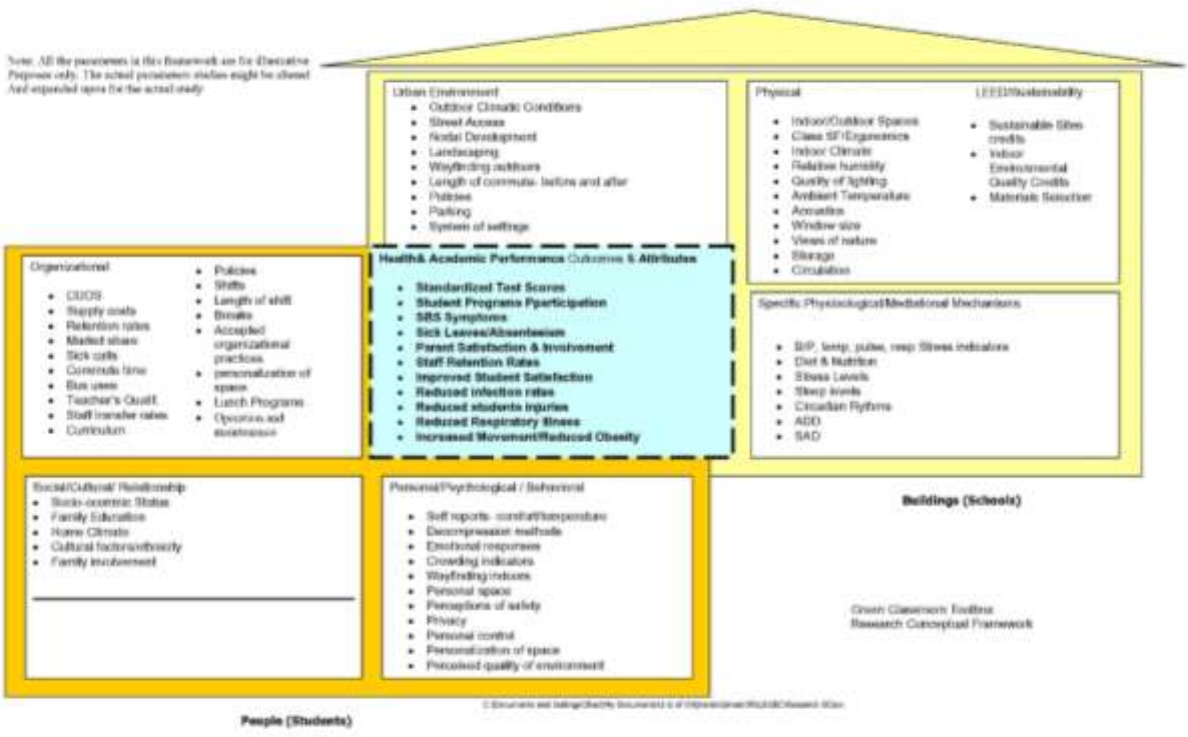

Figure 2: Project Literature Review and Conceptual Framework (after Elzeyadi, 2012)

2.3. Research methodology

To generate comprehensive evidence-based design guidelines for green classroom retrofits, the following tasks were conducted:

1. Surveyed and classified existing classroom types and typologies.
2. Held focus groups with school building designers, operators, principals, and contractors to generate a check list of best practices of green retrofit scenarios and products for classrooms.
3. Performed energy and carbon performance simulation analyses of the best practices (identified in the focus groups) for a prototypical K-12 school. This analysis simulated the energy and carbon performance of each suggested best practice of green retrofit as compared to a base case of a proto-typical school building in the Pacific Northwest.
4. Reviewed and analysed previous studies linking the identified green design strategies to students' health and performance outcomes.

This project was planned in three phases. The first phase researched and identified green classroom retrofit best practices (BP) based on a survey of opinions from school principals, building designers, and facility managers. The second phase used an experimental design approach to test the energy and carbon emissions performance of each retrofit BP strategy identified in the first phase using computer simulation and energy modelling software. The third phase analysed the BPs based on their impact on occupants' performance relying on meta-analysis of previous studies.

3. PROJECT PHASES AND TOOLS

The following sub-sections detail the research procedure for each phase of the project.

3.1 Phase 1: survey of best practices

A cross-sectional survey was designed to elicit responses from K-12 school owners and principals (O&P), architects and engineers (A/E), and facility managers (FM) on their views of best practices for green retrofitting of classes. The survey participants were chosen to represent a sample of each of the groups involved in decisions regarding school and classroom energy and environmental upgrades. Data was collected using focus groups and interviews across building professions and geographical locations. This enhanced the study's analysis of the various opinions by subgroups and helped achieve stronger research triangulation. A total of 24 professionals participated in focus groups as well as phone and personal interviews. Each interview lasted approximately 20 minutes and included both open-ended and structured questions. Focus groups were 60 minutes on average. The stratified sample of respondents was theoretically weighted to include a larger number of building designers since they represent the most diverse group. They included architects, energy/mechanical engineers, and lighting designers. Thus more emphasis was placed on the sample design to include a higher representation from this group. Building owners/principals comprised the second most important category, and it included an equal number of respondents from those two groups (Table 1). From the results of this phase of the research, a checklist of best practices was compiled for classroom retrofits and green remodel strategies, which are available in a previous report by the author (see Elzeyadi, 2009).

Table 1: Survey participants and locations of focus groups

Location	A/E Designer	F. Man.	O & P	Total
Portland, OR	3	2	3	8
Salem, OR	2	1	2	5
Eugene, OR	6	2	3	11
Total	11	5	8	24

3.2 Phase 2: Experimental Simulations

Energy analysis computer simulations were conducted for each best practice strategy identified in phase 1. These simulations were run using Integrated Environmental Solutions Virtual Environments™ (IESVE, see www.iesve.com) ApacheSim module. ApacheSim is a rigorous building thermal simulation approach that conforms to ANSI/ASHRAE Standard 140. The simulations were conducted on 6 two-story prototypical elementary school building in Portland, OR. The buildings are double corridor classroom facilities with a gross area of 54,802.11 sq. ft. and a 25% glazing-to-outside-wall ratio (Figure 5). For experimental purposes, all best practices were compared to a base case model using one geographic climate location, Portland, OR (45.12◦ North Latitude, 123.22◦ West Longitude and elevation of 357 ft). Every design retrofit strategy related to the building envelope or building performance was conducted. The energy simulations were based on a GBXML™ model in conjunction with IESVE pro modules (Figure 5).

Each of the identified best practices was performed separately to determine its specific impact on the building energy use and carbon generation, as proposed in the Architecture 2030 challenge (Mazria, 2006). In addition, a combined and optimized best practices model with most strategies combined was also modelled to provide an indicator of the mega impacts of the identified best practices on the total energy and CO2 emissions performance of the building. The detailed energy and emissions analysis included: Energy consumption (MMBtu), Carbon emissions (lbCO2), 2030 Challenge Targets (kBTU/ ft2), Thermal Comfort (%PPD limits), Peak HVAC loads (btu/h.ft2), Ventilation rates (cfm), and daylighting analysis (avg. fc/h operation).

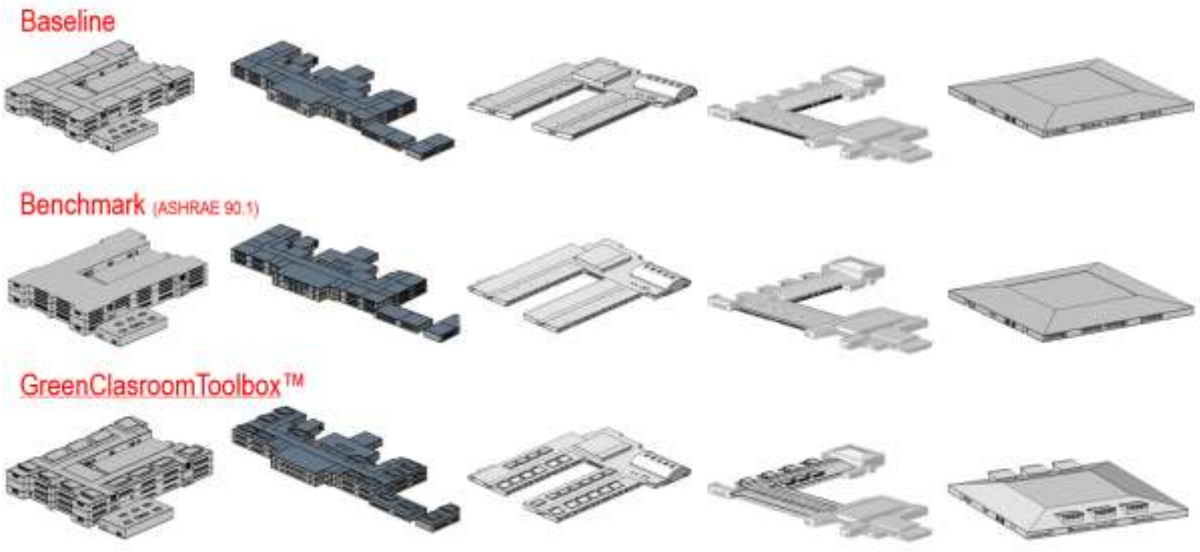

Figure 5: Six Types of K-12 school buildings modelled for experimental simulations using IESVE™

3.3 Phase 3: Meta-analysis of Health and IEQ Impacts:

Results of the meta-analysis is classified under impacts related to health, productivity, task performance, and test scores. These impacts refer to the general heading of "human performance." Summaries of the conclusions from these reviews are given below under Green Retrofits related to three categories: Indoor Air Quality, Temperature Control, and Day/Lighting Quality.

3.3.1 Indoor Air Quality Positively Impact Occupants' Performance by 5-20%:

The BIDS program identified 17 substantial studies that document the relationship between improved air quality and health. The health impacts include asthma, flu, sick leaves, sick building syndrome, respiratory problems, and other building-related illnesses. These 17 separate studies all found positive health impacts correlated with improved indoor air quality ranging from 13.5% up to 87% improvement, with average improvement of 41%. In a study of Chicago and Washington, DC schools, better indoor air quality in school facilities was correlated to a four percentage points increase in students' standardized test scores (Schneider, 2002b). Although many of these studies did not isolate the specific impacts of practices on performance, the health impacts that were documented are related to many of these practices, such as increased ventilation rates, natural ventilation, increased insulation, and HVAC pollutants control. Based on the above results, it can be very conservatively estimated that better indoor quality afforded by the different best practices results in a 5-20% improvement in occupants' performance (Figure 6).

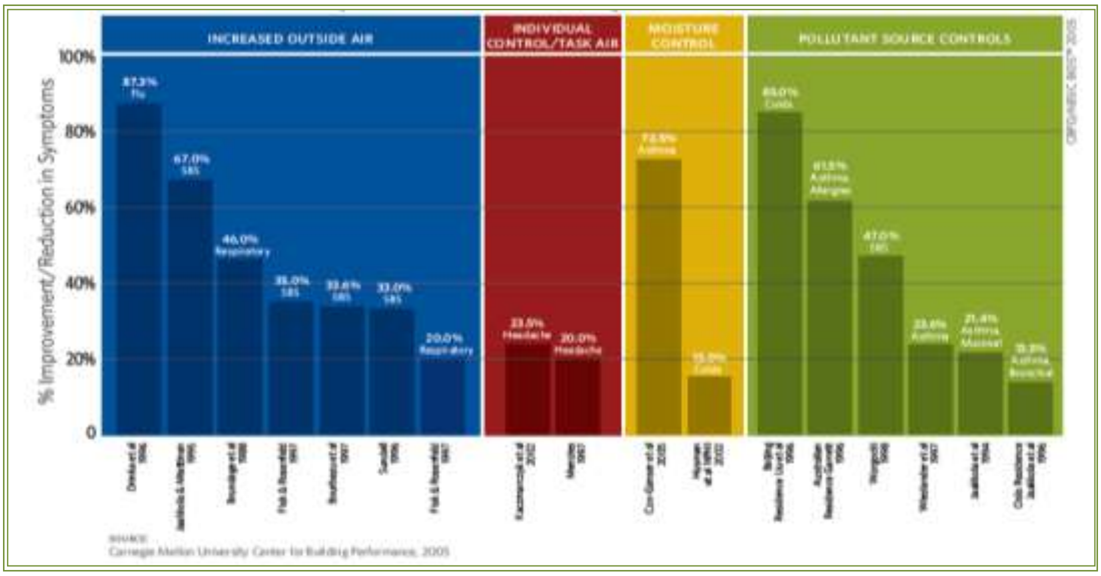

Figure 6: Health and productivity gains from better indoor air quality associated with green buildings
Citation: Kats, 2006 used with Greg Kats permission, December 2008

3.3.2 Temperature Control Positively Impact Occupants' Performance by 3-10%:

The effects of indoor temperature control and thermal comfort on teachers' and students' satisfaction in classrooms are clear. In a large office phone survey conducted with key personnel from a range of best practices companies and schools in the USA, Ducker Worldwide (Ducker. 1999) found a high correlation between the indoor air temperature acceptability and occupant satisfaction. Teachers perceive a high correlation between thermal comfort and student comprehension of lessons (Elzeyadi, 2008). Research indicates that the best teachers emphasized that their ability to control the temperature in classrooms is very important to student performance (Heschong, Elzeyadi & Knecht, 2001). A review of 14 studies by Carnegie Mellon on the impact of improved temperature control on productivity found a positive correlation between both perceived and experienced control and productivity improvements of up to 15% and with an average (mean) of 3.6% (Loftness et al., 2005) (Figure 7).

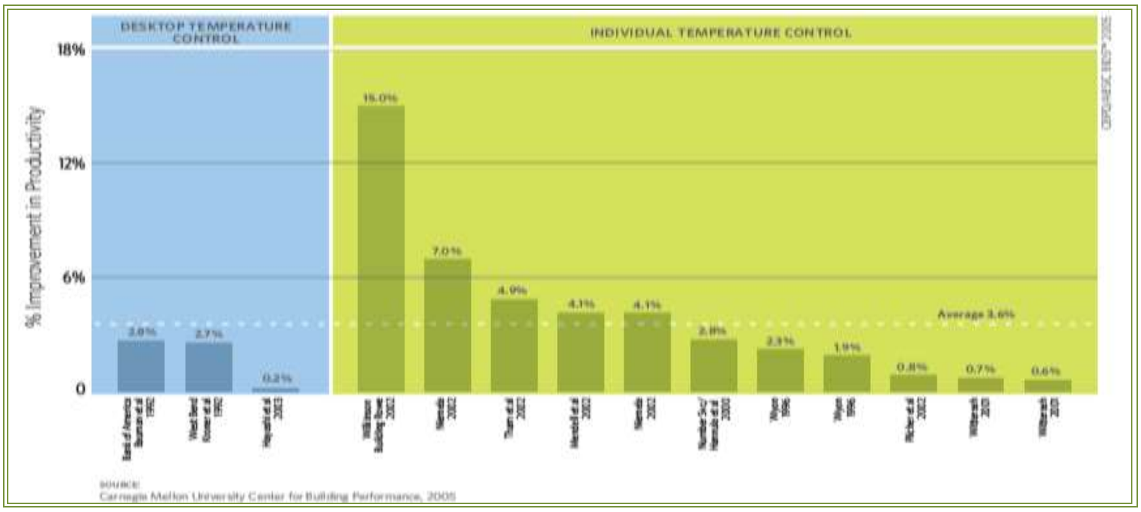

Figure 7: Health and productivity gains from better temperature control
Citation: Kats, 2006 used with Greg Kats permission, December 2008

3.3.3 Day/Lighting Quality Positively Impact Occupants' Performance by 5-20%:

Green school design typically emphasizes providing views and ambient daylight for classrooms and educational facilities. These strategies have been associated with improvements in performance on students' standardized test scores of 10-20% on average (Heschong Mahone Group, 2003; Heschong, Elzeyadi & Knecht, 2001). In a study of 200 utility workers, those with the best views performed 10-25% better on tests (Loftness, 2002). The consensus findings in a review of 17 studies from the mid-1930s to 1997 found that good lighting "improves test scores, reduces off-task behaviour, and plays a significant role in the achievement of students" (Loftness et.al., 2005). Another synthesis of 53 generally more recent studies also found that better daylighting quality fosters higher student achievement (Elzeyadi, 2002) (Figure 8).

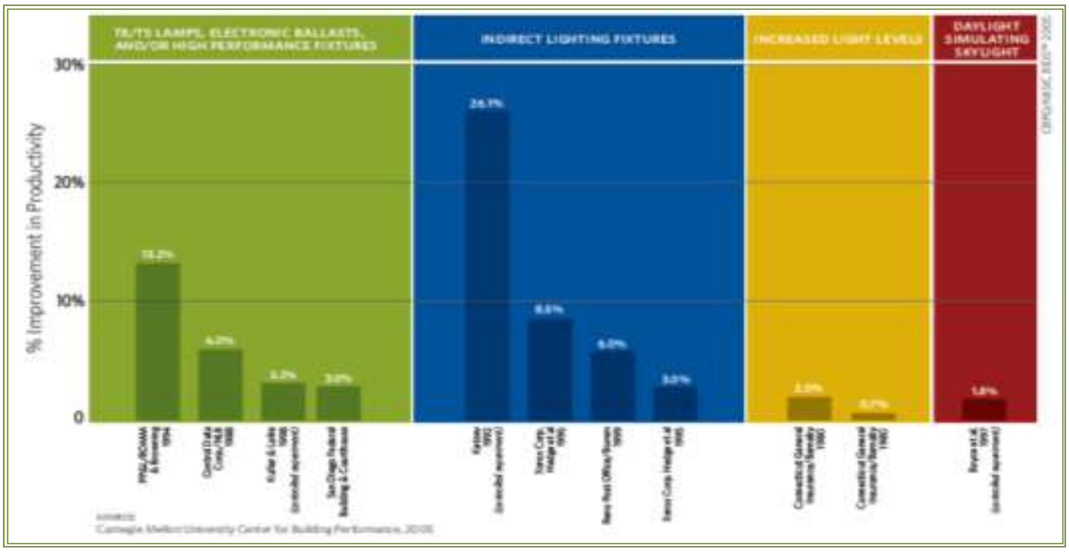

Figure 8: Health and productivity gains from lighting quality associated with green buildings
Citation: Kats, 2006 used with Greg Kats permission, December 2008

4. FINDINGS: ANATOMY OF THE GCT™:

One of this project's objectives is to evaluate and analyse the best practices identified earlier for their impact on school buildings' and classrooms' energy conservation as well as carbon (CO_2) emissions, as one of the main causes for climate change. For this task a dynamic energy simulation analysis was performed for each best practice strategy identified earlier. These simulations were conducted using IESVE™ ApacheSim module (www.iesve.com). The simulations were conducted on six prototypical two-story elementary school buildings base cases. These base cases are all double-loaded corridor classroom facility with a gross area of 54,802.11 sq. ft. and a 25% glazing-to-outside-wall ratio (Figure 9). Similar to national trends of school buildings' energy use, the current simulation model predicted that the existing school base case would consume 46% of its total energy for space heating, 20% for water heating, 19% for Lighting, and 15% for cooling, and other equipment.

		Existing Schools Actual Energy Use								
		FINGER		DUMBBELL	MULTISTORY		CLUSTER	L-SHAPE		H-SHAPE
		LEE - 2008	LEE - PPS Upgrade	ABY - Orig.	MLC - 2008	MLC - PPS Upgrade	HLY - Orig.	CST - 2008	CST - PPS Upgrade	MILL - Orig.
EUI	*Baseline*	*100*	*94*	*93*	*92*	*77*	*103*	*105*	*101*	*76*
	Original	**71**	**55**	**57**	**89**	**50**	**73**	**100**	**76**	**47**
	Benchmark	*40*	*38*	*37*	*37*	*31*	*41*	*42*	*40*	*30*
Carbon	*Baseline*	*467*	*445*	*318*	*408*	*383*	*213*	*577*	*513*	*372*
	Original	**332**	**261**	**195**	**394**	**248**	**150**	**551**	**386**	**239**
	Benchmark	*187*	*178*	*127*	*163*	*153*	*85*	*231*	*205*	*149*
Cost	*Baseline*	*$90,168*	*$86,740*	*$69,234*	*$89,088*	*$82,773*	*$46,102*	*$110,453*	*$103,215*	*$79,806*
	Original	**$64,103**	**$50,850**	**$42,469**	**$86,137**	**$53,573**	**$32,482**	**$105,566**	**$77,763**	**$49,781**
	Benchmark	*$36,067*	*$34,696*	*$27,694*	*$35,635*	*$33,109*	*$18,441*	*$44,181*	*$41,286*	*$31,923*

Figure 9: Energy performance breakdown of the six typical K-12 schools in climate zone 4c

The total yearly energy consumption calculated for the simulations was converted to kwh/ft2/year from kbtu/ft2 /year to normalize for the different sources of power supplied to the building. Figure 10 compare the impact of different envelope best practices on the yearly total building energy consumption (kwh/ft2), heating energy (kwh/ft2), CO_2 emissions (lb/ft2), and average daylight levels in foot candles (fc) for the classrooms schedule. Figure 10 shows ceiling insulation (R40), as well as cool roofs with radiant barriers coupled with daylighting strategies to be one of the most effective retrofit solutions for reducing energy loads and carbon emissions with respect to the envelope upgrade categories of the best practices check list.

Figure 10 shows the effective impact of top lighting strategies such as roof monitors and modular skylights on energy and emissions reductions. The same figure also shows that effective side lighting ranges between 35%-45% wall-to-glazing ratio for this climate and specific building typology. Figures 11 provide a comparison of thirteen of the envelope and daylighting best practices upgrades for the six school prototypes compared to the base case schools as well as with an optimized best practices models with most of the green upgrades. The optimized best practices models is shown to reduce energy consumption for the six comparative schools by an average of 50% in lighting and heating energy and an associated 59% reduction in carbon emissions (Figure 11).

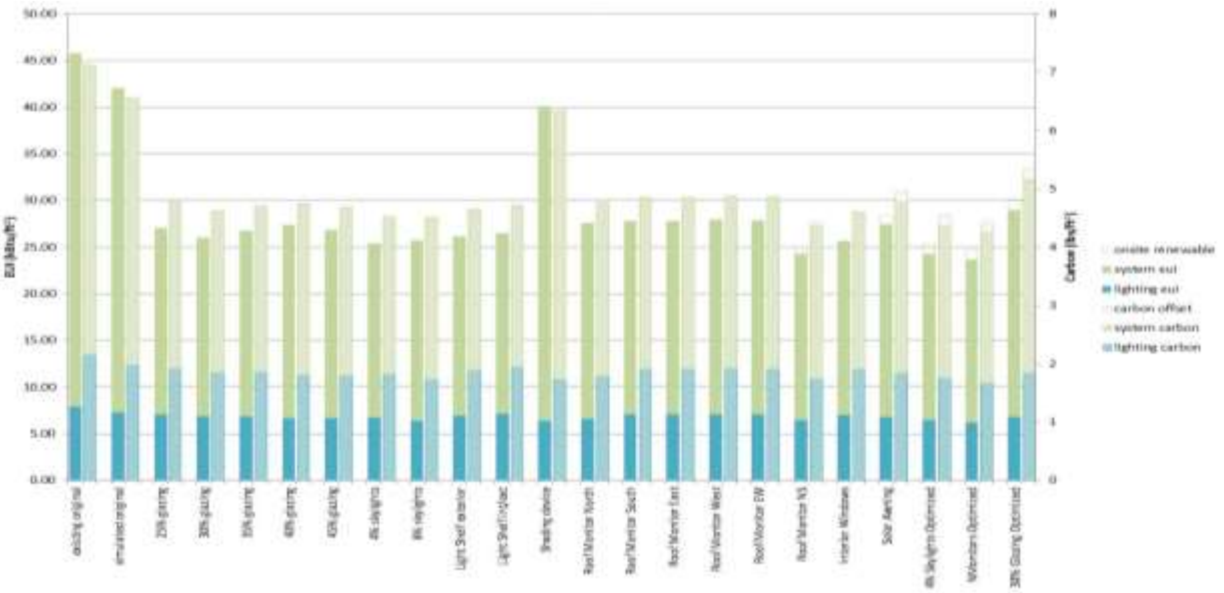

Figure 10: Energy and CO2 yearly emissions simulated by applying GCT™ retrofits to base-case schools

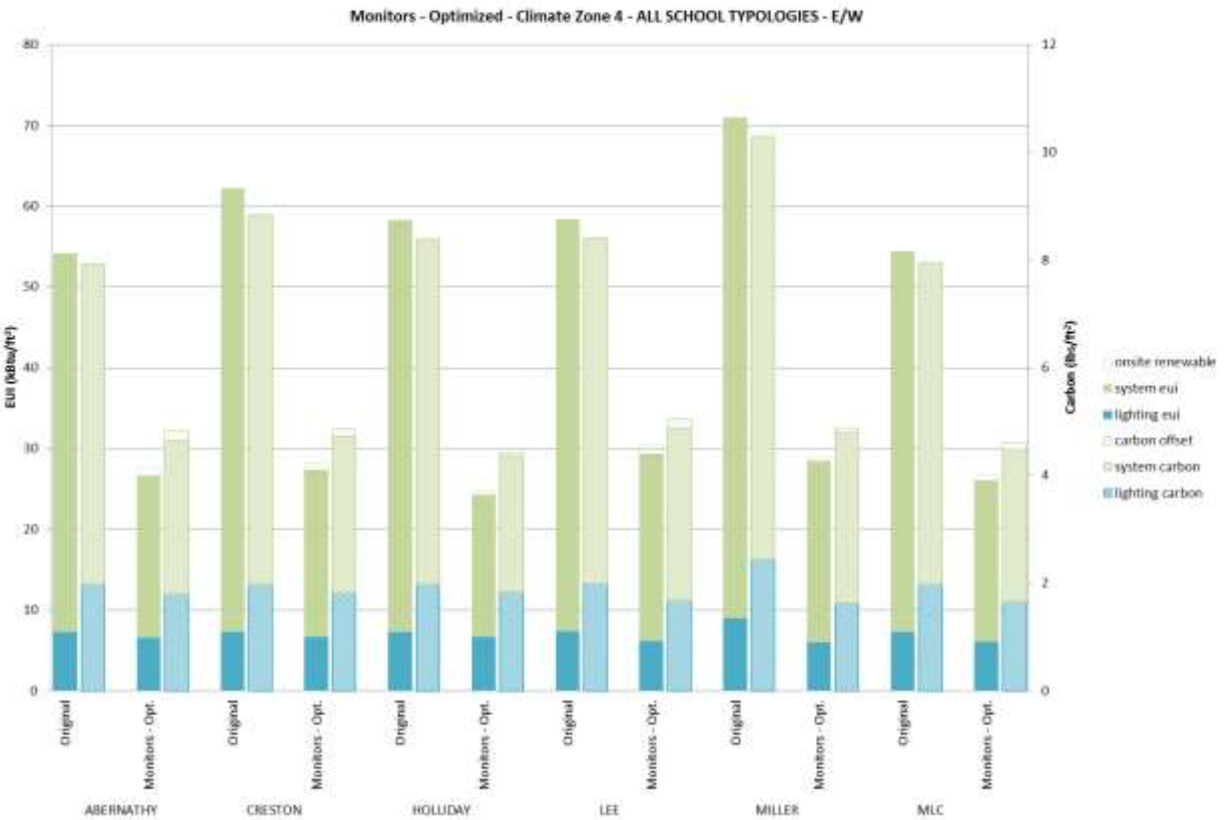

Figure 11: Six schools typologies comparative energy and carbon savings over ASHRAE 90.1 code.

5. CONCLUSIONS: ARCHITECTURE AS A THIRD TEACHER

One of the compelling challenges of creating evidence-based design guidelines is the reliability of applying research assumptions and guidelines to practice. In order to overcome this limitation, the developed guidelines were tested for an energy deep-retrofit project of an existing school in Eugene, OR, USA. The objectives was to apply the guidelines by transforming the existing school into a model case for school retrofits while engaging, the school, the students, and the school district in the design and transformation process (Figure 12). By employing a design charrette with elementary school students early in the design process, it was surprising that not only are students excited to contribute to a better and greener environment for their education but they are enthusiastic to learn from the experience on a daily basis. This lead to the design of a school science and math curriculum that engages the students in their classroom environment and its performance through daily and monthly in-between classrooms low-energy consumption competitions. In fact, the classroom itself became a dynamic text-book for daily science and math topics and provided an environmental hands-on learning experience for students. As a result environmental sustainability education became weaved into the school curriculum and provided a behaviour change for school children, teachers, and the community.

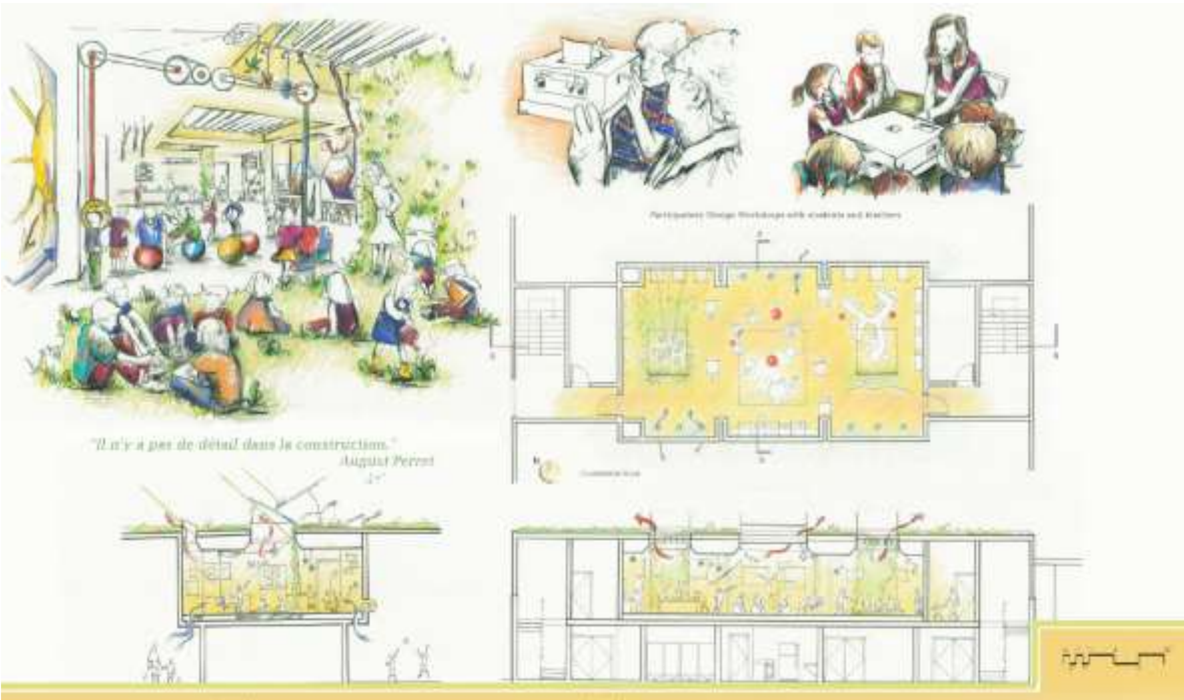

Figure 12: Application of GCT™ in Practice – Classroom Architecture as Text-Book

In terms of achieving the objective of documenting the triple bottom line benefits of the green classroom retrofitting best practices for the planet (CO2 reductions), profit (energy savings), and people (health and performance), the data presents a clear and compelling case that retrofitting existing schools today is extremely cost-effective, and is the right thing to do for the health and learning of our children (Figure 13). The hope that this information will aid school designers, facility managers, and principals in making informed decisions for retrofitting existing classrooms to meet the Architecture 2030 challenge (Mazria, 2006).

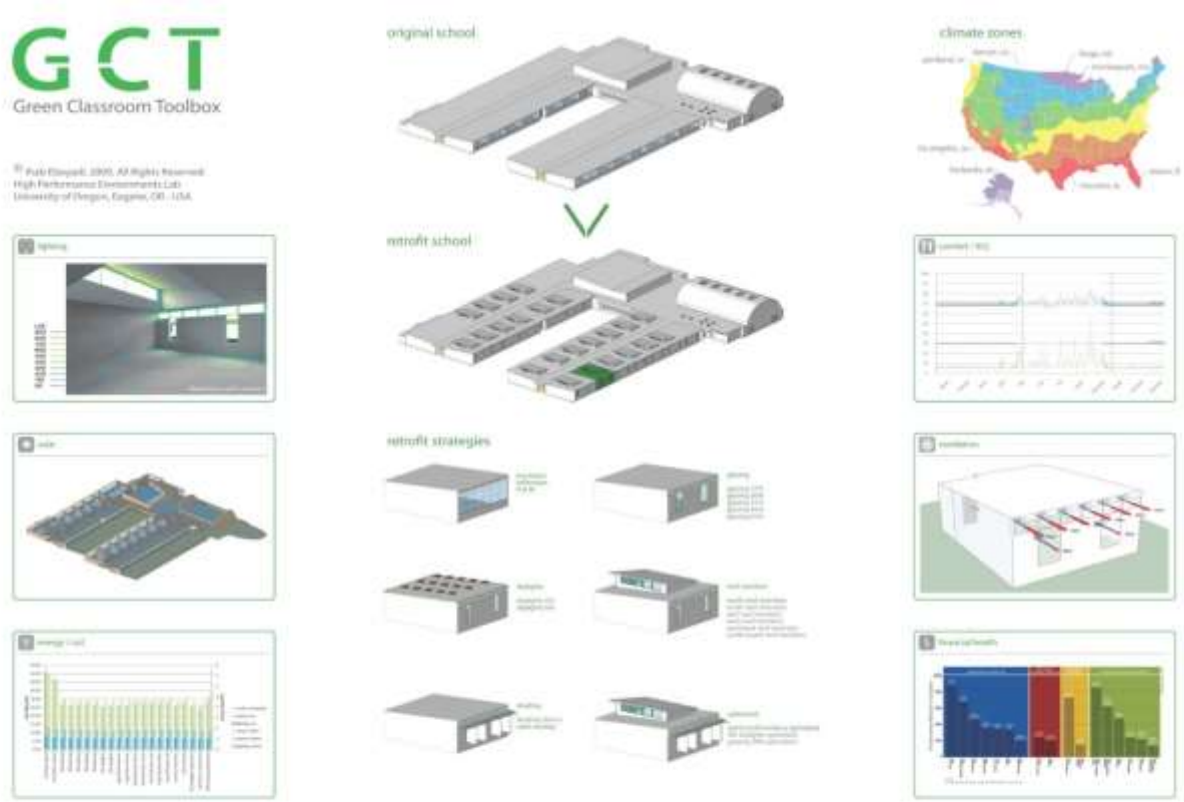

Figure 13: Green Classroom Toolbox™ (GCT) Project Model

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Theme IV

BIM and Innovative Project Management

The role of Green BIM in energy efficiency of buildings

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Abstract: *The emerging trends of Sustainability and Building Information Modelling in the built environment are intensively pulling the attention of the contemporary AEC industry. Although BIM and Sustainable Design have derived from quite discrete underlying needs and market factors, they share a significant mutual thread: the success of both endeavours relies heavily on a front loaded, deeply integrated building design philosophy that aims to encapsulate all team players from the very beginning of a project. This paper reviews the interrelationship between BIM and sustainability and extends it to be utilized for the achievement of energy efficient buildings. The study includes analysis of the background of the synergy, commonalities between them, benefits of their intersection and frameworks for their application. Concurrently, challenging issues are discussed and future research opportunities indicated. However, the reviewed literature in the paper is limited to the impact of BIM on energy efficiency, as an aspect of sustainability, during the early stages of the project, although the contribution of post-occupancy stages to energy consumption is recognized. The paper concludes that the combination of the two trends is driven by necessity, in fact, since BIM can enable the substantial adoption of sustainability. Meanwhile, efficient energy modelling and analysis, facilitated by BIM tools and BIM-friendly applications, have the potential to result in energy efficiency and in further successful implementation of certification systems. Thus, acknowledging the supportive approach of the new emergences, further research is recommended in the terms of simplification of the practice, and design of the lines of communication between the multidisciplinary project team, as a vital condition of BIM, sustainability and Green BIM.*

Keywords: Building Information Modelling, Energy Efficiency, Energy Modelling, Sustainability

1. INTRODUCTION

Recent studies highlight the increasing necessity of sustainable building facilities with minimal environmental impact. Catalysts for attributing such high significance to the role of sustainability in the contemporary built environment are the escalating global concerns of the scientific community about the survival of the planet, the species and the next generations, greatly affected by the rising and unconscious energy consumption. However, the green initiatives for the environmental and social benefits of health and quality of life could be further kindled by the economic viability of sustainability. Investing on sustainable design; with a slight rise in upfront costs of 2%; promises 20% reduction of the lifecycle costs (Azhar, et al., 2011). Simultaneously, the modern Architecture, Engineering and Construction (AEC) industry has displayed great developments during the last decades due to its interaction with Information Technology. Moving to an era when the previously prevalent Computer Aided

Design (CAD) is being gradually substituted by Building Information Modelling (BIM), the areas of its beneficial application are investigated.

As a result, in an attempt to investigate how Information Technology exerts influence on sustainability, the majority of the literature concludes that conventional methods result in lost opportunities to maximize the utilization of energy efficient building design options, due to lack of integration into the design process (Moakher & Pimplikar, 2012). On the contrary, it is increasingly advocated that endowing energy analysis with BIM principles and tools during the early design stages is proving to be essential for energy-conscious green buildings. The inherent characteristics of BIM seem to be tailored for the desirable deliverable of energy efficiency, engendering a unique combination with sustainability under the term of GreenBIM. Consequently, the provision of a holistic model through holistic procedures across collaboration of multidisciplinary interdependencies, triggered by the early realisation and integration of the need for sustainability, intensifies the importance of exploring the background and the capacities of this synergy. In that context, this paper investigates the interaction of BIM with sustainability, discussing specifically the impact of their symbiotic convergence on the energy efficiency of buildings. For that reason, the background of the two terms is analysed, as a basis for the understanding of their common term of Green BIM, the benefits of which are examined, as well. In order, to reach the practical implementation of Green BIM for energy efficiency, energy modelling is described, while the actual outcomes are evaluated by linking Green BIM with the performance assessment system of Leadership in Energy and Environmental Design (LEED). However, in order to contribute towards the substantial clarification of the topic under discuss, obstacles and constraints across technology, relationships and interconnection of procedures are presented to motivate improvements and future research in a promising field.

In order to cover the above subjects, the paper commences by analyzing the concept of sustainability and Building Information Modelling to subsequently introduce their combination under the concept of Green BIM. Following, energy modelling of buildings as a necessary step is identified and prepares the next subsection regarding to the application of BIM in support of efficient energy analysis. Finally, the paper discusses the impact of BIM on LEED certification process.

2. THE CONCEPT OF SUSTAINABILITY

While society and technology are rapidly developing, the physical environment is deteriorated, being sacrificed for technological advancements and economic interests. The phenomena of greenhouse effect, global warming, ozone layer depletion, pollution of the atmosphere and the water have raised global concerns about the environmental impact. Since these environmental issues are greatly affected by either the excessive or the inappropriate and unconscious use of energy and materials, the fact that according to EUROPEAN COMMISSION, (2013) buildings account for the 40% of global energy consumption and cause the 36% of greenhouse emissions, has set sustainability as a mainstream design objective. The majority of the authors agrees on attributing to sustainability the ability to function and survive gracefully into the future without compromising the level of quality of the environment and the social and economic context.

For that reason, the concept of sustainability is classified into three pillars:

- The environmental pillar refers to the consideration of the environment in regard to the atmosphere, land, water and natural resources. It pulls the attention towards the protection of eco-systems and the creation of eco-friendly products adapted to them.
- The social pillar considers the social justice and the satisfaction of all stakeholders' expectations alongside with the provision of a high level quality of life.
- The economic pillar is related to the utilization of local economies and the economic feasibility of commencing projects and operating existing ones.

Turing into construction terms, the environmental sustainability focuses on the construction and management of projects with efficient use of natural resources and on design driven by the target to minimize the environmental impact. Social sustainability is specified as the provision of safe and healthy environment for the staff, the local community and the world, whereas according to economic sustainability in construction emphasis is given on cost-effectiveness during the project's lifecycle (Wong & Fan, 2013). Although respect should be addressed to sustainability from a holistic point of view, the conflicting nature of some factors affecting it requires the optimization of decision-making (Anastas & Zimmerman, 2003). For instance, most of the times the most environmentally friendly design concept is not the most aesthetic or cost efficient solution that could be suggested for the project. Against to this challenge, optimization of sustainability calls for overall consideration of information deriving from various disciplines with different perceptions of how sustainable aims are to be translated. At this point the challenge of fragmentation among the AEC industry comes to complicate the desirable deliverable of sustainability. Consequently, the adversarial culture of construction creates a necessity for procedures, mechanisms and tools which will ensure compliance under the common target. In terms of the sequence of procedures, Azhar & Brown, (2009) argue that decisions regarding to sustainability are more efficient when made during the early stages of the project. Indeed, including sustainability among the three standard objectives of time, cost and quality from the beginning of the project can ensure its unanimous adoption. Therefore, sustainability should commence from the conversion of client's requirements and project's specifications into the intended sustainability performance criteria. Secondly, the relevant design information need to be applied in order to conduct an inclusive sustainability analysis as a result of the various related disciplines. This is the point where the essential mechanisms and tools are required in order to confirm the literally successful implementation of sustainability. Finally, the evaluation of sustainability is measured via the increasingly adopted performance rating systems (e.g. LEED, BREEAM) which operate as sustainability benchmarking.

3. Building Information Modelling

Building Information Modelling (BIM) is an innovative technology that has emerged in AEC industry during the last years. Whereas, Building Information *Model* is a digital representation of physical and functional characteristics of a facility, Building Information *Modelling* describes “an integrated process which is used to facilitate the exchange of design and construction information to project participants” (Moakher & Pimplikar, 2012). Even though, the ultimate end product is the 3D-model, it is far more different from the drawings produced by the conventional Computer Aided Design (CAD). It is not just the fact that a building information model consists of the actual assemblies of the structure rather than the two-dimensional representation of CAD. A substantial variance is that BIM-model is a database of the information collected from a variety of project participants and, thus, gathering legal, financial, scheduling, environmental, geospatial, design, construction and other extensive data. Moreover, the attributes of collaboration, integrated project delivery (IPD) and lifecycle management differentiate BIM from traditional methods. The collaboration of the stakeholders of the project to insert, extract, update or modify information on a central and flexible model maximizes efficient communication, quality, cost and time effectiveness and minimizes errors and omissions. The early collaboration of various professions in decision-making establishes the factor of IPD which accompanies the BIM orientated project during its lifecycle (Jones, 2014). Finally, lifecycle management of the facility is enabled via this complete multi-informed model, giving the opportunity to manage the requirements of the project from inception to operation. The distinctive characteristics of BIM are those that form the benefits deriving from its application and can be summarized to improved productivity, improved communication and coordination, improved quality control, accurate cost estimate and time scheduling (Dowsett & Harty, 2013). In an effort to establish these benefits into construction industry, UK mandates BIM for all government projects by 2016 with ultimate aim to replace the adversarial culture of the industry with a collaborative one, innovate within the supply chain and take advantage of the full potential of Information Technology in construction market (Withers & Matthews, 2011).

However, the obstacles to the adoption of BIM operate for the conventional part of the industry as the negative aspects of it. As those, the adequate training, the cost of the software and hardware upgrades and the non-negotiable necessity of good communication between the parties, can be regarded (Che, et al., 2010). The allocation of remarkable time, money and human resources can lead many firms to avoid inventing in BIM. Additionally, the fact that the major benefit of qualitative communication is a vital provision, as well, could be difficult to be smoothly realized among the competitive nature of the related professions. Consequently, the successful implementation of BIM does not depend exclusively on the application of technology, but a process-orientated framework is required. According to Dowsett & Harty, (2013) apart from the project-level application, a strategic-level organizational planning is of prime importance, which can include the rationalization of the additional cost, the support of the workplace environment for the acquirement of BIM skills and the customization of the framework for the individual characteristics of every project. As a result, what seems to be fundamental is the mutual adjustment in order to qualify the adoption of BIM technology in inter-organisational collaborations, where teams have bridged the boundaries between management, design, construction and operation and the advantages of innovation can be revealed without obstacles during the overall lifecycle of the project, affecting positively the enhancement of several areas in AEC industry.

4. The concept of Green BIM

Sustainable design and development are rapidly pulling the attention of AEC industry to the need of green buildings. Simultaneously, Building Information Modelling is gaining increasingly ground among major design and construction firms. As a logical sequence of these emerging trends, a term that reflects their growing interaction has been established. *Green BIM* refers to the utilization of BIM tools in order to achieve sustainability and/or enhance building performance objectives on a project (CONSTRUCTION, McGraw Hill, 2010). It is the inherent characteristic of BIM, that of Integrated Project Delivery (IPD), that contributes particularly to the “greening” of projects, as it allows multi-discipline teams to collaborate from conceptual design stages towards sustainability goals (Jones, 2014). Constructing a digital virtual 3D-model where various stakeholders (architect, structural engineer, MEP engineer, construction manager, facilities manager) have access from the early stages, provides the capacity to consider and analyze alternative sustainable options in order to apply the most efficient one (Stumpf, et al., 2009). Consequently, BIM comes to stand out from traditional methodologies, where environmental and energy analysis are conducted by specialist consultants after the completion of the design due to the incapability of CAD to perform sustainability analysis at early design phases (Jrade & Jalaei, 2013). Causing cost and time-consuming procedures of potential reworking, indicates that BIM is a useful tool for timely decision-making, affecting significantly the conscious application of sustainability. However, the provision of appropriate technology through BIM is not the sole factor that can guarantee the successful implementation of green processes. According to Hakkinen & Belloni (2011) sustainable construction is not obstructed by lack of technology, but hinges upon the organizational willingness to adopt innovative methods. Furthermore, Bynum, et al., (2013) advocate the urgency of willingness to cooperation between the project parties in order to maximize the potential of BIM for sustainability. Therefore, it can be argued that the organisational barriers and individual resistance to changes of the well-known conventional procedures extends from the general adoption of BIM, as stated to the previous section, to its application to specific areas of interest. Nonetheless, the recognition of the fragmentation that AEC industry traditionally experiences should operate as a motivation to embrace not only BIM technology, but also the principles of BIM. For that reason, Green BIM should be contemplated not just as a summation of methods and tools but as a synthetic synergy of concepts, procedures and people. Even though sustainability in the built environment is achieved through practice, the theory that frames it is vital for a deeply integrated sustainability rather than a superficial compliance with the minimum requirements set by legislation. Therefore, it is crucial to investigate how literature confronts both practice and theory behind this symbiotic convergence.

5. Energy Modelling

One of the most critical factors that affect the sustainability of a building project is the energy consumption during its lifecycle. Thus, energy efficient is one of the main features of green buildings and, as a result, they are considered eco-friendly. Nevertheless, having already referred to the remarkable quantitative responsibility that buildings hold for the global energy consumption, energy efficiency acquires a dominant role in construction industry, being reinforced by the target of European Union towards Nearly Zero-Energy Buildings (NZEB) by 2020 (EUROPEAN COMMISSION, 2013). The fundamental step to the essential energy analysis, which will determine the efficiency of the designed project is energy modelling. Currently, energy modelling is mainly carried out by the traditional CAD late in design, using energy simulation packages which take into consideration building design elements and external data. Evaluating energy performance based on building representations by CAD solutions requires a great deal of human intervention and interpretation without guaranteeing the success of it. On the contrary, it can prove a painful procedure where changes cannot be settled and thus, actual energy efficiency is jeopardized. Indeed, as Motawa & Carter, (2013) claim the repetition of data entry in the packages and the absence of a central model, aware of the amendments in building features during their lifecycle, indicate the necessity of an integrated approach to energy modelling.

For instance, in that ideal scenario architects can use a central model to enhance building's envelope or determine glazing ratio for balancing energy consumption. Engineers can reduce energy demands taking into account natural lighting and ventilation for HVAC systems, while contractors and sub-contractors can use the model to reflect site conditions and local climate and, consequently, adapt energy usage and reduce carbon footprints during construction stage (Hardin, 2011). Further to that, the project team can be more confident of what the outcome will be, having the ability to try alternative solutions until the criteria are met.

In order to create a complete energy model, a number of elements need to be included such as: orientation, building mass, daylight, materials, natural ventilation, and climate conditions. The design team must take into consideration all the energy related factors to assess whether the building is regarded as energy efficient by the appropriate software or changes need to be implemented. The development of Green BIM tools provides with an integrated model where multi-disciplinary information construct a simulated energy model, which improves the energy analysis and decreases the errors of data management (Azhar, et al., 2011).

6. The application of BIM for Energy Analysis

The application of energy modelling into BIM practice during building energy simulations has profoundly enhanced the energy analysis process (Cho, et al., 2011). What needs to be clarified is how energy-related issues can be allocated at the pre-design and design phase of the project, as according to Azhar & Brown, (2009) decisions made at these early stages are considered as the most effective ones as far as sustainability is concerned. Indeed, data extracted from early energy analysis can be used as a comparative tool in order to select the most sustainable option. In an attempt to figure out the process that will lead to the realisation of these benefits, different authors have suggested procedures for incorporating energy modelling into Building Information Modelling. Krygiel & Nies, (2008) propose that analysis through BIM should be based on the following steps:

- Building the BIM model of the project
- Selection and application of an energy simulation software
- Interpretation of the data and decision-making

Mojtaba, et al., (2015), similarly, refer to the provision of the 3D-model, integration of it into an energy modelling tool and, finally, evaluation of calculations and examination of alternative solutions. Stumpf, et al., (2009) describe a quite different process where the first step encompasses the definition of the project requirements among the variety of participated stakeholders. The second step, that of energy modelling, is divided into the phases of concept design or macro-level energy analysis and detailed design or micro-level energy analysis, which is eventually exported to an energy analysis tool. The process ends with the refinement process validation where the energy analysis is validated by being compared with an analysis produced by another software. Despite of the fact that all of the procedures have proved to be efficient as their results are presented through case studies by their authors, Krygiel & Nies, (2008) approach is to be adopted in this paper since it can provide a generic framework, synthesizing the components of the other approaches and being adjusted to every occasion.

6.1. The BIM model

Several BIM software environments can be used for the models such as Autodesk, Bentley Systems, Naviswork, Graphisoft and Nemetschek (Che, et al., 2010). The majority of the authors prefer the applications fact that can smoothly manage the database of the building from planning to design, to construction and to demolishment, embracing the attributes of interoperability and bi-directional information. For instance, a revision made to the structural model will be automatically appeared in the architectural model, without entailing manual update. However, users should select the software that is the most appropriate for their organisations and the projects they are committed to.

A solid, well-built and adaptable to energy modelling application, building model must include roofs and floors, walls attached to roofs and floors and building geometry must surround all the required areas. Moreover, in order to prepare the model for the next stage of energy analysis, some specific parameters need to be captured which are the project location, building envelope, room volumes and any specific requirements of the respective software (Krygiel & Nies, 2008).

6.2. Energy simulation applications

Transferring the model from one tool (BIM) to be read by another tool (energy analysis) is achieved via IFC and gbXML schema which are BIM standards that facilitate the communication of building information and enable the interoperability between design models. Subsequently, the selection of the most suitable software depends on factors such as the project stage, skills and expertise of the user and time availability. The advantages and disadvantages of the four most popular in the market of energy modelling applications are gathered in Table 1 with information collected and assessed from Krygiel & Nies, (2008), Azhar & Brown, (2009) and Moakher & Pimplikar, (2012).

Table 1: Advantages and Disadvantages of energy modelling applications

Software	Advantages	Disadvantages
Green Building Studio (GBS)	• Free online service • Simple user interface • Quick production of graphical simulation for building energy performance • Easy drop-down menus for quickly adapted changes • Automated gbXML error check • Incorporated LEED daylighting credit test	• Unstable when using large file sizes • The survey details are not high • Unable to specify individual analysis types (i.e. provides one predetermined) and may result in inaccurate results
Ecotect	• Friendly graphical interface • Easy to run and use • Resultant graphics are easily understood and available • Supported by other tools (day lighting, weather, ventilation, airflow analysis) • Incorporated model viewing capabilities	• Analysis results stored in a single file • Analysis steps are not clear • No gbXML error check • Very long analysis run times • Challenges with importing, exporting BIM model directly, depends on program used
eQUEST	• Free tool • Capacity for energy simulation including (heat loads, HVAC, climate data • Ability to import from CAD programs	• Unable to export geometry to programs • Unable to estimate thermal comfort and analyse natural ventilation
Integrated Environmental Solution IES<VE>	• High level of accuracy and interoperability with BIM • Short analysis run times • Results are displayed in an organized manner • Incorporated LEED daylighting credit test	• Complex for the user • Expensive comparing with relative tools • Unable to import a large number of gbXML • Limited model viewing capabilities • Model preparation requires manual gbXML error check resulting in limited error report

6.3. Optimizing the energy use

The results deriving from the energy analysis software can be evaluated in order to optimize the energy efficiency of the building. In case that the interpretation of the outcomes does not comply with the expected ones, decisions regarding to changes can be made and easily homogenized. In Krygiel & Nies, (2008) example, the impact of an additional sun shading device was tested, proving that its presence reduces the annual energy consumption and cost. Equivalently, many alternative solutions can be assessed in order to maximize the implementation of the described procedure and, consequently, the benefits of energy efficiency.

However, Motawa & Carter, (2012) supports that the synergy of BIM and sustainability requires further development, demonstrating the fact that although IFC and gbXML schema enable BIM models to be integrated into energy software, the opposite procedure finds obstacles, in case that a building model needs changes for an improved performance. Therefore, although the benefits of this emergence are acknowledged there is still research to be done and application to be tested.

At this point, it is realized that literature mainly emphasizes on the provision of a framework as far as practical implementation is concerned and seems to neglect the significant challenge of the multi-disciplinary interaction without which the first is impossible. Having underlined the major role of collaboration in the concept of sustainability, the adoption of BIM and in their combination under Green BIM, literature should provide further analysis for the interrelationships between the project participants who affect and are affected by the BIM-based energy efficiency. Consequently, it is the human-centric approach that should accompany the techno-centric developments.

7. The impact on performance rating systems: BIM for LEED

The contemporary necessity of the promotion of sustainability in the built environment has led to the worldwide positive correspondence of organisations to initiate rating systems for the sustainable performance of buildings. As a result, there are numerous systems provided in order to measure the sustainability, as each one of them defines it. A rating system that holds a dominant position in AEC industry is the internationally recognized Leadership in Energy and Environmental Design (LEED), developed by the U.S. Green Building Council in 1998. LEED was created with the purpose to offer an accurate framework for the execution of green design, construction, operation and maintenance. What needs to be mentioned is that under LEED system, a structure is capable of acquiring up to 110 points. The 110 points are allocated between the eight categories of Location and Transportation, sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, innovation in design, and Regional Priority (U.S. Green Building Council, LEED v4 2016). Meanwhile, the major role that energy efficiency plays in the characterization of a sustainable structure is reflected by the fact that “energy and atmosphere” is the most determining category, accounting for the most of 33 points.

Having already mentioned the gravity of the early adopted principles of sustainability and how BIM incorporates energy features throughout the design phase, the beneficial impact of this combination on LEED is examined. Initially, the ability to assess the performance of a building at its pre-construction stages is uniquely provided by BIM. In contradiction with CAD methods, BIM gives access to the form, mass, materials, context and mechanical-electrical-plumbing systems data of the building through one central model. Hence, creating the opportunity for energy measures to be reviewed, the potential for a LEED certification is notably increased. Additionally, the advantage of BIM to modify changes easily can be proved vital for LEED, in case that some building features may prevent the acquisition of LEED points. However, the conjunctive link between the BIM model and LEED concept should not be underestimated. It is the energy analysis software, analysed in the previous section, which interprets the BIM data into green terms for the LEED to evaluate them.

Nevertheless, in order to produce LEED documentation, it is essential to implement the LEED credit calculation. According to McGraw Hill CONSTRUCTION, (2010), among the users of Green BIM, 42% support the usefulness of BIM models for calculating LEED credits, whereas 38% characterize the usefulness as low and 20% describe it as absent. The reasons behind the views of inefficiency of the technology may include both the lack of unlimited exploitation of it and also inherent gaps in the process. For instance, there may be firms which employ BIM on green projects at the completion stage to define the implications of the design in LEED requirements, rather than designing according to sustainable and, thus, LEED standards, following the sequence depicted above. On the other hand, the lack of automation in the procedure of BIM-based calculation of LEED credits according to Green BIM users influence their satisfaction. As far as non-Green BIM users are regarded, their reluctant position is affected by the high level of sophistication for calculation, the lack of tools, the missing functionality of tools and their complexity (McGraw Hill CONSTRUCTION, 2010). Indeed, innovative methods always cause insecurity which is intensified by omissions or negative aspects. As a quite negative aspect, the additional cost of LEED certification procedures in combination with BIM can be regarded.

Although BIM facilitates LEED system, there is no one-to-one relationship between the certification process and BIM-based energy analyses due to the lack of integrated LEED features in the available software. However, apart from increasing the potential for certification acquisition, as described above, the results of the energy analyses, run on BIM models, can be used to directly, semi-directly or indirectly generate LEED documentation in a more efficient way, saving time and resources (Azhar, et al., 2011).

With LEED being adopted continuously in the construction industry, highlighting the importance of sustainability, and BIM coming to facilitate every procedure and objective, their intersection can be nothing but advantageous. Accordingly, the research community should shed lights on BIM implementation in LEED/sustainable design, credit analysis and documentation in order to reduce the constraints and increase their potential.

8. Conclusion

The escalating global concerns about the environmental impact and the energy consumption have set sustainability as an issue of major importance in the contemporary society. Simultaneously, the remarkable contribution of buildings to these worldwide phenomena has necessitated the embracement of sustainability in the AEC industry, as an objective of high priority. In an attempt to assure the sustainable outcomes and enhance the procedure to reach them, many authors interrelate sustainability with the other emerging trend of the era, Building Information Modelling (BIM). Under the term of Green BIM the two concepts unify their principles and processes in order to innovate creatively in the industry. On account of this recently suggested innovation, this paper has reviewed the relationship between the two concepts and investigated how they interact in the terms of energy efficiency. The review also explored the common attributes that justify their interaction and their synergy and the potential of their reflection on formal rating systems, with ultimate scope to display the benefits of the application and indicate the drawbacks or omissions in order to offer ground for amelioration.

The social necessity of sustainability in combination with the technical explicitly of BIM and its capacity to enhance the culture of the AEC industry through its inherent characteristics imply that their application is driven by necessity rather than superficial trends. Their power of interaction is further reinforced by the established term for describing the convergence, while the benefits underlying Green BIM include the integration of sustainability from the early stages of the project when it is more determining and, thus, efficient. Additionally, the multidisciplinary collaboration of project participants who affect and are affected by sustainability issues is considered as a respectively significant attribute. Under the BIM characteristic of IPD, sustainability acquires substantial existence, since project team collaborates towards the common objective during the lifecycle of the project. However, the technology that BIM employs is equally important to the principles which form the procedure. Providing a central, flexible, virtual 3D-model where amendments are automatically adapted, facilitates the process of the essential to sustainability modelling. Referring specifically to the energy modelling, BIM software contributes to overcoming the problems deriving from conventional methods. Having examined various procedures for the application of BIM to energy modelling, the paper concluded in following the one that offers a straightforward and adaptable to a wide range of occasions. As a result, the creation of the BIM model is followed by its transfer to a BIM-friendly energy simulation software, selected among a variety by balancing the advantages and disadvantages of each of them, since literature does not favor any specific. The deriving outcomes are interpreted according to the formerly set criteria and decisions are respectively made. As far as the impact of BIM on LEED rating system is concerned, authors are increasingly supporting their helpful intersection both for the procedure that leads to gaining LEED credits and for increasing the potential to achieve the ultimate certification, finally.

The beneficial interaction of BIM and sustainability and their impact on energy efficiency of buildings should be considered thoughtfully by the AEC industry and the research community in the future. Developments on BIM tools and simplification of the procedures could attract new practitioners of the field. Nevertheless, consideration should be devoted to the human factor, which seems to be neglected by the literature. Due to the fact that successful implementation of Green BIM depends on smooth collaboration of people, emphasis should be given on the interrelationships between them, structured by a framework for the allocation of activities and communication.

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Towards BIM Enabled Sustainable Urban Developments in the UAE

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Abstract: *Building Information Modelling (BIM) is a revolutionarily technology and coordinated process to create an intelligent and information-rich 3D representation of the projects for stakeholders to cost-effectively design, construct, operate and manage construction projects. Effective implementation of BIM throughout the life cycle of construction projects can provide a comprehensive, intelligent and reliable data source to support better decisions and mitigate subsequent risks early in projects, thus providing a better project management paradigm to achieve sustainable construction projects. This research investigates the potential of using BIM as an enabling technology and collaborative project management process to achieve sustainable and smart built environment, especially in the context of the UAE construction industry. UAE is passing through an enormous period of urban growth in recent years and has shown strong commitment towards building a sustainable urban infrastructure. Policy makers can play a significant role in making most of BIM in supporting sustainable development by leading the way for its implementation in the UAE and a resolve to effectively use best of the available technology and innovation to improve the construction industry, and hence the environment in the UAE.*

Keywords: BIM, construction, life-cycle, project, sustainable

1. INTRODUCTION

The construction industry is a key contributor to the UAE economy and environment but also responsible for yielding 75% of waste in the UAE. The UAE Government is committed to create sustainable built environment and aiming to host the most sustainable world expo event in 2020 by transferring Dubai into a SMART and sustainable city.

The Government led initiatives, such as Estidama, are leading the change to improve handing and selectin of materials and environmental regulations to achieve the sustainable development goals. However, these efforts are not being backed by the industry due to non-collaborative practices and adversarial nature of construction contracts. So, in order to translate sustainable concepts into sustainable infrastructure, there is a need for innovate technology and collaborative working, such as BIM, to connect the different levels of the industry (such as decision makers, urban planners, economists, architects, contractors and construction supply chain from strategic urban and infrastructure planning to maintenance and operations of the built assets. The objectives of this research are to explore the benefits of BIM as a project management tool from a project life cycle perspective, demonstrating the effectiveness of BIM in taking sustainable decisions. The research will also benefit key players in the local industry by encouraging use of BIM as a project management tool to achieve sustainable and cost effective construction projects.

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2. LITERATURE REVIEW

Construction projects have become more complicated and difficult to be managed (Williams, 2002; Alshawi & Ingirige, 2003; Chan et al., 2004; Muhammad Ariffuddin, 2015). During the last decade, the major shift in ICT for the construction sector has contributed to the emergence of Building information Modelling or BIM (Bryde et al., 2013). BIM is a new paradigm in the construction industry where it encourages the integration of all stakeholders of a project (Azhar et al., 2008; Bryde et al., 2013). Many scholars defined BIM in the Architecture, Engineering and Construction (AEC) industry as a technology or tool that has a variety of names that may be attributed to different research and industrial bodies as well as software developers. However there are a few subtexts that overlap with the function of BIM. Succar (2009) has indicated the connotations associated to BIM as follows:

	meaningful,	to **virtually construct** a	
	actionable	to **extend the analysis** of a	
Modelling	**Information**	to **explore the possibilities** of	**Building**
shaping	*an organised*	to **study what-if scenarios** for a	*a structure*
forming	*set of data*	to **detect possible collisions** within a	*an enclosed space*
presenting		to **calculate construction costs** of	*a constructed*
scoping		to **analyses constructability** of a	*environment*
		to **plan the deconstruction** of a	
		to **manage and maintain** a	

Figure 1: Some Common Connotations Associated to BIM

Succar (2009) has further addressed BIM as "a set of interacting policies, processes and technologies generating a methodology to manage the essential building design and project data in digital format throughout the building's life-cycle." However, Thomassen (2011) in tackling this matter has clarified that BIM is not just a type of software, but a process to generate and manage a building data that encourages the collaborative effort between the interdisciplinary design team in 3-dimensional (3D), compared to 2-dimensional (2D) that has been used in the past. Furthermore, BIM has the ability to incorporate the 4th and 5th dimension and even up to the 6th dimension; construction scheduling, or time (4D), the component pricing and budgeting, or cost (5D),and the sustainability aspect and life-cycle facility management (6D) (Thomassen, 2011; WCEC, 2011). Philosophically, BIM, it is proposed, is a "collaborative work" or "collaborative effort" that utilised a set of tools to combine and manage the data between the design disciplines in 3D or beyond.

• Levels in BIM

According to WCEC (2011), there are three (3) levels for BIM, and that the "majority" of BIM users are currently using level 1. The characteristic of every level is described in Table 1.

Table 1: Levels of Details (LOD) in BIM (WCEC, 2011)

Level	Characteristic	BIM
0	Unmanaged CAD, in 2D, with paper (or electronic paper) data exchange.	No
1	Managed CAD in 2D or 3D format with a collaborative tool providing a common data environment (CDE) with a standardised approach to data structure and format. Information content at level 1 is created by using standardised approaches to data structures (CAD standards), and stored in standard formats that can be exchanged among different CAD applications.	Yes
2	A managed 3D environment held in separate discipline 'BIM' tools with data attached. BIM Level 2 represents a managed BIM environment that contains intelligent BIM models held in separate disciplines (discipline models), shared and coordinated using a structured approach on a CDE and integrated using proprietary or bespoke middleware software for design (e.g. Architectural structural etc.), analysis (e.g. Energy analysis, clash detection), project management (e.g. 4D, 5D) and maintenance purposes.	Yes
3	Level 3 BIM represents fully integrated and collaborative BIM enabled by web services to collaborative building information using open standards (such as Industry Foundation Classes) without interoperability issues and extending BIM applications towards lifecycle management of building projects. .	Yes

• Dimensions in BIM

The following section explains how the 3D model is utilised in BIM and integration by three (3) design disciplines.

• The 3rd Dimension (3D)

The main difference between 3D of BIM and the conventional 3D Computer Aided Design (CAD) is that the latter describes the building in independent 3D views such as plans, sections and elevations which required vetting to the whole documents when one of the views is edited, whereby BIM models utilised 'intelligent contextual semantic' where objects are defined in elements such as spaces, walls, beams and columns (Azhar et. al., 2008).

• The 4th Dimension (4D)

The 4th Dimension or 4D is achieved when the BIM 3D data is linked to the programme management that enables the users to visualise the whole construction process and analyse in detail the phasing requirements of the project. The owner or client benefits from the visualisation of the process, and the contractor gain benefit from the management and hazard prevention. Effective management via 4D BIM can also help in visualising clash detection before it happens, thus saving money and time on site (WCEC, 2011).

• The 5th Dimension (5D)

The 5D BIM comes to light when the concept of quantity and cost plan is linked to the BIM data set; where the take-off and quantification is done automatically from a BIM model, linked to costing data and thereof creates a dynamic cost plan. (WCEC, 2011).

• The 6th Dimension (6D)

The linking of the facilities management (FM) and life-cycle costing (LCC) to BIM data is called 6D BIM. The FM processes is integrated with the use of BIM models and data thus provide a significant financial savings and improving maintenance in long-run operation (WCEC, 2011). BIM implementation in the operation of buildings gives rise to several capabilities and challenges. As stated by several scholars (Akcamete et al., 2010; Becerik-Gerber et al. 2011) employing BIM in FM seems to provide significant possible support, e.g. as invaluable 'as-built' (heritage) records (Eastman et al. 2011), recording warranty and service documents (Arayici 2008; Becerik-Gerber et al. 2011; Singh et. al., 2011), quality control (Akinci et al. 2006; Boukamp & Akinci, 2007), assessment and monitoring (Arayici 2008; Bryde et al., 2013; Eastman et al. 2011), space and energy management (Becerik-Gerber et al. 2011; Cho et. al, Alaskar & Bode 2010), emergency management (Arayici, 2008) or retrofit plans (Arayici 2008; Mill et al., 2013).

• The 7th Dimension (7D)

Incorporating sustainability components to the BIM model generates 7D models, which enable designers to meet carbon targets for specific elements of the project and validate the design decisions accordingly or test and compare different options (Hardin, 2009).

The 6th & 7th dimensions of BIM are yet evolving and so as their understanding. Some authors have argued that BIM can unlock any number of dimensions, calling it nD modelling, indicating that the applications of BIM model are numerous and can achieve any number of dimensions in future (Aouad et al.,2005 and Fu et al., 2006).

• Purposes of BIM

A fully coordinated and functional BIM model can be used for a number of applications in the all phases of a project life cycle. It is important to note that the BIM uses and applications depend on the nature of project, work environment and technical maturity of project participants. However, the overall objective of BIM use remains same which is to create a shared pool of data to increase collaboration among all project stakeholders, and as a result, achieve better project results.

According to Azhar et al. (2008), BIM can be utilised for various purposes such as visualisation, fabrication/shop drawing, code reviews, etc. as shown in Table 2.

Table 2: Purposes of BIM (Azhar et al., 2008)

Visualisation	3D renderings can be easily generated in-house with little additional effort.
Fabrication/Shop Drawings	It is easy to generate shop drawings for various building systems, e.g., the sheet metal ductwork shop drawing can be quickly produced once the model is complete.
Code Reviews	Fire departments and other officials may use these models for building projects review.
Forensic Analysis	A building information model can easily be adapted to graphically illustrate potential failures, leaks, evacuation plans, etc.
Facilities Management	Facilities management departments can use BIM for renovations, space planning, and maintenance operations.
Cost Estimating	BIM software(s) have built-in cost estimating features. Material quantities are automatically extracted and changed when any changes are made in the model.
Construction Sequencing	A building information model can be effectively used to create material ordering, fabrication, and delivery schedules for all building components.
Conflict, Interference and Collision Detection	Because BIM models are created, to scale, in 3D space, all major systems can be visually checked for interferences. For example this process can verify that piping does not intersect with steel beams, ducts or walls (as shown in Figure 5).

• BIM and Project Management

Eastman et al. (2011) in relating BIM with project management has contended the idea that BIM may fit into the project management framework i.e. Integrated Project Delivery (IPD) that will increase the need for closer collaboration and more effective communication; and this tallies with the philosophy of BIM which is collaborative working between all the stakeholders of a project. The inter-organisation way of working in BIM will help to produce better circumstances in a construction project. Allison (2010) and Bryde et al. (2013) have outlined the potential benefits of using BIM for project managers (see Table 3).

Table 3: Potential Benefit of Using BIM for Project Managers (Bryde et al., 2013)

Potential benefits for PMs	Why?
Organize the project schedule and budget	An integrated 5D BIM model immediately updates both the schedule and budget when any design change occurs.
Work well with the Design Team	By using the integrated BIM model to visualize and explore the impact of changes, PM can keep project scope in check and become a trustworthy liaison between the designers and Owner.

Hiring and controlling the Subcontractors	Having a handle on clash detection and coordination plays a key role in keeping Sub-contractor's work predictable.
Requests For Information (RFIs) and Change Orders	Utilizing Coordination Resolution in preconstruction, these numbers can be brought to near zero.
Optimize the Owner's experience and satisfaction	Owner can receive a big injection of confidence in design and construction through visualisation and simulation of how design decisions can impact cost and schedule information.
Project closeout	PM to present a 6D BIM – an as built model incorporating facility resource with information on warranties, specifications, maintenance schedules, and other valuable information.
Profit margin	By thoroughly understanding the project in 5D, the PM has more tools at his disposal to keep tight reins, and more reports to monitor progress.
Progressive Owners are mandating BIM on their projects	Becoming the BIM expert, in both preconstruction and out in the field, makes the PM invaluable and a key player.
PM Firm Growth	Project's success with BIM means the opportunity to grow the firm's reputation and helps the corporate team win new business.

In addition, Bryde et al. (2013) has further analysed the relationship between PMBOK Knowledge Areas and success criteria for projects that used BIM to measure the positive and negative benefits of BIM throughout the world. The subsequent table shows the result obtained from the 35 projects that utilised BIM (see Table 4). The result shows that there are many positive benefits of BIM to construction projects. Without overlooking the fact that there are many areas to be improved, it is proper to signify that BIM has contributed to the success in terms of cost-time reduction, communication-coordination improvement and quality control.

Table 4: The Success Criteria Ranking of BIM Use (Bryde et al., 2013)

	Positive benefits			**Negative benefits**		
Success criterion	**Total instances**	**Total number of projects**	**% of total projects**	**Total instances**	**Total number of projects**	**% of total projects**
Cost reduction or control	29	21	60.00	3	2	5.71
Time reduction or control	17	12	34.29	4	3	8.57
Communication improvement	15	13	37.14	0	0	0.00
Coordination improvement	14	12	34.29	7	3	8.57
Quality increase or control	13	12	34.29	0	0	0.00
Negative risk reduction	8	6	17.14	2	1	2.86
Scope clarification	3	3	8.57	0	0	0.00
Organisation improvement	2	2	5.71	2	2	5.71
Software issues	0	0	0.00	9	7	20.00

3. BIM, PROJECT LIFE CYCLE COST AND SUSTAINABILITY

Early texts such as Wubbenhorst (1986) divided the life cycle of a project into five phases, namely initiation, planning, realisation, operation and disposal. This is parallel with the definition by Kehily et al. (2012) in quoting BSI (2008) in differentiating Whole Life Cycle Cost (WLCC) and LCC.

Labuschagne et al. (2012) has put down the definition of process asset systems in the Figure 2. Other scholars may perceive the “project life cycle” to be different from what has been defined in this paper. The concept of Life Cycle Cost or LCC can be traced back to the early 1930s when the Comptroller General of the General Accounting Office stated that the cost of maintaining and operating of equipment to be taken into primary consideration beside the price of acceptance and rejection of bids (Wubbenhorst, 1986).

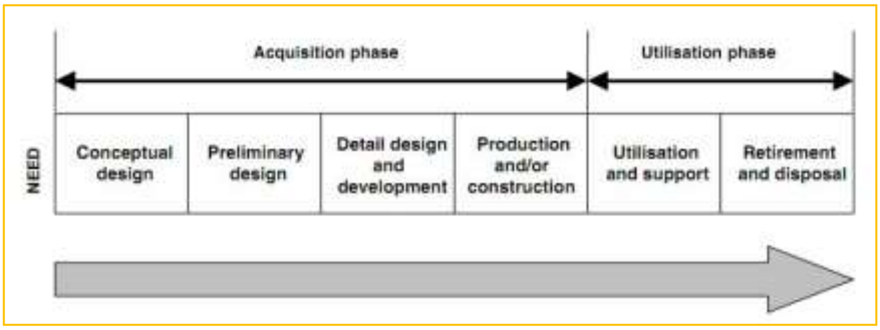

Figure 2: Life Cycle Phases of Process Asset Systems (Labuschagne et al., 2012)

Woodward (1997) in quoting White et al. (1976) has defined LCC as: “The life cycle cost of an item is the sum of all funds expended in support of the item from its conception and fabrication through its operation to the end of its useful life.” LCC is subjected to predicting when elements of the building and its services will deteriorate to a condition where intervention is needed, and what the discounted cost of each intervention will be. Thus, LCC calculations depend on numerous assumptions subjected to a degree of uncertainty (Kehily et al., 2012). BIM comes into view as a tool that requires the life cycle data to be assembled to facilitate appropriate virtual prototyping in assisting the correct specification choice prior to construction (Whyte et al., 2010). BIM has the ability to provide cost estimation with the 3D model, and can be used to incorporate the Life Cycle Cost. Kehily et al. (2013) has indicated that BIM can be used to incorporate time model (4D) and cost model (5D). And although there are several limitations in incorporating LCC data in the existing BIM software, external software such as CostX, CostOS and BuildSoft can be used to integrate the LCC job specifics (Kehily et al., 2013). This is analogous to the concept of sustainability where during the design and preconstruction stages of a building, the most significant decisions regarding sustainable design features can be made (Azhar et al. 2011). Dowsett et al. (2013) in citing Krygiel and Nies (2008) stated that BIM may address these areas in terms of sustainability as shown in Table 5.

Table 5: BIM and the Area of Sustainability

Building orientation	Selecting a good orientation can reduce energy costs
Building massing	To analyse building form and optimize the building envelope
Day-lighting analysis	Reduce lighting loads, and reduce cooling loads.
Water harvesting	Reducing water needs in a building
Energy modelling	Reducing energy needs and analysing renewable energy options can contribute to low energy costs
Sustainable materials	Reducing material needs and using recycled materials
Site and logistics management	To reduce waste and carbon footprints

Wong et al. (2013) summarised that there are two main components of BIM and sustainability; Integrated Project Delivery (IPD) and design optimisation. Although the notion of sustainable project has a long history, consideration of the implications of BIM in this field is very recent. During the last few years, a large number of researchers have studied capabilities of BIM in supporting tools and processes on sustainable projects which in this paper were categorized according to the key stages of building development as follows.

- **Planning and design phases:**

As stated by (Azhar et al. 2011; Azhar et al. 2008; Liu et al. 2011), the planning and design stage is the point at which the most basic sustainability, energy use and environmental decisions are made. It is no arguable that informed and accurate design decisions that are made as early as possible can aid development of a sustainable design to be more efficient and cost-effective. For instance, based on BIM analysis tools, quickly evaluating various design choices and selecting greener designs the design team can make better-informed decisions (Bynum et al., 2012). These analyses aid planners to understand the performance of their designs on the environmental issues and efficiency of a building and its occupants.

In the traditional design platform, the designers and project stakeholders had much less efficiency on the early design decisions due to visualization difficulties. Azhar (2011) studied about large number of US design and construction practitioners approach in regard to the sustainability criteria of BIM and concluded that BIM provides 'some-to-significant' cost and time savings comparing to the traditional platform.

The possibility of employing computational assessment tools to calculate actual environmental performance of buildings has been recognized only since the late 1990s (Curwell et al. 1999). Over the past few years, technological development and widespread use of BIM has led applications of BIM for providing more sustainable design decisions. For instance, Inyim et al., (2014) developed 'SimulEICon' as a BIM-extended tool that enables decision-making regarding sustainability in the early phase of design phase. 'Evolutionary Energy Performance Feedback for Design' (EEPFD) developed by Lin and Gerber (2014) comments on energy performance at the design stage by means of several iterations and provides performance feedback via effective parameters, automation and multi-objective optimization.

A study by Krygiel and Nies (2008) identified the ways that BIM applications can support sustainable building at the planning and design phases. They categorized these supports into seven area of:

1. building orientation assessment (selecting an proper orientation that can minimize energy consumption);
2. analysing form of building and optimizing the building's envelope in terms of equivalent transparency ratio;
3. daylight analysis;
4. assessing water harvesting to reduce water requirements in a building;
5. modelling energy performance in order to minimize energy needs or analyzing options for renewable energies that contribute to low energy cost;
6. examining sustainable material requirement and possibility of recycled materials replacement; and
7. reducing wastes and carbon footprints by proper site designing and logistics management.

In the recent years, ability of the BIM to provide rating for sustainable building systems has been studied. Biswas et al., (2008) introduced a tool implementing BIM technology to evaluate environmental consequences of design decisions. This study is one of the earliest attempts to integrate BIM with the certification and rating of sustainable buildings. Barnes and Castro-Lacouture (2009) suggested that Autodesk Revit BIM tool can directly assess 13 credits and 1 prerequisite of the LEED rating system. In another study, (Azhar 2011; Azhar et al., 2010) also found that adopting BIM applications can assess 17 credits and 2 prerequisites in the LEED.

In addition, some of the commercial software from Autodesk Company (Revit Conceptual Energy Analysis) have been designed to assist designers in exporting their conceptual designs to analyzable energy models for facilitating an integrated whole-building energy assessment. Furthermore, daylight and solar access analyzing tools are developed to help the complicated design process of sustainable projects. Furthermore, by means of these automated tools, the drudgery of calculating material quantity takeoffs is tackled (Wong & Zhou 2015).

- **Construction phase:**

The low carbon emission in the construction process and clean and sustainable workspace are among the main concerns of the industry. Energy consumption at the construction stage is as significant as the value of it at the operation stage. As a result, a large number of studies have concentrated on low-cost and practical methods for monitoring construction-related emissions (Wong et al. 2013). A tool developed by Artenian et al., (2010), integrated BIM and a geographic information system (GIS) technology to identify optimum routes for concrete mixer trucks and decrease emissions risen from excessive procedures. In a more comprehensive view, a BIM supported tool developed by Wong et al. (2013) calculates and provides visual presentation of emitted carbon value from the construction process. Martinez and Ioannou (1999) used discrete-event simulation (DES) modeling for complex operations in construction which provides emission estimations of equipment as the output. A framework established by (Peña–Mora et al. 2009) provides planners with different options on low-emission strategies for construction.

- **Operation phase:**

Energy consumption at the operational stage of buildings is valued as the highest among the other phases of project life-cycle which is nearly one-third of the global carbon emissions of buildings (Wong & Zhou 2015). According to US statistics, 40% of primary energy consumption and 20% of the national CO2 budget release are mainly used for heating and/or cooling commercial and residential buildings (Costa et al. 2013). Several applications of BIM are identified to support sustainability notion at this phase which could be categorized into the followings: heating and cooling requirement analysis; daylighting analysis to optimize electrical lighting value as well as energy load for heating; and building equipment assessment of energy consumption (Tzivanidis et al., 2011). BIM tools such as Autodesk Green Building Studio contain the very recent cloud computing technology to analyze energy consumption of buildings. By means of this software values of total energy consumption and carbon emission can be determined and possibilities for implementing renewable energy are assessed.

BIM applications in the area of FM has constructive supports in terms of efficient property operation, customer service quality, minimizing number of emergencies of the operating buildings, safety measures and waste management (Costa et al. 2013; Liao, Tan and Li 2012). The idea of sustainable buildings could be achieved by making use of all these benefits. It is expected by developers and investor to have BIM support on energy efficient and sustainable properties.

- **Maintenance and repair phase:**

For a structure that has spent its practical life, modification and retrofitting of the building in terms of lower energy usage, healthier and safer environment can be the main concerns of the sustainability approaches (Hammond et al., 2014). Meanwhile, it’s a prime concern for owners of existing properties to enhance energy efficiency as well as lowering the operational costs, minimizing environmental effects and improving resiliency of the property.

BIM applications in the sustainable maintenance of buildings have been practiced by Motawa and Almarshad (2013) through integrating BIM as a database capable of sharing data and a case-based reasoning (CBR) module that investigates rational relationships among the components. This integrated tool can aid facility management process by means of analyzing the past experiences and records of the different components of a property.

A study by Wong and Lau (2013) analysed overshadowing of a building in an over-populated region which was surrounded by several tall buildings. Their study which was supported by BIM applications, simulated orientations and proximities to neighbouring tall buildings in order to determine areas of roof that are not under shadow. Hammond et al., (2014) developed a framework for sustainable retrofitting along with best industry practices. In this study BIM has been used as the main tool to achieve a sustainable design for renovation of existing properties.

- **Demolition phase:**

The large number of existing building gives rise to concerns regarding their demolition due to the non-practicality of repair process which could create devastating environmental effects. In developed cities like Hong Kong several attempts are made to tackle this problem such as obligatory waste categorization program and disposal charge program (Cheng & Ma, 2012). BIM applications in the demolition phase are very limited and are concentrated on quantity of the produced waste and recyclable materials, deconstruction process and waste management process. In a study by a general contractor community in US, a BIM application employed for calculating volume of waste materials and identify their type (Wong & Zhou 2015). In a similar study, Cheng and Ma (2013) presented BIM supported tool that extracts very detailed estimations of wastes and provides number of delivery times required by trucks to collect the wastes as well as the charge of disposal. Akbarnezhad et al., (2014) developed a model by means of BIM application that analyses several possibilities of building deconstruction in regard to their environmental impacts and economic costs.

4. CONCLUSIONS

United Arab Emirates (UAE) is as a fast growing country with the architecture, engineering and construction (AEC) as a significant sector, it is therefore vital to examine Building Information Modelling or BIM as a tool of delivery and sustainability. With UAE construction sector is expected to grow by 9.3 percent in 2015, with the value of investment forecasted to be around AED 155 billion (quoted from ameinfo.com) it is important to ensure that the development of large and mega-scale infrastructure go smoothly. BIM has proven to aid the AEC sector in terms of decreasing the cost, reduce the delivery time, and increase efficiency and quality of the project. However, apart from that, BIM has potential to be used at all stages of the project life-cycle where it can be used by the client to understand the needs of the project; by the consultants to analyse, design and develop the project; by the contractor to manage the construction processes; and by the facility manager during the operation and decommissioning phases (Grilo et al., 2010; Bryde et al., 2013). The correct usage of BIM throughout these stages will realise the true potential of BIM in terms of coordination and communication thus mitigating any potential risk and producing the best output from a construction project.

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Using Intelligent Case-Based Reasoning (CBR) for Parametric Cost Estimating in Construction

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Abstract: *Estimating project cost can be fairly challenging during the project's early stages due to the limited job information and details. This type of estimates, which are typically called parametric cost estimates, embarks on historical records and expert judgment to perform the costing function. Over the past two decades, attempts have been made to use artificial intelligence (AI) technologies, such as neural networks, for such purpose with varying levels of success. The paper investigates the suitability of another contemporary and innovative AI technique known as Case-based Reasoning (CBR) for the same. CBR can search an existing database/library of past projects for the most relevant cases and perform the costing of a new job based on the most relevant project cases. Study exemplifies this innovative approach in highway construction projects in Egypt. For implementation, 23 drivers of project cost have been identified, based on literature review and unstructured interviews with subject matter experts in Egypt. Data pertinent to these cost drivers for 36 highway projects was collected and used for constructing the CBR case library. The retrieval and adaptation approaches are employed to extract useful knowledge embedded in the case library and then use for estimating the cost of a new highway project. Automation of the retrieval and adaptation process was done through the software CBR Works™ version 4.0. CBR shows promise in estimating the costs of tested cases. Paper concludes with comments on the parametric cost estimating function and recommendations on the usage of innovative approaches such as CBR in performing it.*

Keywords: artificial intelligence (AI), case-based reasoning (CBR), cost management, estimating.

1. INTRODUCTION

Costing is one of the most critical functions undertaken by project participants. Interestingly, project costing can be more challenging at the early project stages than later when more substantial information is available. The difficulty in performing the costing function at such an early stage may be attributed to the lack of documentation and historical records for completed projects, the lack of proven cost estimating methods that suit the early project stage context, among others.

Efforts by academics and practitioners have been made over the last two or three decades to address the need for a reasonably reliable cost estimating process at a project's early stages. Such efforts were primarily directed to: (a) establishing means to improve the quality of information and (b) establishing comprehensive analytical approaches that can help with the project cost estimating process. One example of an early attempt to improve the quality of information in the industry is the World Bank's development of a comprehensive highway project database in developing countries via its Transport Unit, which yielded the so-called Road Costs Knowledge System (ROCKS). This knowledge system has been used to estimate and benchmark cost of highway and road projects funded by this major international entity (World Bank, 2002; Sodikov, 2005). Researchers, on the other hand, were adept to address the second need. Many studies have attempted to devise approaches and suggest techniques that may help perform such an important project management function. These studies were quite diverse in terms of the routes they pursued, ranging from conventional statistical methods to the more sophisticated artificial intelligence (AI) methods (Georgy and Barsoum, 2005; Hegazy and Ayed, 1998; Sonmez, 2005). With these different techniques in place, the question of which one is most suitable still raises a lot of discussion.

This paper reports on a study set out by the authors to investigate the use of a relatively new AI technique, called case-based reasoning (CBR), to facilitate the cost estimating process at the early project stages. Unlike some of the other techniques previously presented in the literature for such purpose, CBR resembles the reasoning process carried out by practitioners when performing the same cost estimating function. However, CBR provides a solid theoretical basis that enables a more systematic process to take place as detailed later in the paper. Following a brief literature review, the paper will introduce CBR and its underlying principles. Afterwards, the application in the Egyptian highway sector is presented. The paper concludes with comments on the costing function and the potential of CBR in that respect.

2. LITERATURE REVIEW

Estimators are usually under pressure to produce accurate estimates (Artidi et al., 2002). On the other hand, the construction industry still needs better means to support the cost estimating process. Akintoye and Fitzgerald (2000) and Artidi (2002) reported on a market analysis of the UK construction industry that illustrated such need. While study was conducted several years ago, significant research is undertaken till this very day to address the cost estimating process and the facilities that can help in that respect, which implies that the need has not faded.

Uher (1996) and Popescu (2003) highlighted the necessity of relevant historical project data to estimating costs of future projects. Unfortunately, a major challenge of conceptual/parametric cost estimating is the lack of reliable information of past projects (Chou and O'Connor, 2007). As such, Chou and O'Connor (2007) attempted to develop a database of highway projects using data from the Texas Department of Transportation (TxDOT). Further, a facility that uses statistical techniques was created to utilize the database for estimating costs of future projects. The use of statistical methods has been preferred by several other researchers as well. For instance, Lowe et al. (2007) used multiple regression techniques for estimating the cost of building in the UK. Sonmez (2008) also attempted statistical regression for the same purpose. In addition, Mahamid (2011) tried to use statistical regression for estimating the cost of road projects in Saudi Arabia.

AI techniques, particularly neural networks, also proved to be viable candidates for performing the parametric cost estimating function. An early application was undertaken by Hegazy and Ayed (1998) for estimating the cost of highway projects using neural networks. The cost of steel buildings was estimated using neural network models by Moselhi and Siqueira (1998). In line with the other studies, Adeli and Wu (1998) advised of the use of regularization neural networks for cost estimating to reduce the effect of network architecture on the quality of the estimate. Later, Georgy and Barsoum (2005) applied neural networks for the cost estimating of educational building projects in Egypt. Also, Petroutsatou (2012) employed neural networks for estimating the cost of road tunnel projects while accounting for underground and site conditions. Shehab and Farooq (2013) used the same AI technique to estimate the cost of rehabilitating underground water and sewer utilities. Further, Elbeltagi and Hosny (2014) undertook conceptual cost estimating of Libyan highway projects using neural networks. Besides neural networks, other AI techniques were used such as fuzzy logic (Mason and Kahn, 1997). A different approach was pursued by Petroutsatou and Lambropoulos (2010) that employed a structural equation model for estimating the cost of road tunnels. In the latter study, the authors reported better results than statistical regression models and neural networks.

Newer AI techniques such as CBR were also suggested in the literature for the purpose of estimating project costs (Kim et al., 2004). Kim et al. (2004) especially pointed out that CBR may provide better value than neural networks when it comes to long-time use and also its ability to explain the results. In practical terms, Georgy (2006) used CBR for estimating the cost of girder bridges, Marzouk and Ahmed (2011) employed in pump station projects, whereas Kim (2011) used it for railway bridge projects. Kim (2011) further pointed out that the performance of CBR in cost estimating can even be improved by incorporating the capabilities of genetic algorithms (GAs).

3. METHOD: CASE-BASED REASONING (CBR)

CBR is a fairly new sub branch of AI. CBR simply employs past experience of similar/comparable problems in current problem solving (Richter and Weber, 2013; Shi, 2011; Watson 1997). This computational technique recognizes that humans often solve a new problem by comparing it with similar ones that they had already resolved or encountered in the past. The underlying principle is that human reasoning that is founded on past experiences can and should form the basis for decision made in future.

3.1. Case library

The term “case library”, also known as “case base”, is used to describe a collection of cases pertaining to a particular domain (Georgy 2006; Richter and Weber, 2013; Shi, 2011; Watson 1997). Cases in a case library resemble records in a conventional database. Each case in the case library is typically identified through a set of attributes. To exemplify, projects executed by a road/highway contractor could form a case library, where cases i.e. projects are defined through attributes such as, type of road/highway, length of road/highway, contract type, completion year, contract value, distance to asphalt mixer, and so forth.

3.2. How CBR retrieves information from a case library

To properly utilize the information in a case library, systematic procedures can be employed through techniques such as CBR. Georgy (2006) reported that unlike other AI techniques such as expert systems, CBR searches the existing case library to retrieve useful case information and use this information to solve a new problem even if no exact or closely-matching cases exist. Indeed, the retrieval process in CBR greatly differs from that of conventional databases. In conventional databases, an exact matching of queried information is essential. CBR capabilities are much broader, as a CBR system retrieves the “most similar” case or a set of cases which represent prospective solution(s). According to Watson (1997), two techniques are typically used for retrieval; they are the nearest neighbor (NN) and the inductive retrieval techniques. As the NN technique is more commonly used in practice, further details are given hereinafter.

First, consider the two attributes “length” and “contract type” which may pertain to any given highway project. Now assume that two projects (or project segments) were undertaken in the past, where the two identified attributes have the values of “11 KM” and “cost plus” for the first project, and the values of “7 KM” and “unit price” for the second one, as illustrated in Figure 1. Further assume that a new highway segment, to be constructed in the near future, has expected values of “10 KM” and “lump sum” corresponding to the two identified attributes. Apparently, this new project (called the target case) is no exact match for the existing projects (called the source cases). However, there is a certain degree of similarity/dissimilarity between the source and target cases. The distance (Δ), shown in Figure 1, signifies how similar/dissimilar the cases are to each other (Watson, 1997).

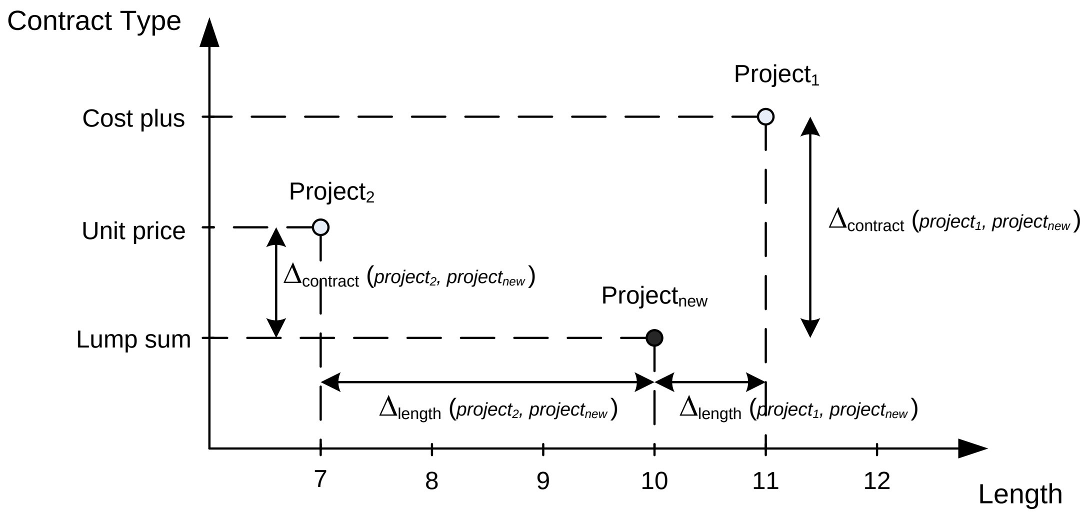

Figure 1: Illustration of the Nearest Neighbour Algorithm

The x-distances between the source cases, $Project_1$ and $Project_2$, and the target case, $Project_{new}$, would be:

Δlength ($project_1$, $project_{new}$) = 1 units (KM)
(1a)

Δlength ($project_2$, $project_{new}$) = 3 units (KM)
(1b)

Similarly, the y-distances between the source cases, $project_1$ and $project_2$, and the target case, $project_{new}$, would be:

Δcontract ($project_1$, $project_{new}$) = 2 units
(2a)

Δcontract ($project_2$, $project_{new}$) = 1 unit
(2b)

Amongst the two projects, whichever source case gives the smaller distance values is the nearest neighbor to the target case. The distances between cases can simply be given by (Watson, 1997):

$$\Delta = w_x * \Delta x + w_y * \Delta y \quad (3)$$

In the example above, this translates into:

$$\Delta\ (project_i, project_{new}) = w_{length} * \Delta length + w_{contract} * \Delta contract \quad (4)$$

where w_{length} is the weight of attribute "length" and $w_{contract}$ is the weight of attribute "contract type". If ratio between $w_{contract}$ and w_{length} is taken as 3:2, then the calculated distance between the target case, $project_{new}$, and the source cases, $project_1$ and $project_2$, would be 8 and 9, respectively. This indicates that $project_1$ is technically a nearer neighbor to $project_{new}$ than $project_2$.

The previous example demonstrated the basic idea behind the NN algorithm. However, in more generic terms, the level of similarity/relevancy/proximity in the NN technique is given by the simple equation (Watson, 1997):

$$\text{Similarity index (T,S)} = \frac{\sum_{i=1}^{n} f(T_i, S_i) * w_i}{\sum_{i=1}^{n} w_i} \tag{5}$$

where T is the target case, S is the source case, i is the attributes defining the cases, as i = 1, 2, …, n, f is the similarity function for attribute i in cases T and S, and w_i is the importance weighting of attribute i. There are several means to define the similarity function depending on the type of attribute. Further details about rules for defining similarities will follow in the next section of this paper. Usually, similarities are normalized to fall within a range of 0 to 1 (where 0 is totally dissimilar and 1 is an exact match).

4. ILLUSTRATION IN THE HIGHWAY SECTOR AND RESULTS

Three steps are fundamental to the use of CBR in cost estimating; they are: (1) identification of the cost drivers for the type of projects under study, (2) construction of the case library that encompasses information of all relevant cost drivers, (3) applying the principles of CBR to estimate the cost for new projects or projects that are not present in the case library.

4.1. Cost drivers

A prerequisite to constructing a case library for highway projects is to identify which attributes typically govern the cost of this type of projects. Apparently, to use these attributes, called hereinafter the cost drivers, in cost estimating at the early project stages, they should typically be attainable at such an early stage.

Meshref (2008) conducted a comprehensive study to identify the cost drivers of highway projects in Egypt. The earlier study was based on a broad review of the salient literature, 20 semi-structured interviews with subject matter experts in Egypt, in addition to a questionnaire survey disseminated to client organizations, highway/road contractors and engineering consultants. A total of 23 highway attributes, Table 1, were found to drive the cost of projects in this sector. This forms the basis for the development of the case library and the subsequent application of CBR principles. As seen in Table 1, the cost drivers are either linguistic or numeric in nature. This is an important aspect to clarify for the next steps of the CBR application.

Table 1: Cost Drivers of Highway Projects in Egypt (Meshref, 2008)

#	Cost Driver	Classification
1	Project type	Linguistic
2	Project scope	Linguistic
3	Year	Numerical
4	Location	Linguistic
5	Project duration	Numerical
6	Guarantee period	Numerical
7	Weather conditions	Linguistic
8	Water body	Linguistic
9	Soil conditions	Linguistic
10	Site conditions	Linguistic
11	Traffic conditions	Linguistic
12	Distance to dumping area	Numerical
13	Topographic conditions	Linguistic
14	Quantity of earthwork	Numerical
15	Base material type	Linguistic
16	Length of the highway	Numerical
17	Width of the highway	Numerical
18	Method statement complexity	Linguistic
19	Method of delivery	Linguistic
20	Type of contract	Linguistic
21	Material availability	Linguistic
22	Fuel/diesel price	Numerical
23	Bitumen price	Numerical

4.2. Construction of the case library

The lack of documentation can be a real obstacle to collecting project information necessary to construct the sought case library. However, a comprehensive effort was made to get information on highway construction projects or project segments in Egypt. Despite the challenges, being clear about the cost drivers, i.e. which project attributes to pursue, greatly helped in guiding the effort. As Table 1 reveals, the information required is quite diverse and represents an array of administrative/managerial and also technical information. As such, different parties of each highway project were consulted including, clients, engineering consultants and contractors. The clients and consultants provided information relevant to the managerial/administrative, geometric, and design-related aspects, whereas contractors were the prime sources of construction-related information.

Complete record for 36 highway construction projects or project segments resulted out of the aforementioned effort. It is not uncommon to retain 20% of the cases for testing and validation purposes (Sodikov, 2005). Therefore, a total of 6 project cases were kept for such purpose, while the remaining 30 cases were used to construct the case library as explained in the next section.

4.3. Applying CBR for cost estimating

As per the common CBR terminology, the cost drivers of highway projects will constitute the input attributes of each case while the cost itself will represent the output attribute of the case. Georgy (2006) informed that the input and output attributes of cases in a given case library can generally be classified into three groups: (1) quantitatively measureable/assessable attributes, (2) descriptive attributes with implied logical relationships, and (3) descriptive attributes with no logical relationships. Following to the classification, the similarity between the possible values that an attribute may take should be estimated.

The first group comprises the attributes that can be numerically represented, such as, length of the highway, project duration, etc. The cases (i.e. projects) in the case library had lengths varying between 0 and 100KM. Being a quantifiably measurable attribute, either a linear or an exponential conversion function can be used (Georgy, 2006). This function relates the various possible values of the "length of the highway" attribute, i.e. 0-100KM, to a 0-1 scale. Figure 2 illustrates this function used in this study to depict the similarity for the "length of the highway" attribute.

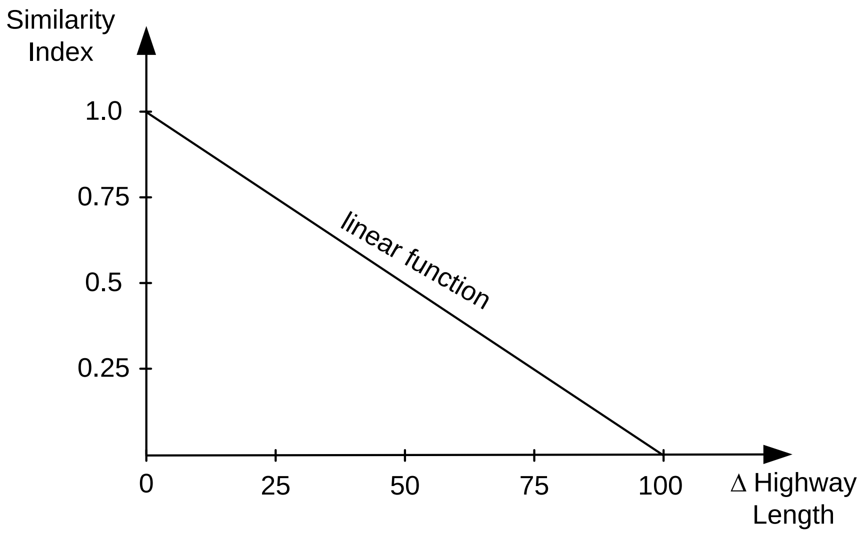

Figure 2: Linear Conversion Function for Attribute "Length of the Highway"

The second group is probably the most challenging to depict. This group requires more sophisticated means to model the relationship between each attribute's possible qualitative values. Examples of this group include, soil conditions, topographical conditions, etc. This relationship, in CBR context, numerically identifies how close or how far the descriptive values are from each other. This is made possible through "taxonomy trees". Figure 3 demonstrates a simple taxonomy tree for the attribute "topographic conditions".

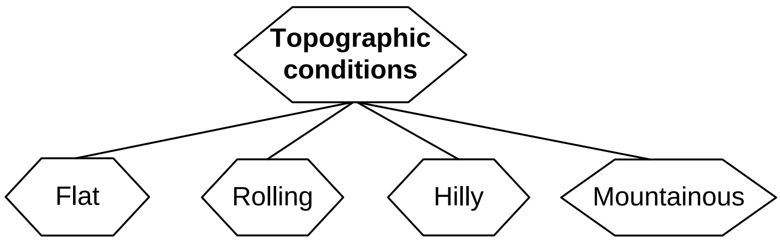

Figure 3: Taxonomy Tree for Attribute "Topographic Conditions"

Question is how to identify the similarity between these constituent values of any given attribute within the second group. The similarity, in this context, identifies how close or how far the two values are with regard to affecting the highway project cost. With no comprehensive knowledge recorded in the literature in Egypt regarding the relative cost effect of several of the attributes within this group, the knowledge had to be sought from industry practitioners. Several subject matter experts were surveyed to acquire such knowledge. Averages were taken and inserted in the matrix in Table 2. As noted in the table, the different values are listed both horizontally and vertically. Each cell within the matrix signifies how the two labels denoting the row and column compare to each other. Apparently the diagonal values are 1.0 since the comparison concerns the same two descriptive values. Meanwhile, when comparing the descriptive values "Rolling" and "Hilly", for example, a value of 0.845 can be found. This indicates a similarity of 0.845 (i.e. 84.5%) between these two specific descriptive values. Same process was followed for the other attributes within the second group.

Table 2: Similarity Matrix for Attribute "Topographic Conditions"

Topographic Conditions	Flat	Rolling	Hilly	Mountainous
Flat	1.0	0.83	0.475	0.255
Rolling	0.83	1.0	0.845	0.475
Hilly	0.475	0.845	1.0	0.755
Mountainous	0.255	0.475	0.755	1.0

The last group addresses descriptive features that do not have obvious or apparent relationship among the feature's possible qualitative values. Examples of this group include, contract type, weather conditions, etc. For this group, the possible values of each feature are treated as discrete points (Georgy, 2006). In other words, since no relationship between the values is recognized, similarity between these values is assumed to be zero. For instance, the attribute "weather conditions" may take values such as "hot", "rainy", and "dry". Herein, each of these values is considered discrete and no implied relationship is assumed.

With the similarity function identified for all 23 attributes, equation 5 can then be used to calculate the similarity between a target case and any of the source cases stored in the case library. The sources cases with a higher similarity index are better representatives of the target case and obviously the presumptive cost of that particular project. A weighted average can be used to estimate the cost of the target case where the similarity indexes are used as the weights used in the weighted averaging process.

4.4. Automation, results and discussion

A commercial CBR shell, named CBR Works™ version 4.0, was used to construct the case library, store highway cases, and run the different CBR similarity and retrieval mechanisms. Prior to constructing the case library, the various attribute types are defined in the CBR Works™ terminology. The identified types are:

(1) *Symbol*, which corresponds to descriptive attributes with no logical relationships.
(2) *Taxonomy symbol*, which corresponds to descriptive attributes with implied logical relationships.
(3) *Integer*, which corresponds to quantitatively measureable/assessable attributes that are represented using integer values.
(4) *Real*, which corresponds to quantitatively measureable/assessable attributes that are represented using real values.

As cited previously, 30 highway project cases were used to construct the case library while 6 more cases were kept for testing and validation purposes. For each test case, the similarity index was calculated for each of the source cases. Similarity indexes can technically range from 100%, which indicates a scenario of perfect match, down to 0%, which signifies zero similarity. One can argue that source cases with 30% or even 50% similarity will not be considered comparable to the test case; therefore a conscious decision was made to only consider cases with similarity indexes of 85% or more as useful sources for estimating the cost of the test case. In other words, 85% was considered the threshold value for accepting a source case as suitable for the cost estimating process. With the threshold in place, more than one source case can be used for making the estimate which prevents a scenario where only one case, i.e. the source case with the highest similarity index, is used.

For the pool of source cases that are found similar/relevant, i.e. exceeded the threshold of 85%, CBR Works™ allows 3 means of manipulating/adapting the results. This allows a better contextualization of the process. The three means are:

(1) *Null adaptation*, which depends on the most similar source case as the source for estimating the cost of the test case.
(2) *Weighted adaptation*, which calculates the weighted average of all cases that exceed the threshold value. The similarity indexes in this context represent the weights used to estimate the weighted average value.
(3) *Neuro-adaptation*, which employs neural network capabilities onto the sources cases to predict the cost of the test case. Further information on the capabilities of neural network can be found in Shi (2013).

When the 6 test cases were examined using CBR Works™, promising results were obtained, see Table 3. The least error percentage was particularly observed in the case of neuro-adaptation. However due to the limited number of test cases it is not possible to make a conclusive comment on which one is better than the others. Also, it is known that the neural network adaptation improves when the number of input/source cases increases (Hegazy and Ayed, 1998). Had a bigger pool of highway projects been available, a more comprehensive examination of the neuro-adaptation would have been possible. But as said before, the results are promising given the fact that, based on the rule of thumb approach, the parametric cost estimates may exhibit an error percentage of up to 30% (Ahuja et al., 1994).

Table 3: Percentage of Estimate Error for the 6 Test Cases Using the Three Adaptation Methods

Method	Test Case 1	Test Case 2	Test Case 3	Test Case 4	Test Case 5	Test Case 6	Average Error Percentage
Null	21%	33%	32%	8%	25%	23%	24%
Weighted	18%	38%	3%	35%	32%	3%	22%
Neuro	21%	3%	4%	9%	34%	15%	14%

5. CONCLUSIONS

Estimating costs is critical to managing construction projects. This applies to all project stages, including the conceptualization and initiation stage when the parametric cost estimates are typically carried out. The paper attempts to apply a relatively new AI technique called CBR whose process resembles the human reasoning made when making a cost estimate. Usually, one tries to draw on past experiences and tie predictions to similar cases in the past. This is technically what CBR does, while having a scientific basis for the process of identifying the similar cases in the past, measuring the similarity of each one of the cases and finally using such information to make a prediction for the new project.

When examined in the highway sector using a pool of 36 projects, the CBR technique showed promising results. While not presented in the paper, the research also investigated the use of more traditional techniques such as linear regression and also the more commonly used AI techniques such as neural networks to make predictions for the same test cases. CBR fared better than both. Given that CBR resembles in its processing the human reasoning activity and in addition provides promising results based on actual project information, it is useful to further investigate this technique and examine ways of adaptation that improve, in other words, reduce the resulting error of the estimates made.

As noted in the paper, the implementation of CBR requires creating a comprehensive case library. Predictions are made based on prior cases that are found to be relevant. This necessitates greater efforts in record keeping of completed projects. Construction companies working in sectors such as highways can implement such technique via capitalizing on the exiting and/or ongoing efforts to record past project data. Collaborative efforts to create industry-wide databases can further contribute to such goal. When benefits of approaches such as CBR are recognized by the different industry players, companies may find an incentive to take part so as to achieve long term benefits. However, one has to be reminded of the challenges that prevent good record keeping. But at least now, there are means to put these records, when made available, to a good use.

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Theme V

Legislation and assessment tools

Evaluating Green Pyramid Rating System: Potentialities & Revival

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Abstract: *Numerous attempts have been accumulated feverishly in last two decades to improve energy efficiency and to proclaim green city. Green Pyramid Rating System (GPRS) promoted by Egyptian Green Building Council (EGBC) is also such type endeavor to achieve energy efficiency as well as sustainability. Though most of the indicators of this corridor are developed to promote green building but it is widely possible to apply those indicators in terms of neighborhood. Again, without a whole neighborhood entity, it is challenging to establish something only for building. GPRS is quite promising though it is still like a new born baby as like its mother organization EGBC. This study discusses various dimensions of existing GPRS guideline and fosters some revival strategies to extend its acceptance.*

Using both primary (interviews, reconnaissance survey, observational survey etc.) and secondary (standards and certification guidelines, reviewed papers, journals etc.) survey, this study reflects on existing gaps or limitations of GPRS which portrays multiple errors in point calculation, policy inconsistency, lack of operational methodology, missing indicators related to economic efficiency and socio-political arena, absence of case specific example and so on which derive to the next stair of reviving it. Finally this study upholds a revised policy guideline blending indicators from ISO, CEN, OECD, ASTM, ANSI, ASHRAE, Green Globe 21, African Green City Index, LEED, BREEAM, DGNB and Pearl; integrating statement of purpose, calculation procedure, submission criteria, further reference etc. to brand it SMART, Visible, Applicable and comprehensive.

Keywords: Green Pyramid Rating System (GPRS), Green Neighborhood, Green City Index, Sustainability

1. INTRODUCTION

The Egyptian Green Building Council (EGBC) was established in January, 2009 consisting government ministers from Cabinet level agencies, officers from respected NGOs, prominent businessmen, seasoned labour leaders, major contractors etc. (EGBC, 2009). The primary motivation was to eliminate any stigma associated with green construction and instead, presented green construction as a financially logical and appropriate course of action that integrates important global and national concerns to produce viable sustainable products which meet the short term and long term needs of people. As an immediate action to activate the role of this council was the approval of developing a national Green Building Rating System called the Green Pyramid Rating System (GPRS), the council has commissioned to define the framework of a rating system and a national committee has been formed to review and ultimately approve the GPRS (EGBC, 2009). There are three levels for green building certification in accordance with the Egyptian GPRS: 1. Silver Pyramid, 2. Golden Pyramid and 3. Green Pyramid. Unlike other international rating systems, the highest level of certification is labelled “green” rather than platinum. To raise the awareness, it confirms that the ultimate goal is to reach at “green” level from the base. (EGBC, 2009).

Egyptian GPRS is a promising tool as it was the first drop of water in the desert to achieve sustainability. It is still fresh and desire to pass through lots of reviews. Still there is no available peer reviewed journal publication which has appraised the current GPRS system in the field of applicability, contents, methodology and so on. Evaluating the GPRS system, raised up multiple sets of issues like its applicability to the neighbourhood level, its scoring method with sophisticated indicators and methodology, its consistency with the other policy documents of Egypt, its operational methodology and significance to the planners, developers and policy makers and evidence based case specific spotlight. Through detailing all these aspects, this study articulates that the most of the indicators of GPRS are possible to apply for neighbourhood development, it is inconsistent with the policy reference, multiple errors or contradictions are existed in point calculation or operational methodology and absence of case specific example accelerates the backlog field which all lead to define a revised comprehensive framework reviewing International, regional & national standards like International Organization for Standardization (ISO), European Committee for Standardization (CEN), African Green City Index (AGCI), Leadership in Energy and Environmental Design (LEED), Deutsche Gesellschaft für Nachhaltiges Bauen (DGNB)-German Sustainable Building Council etc.

So, the purpose of this study is to focus on developing a revised GPRS guideline blending different national and international rating systems which will develop existing system more comprehensive in terms of its theoretical and operational methodology. It also attempts to portray some indications of applicability to rationalize the revised system better.

2. AIM AND OBJECTIVE

The aim of this research is to assess the limitations of GPRS and to develop a revised guideline blending different national, regional and international indicators. The specific objectives are:

- To find out the existing gap or limitations of GPRS system
- To develop a revised guideline with well-defined scoring system and operational methodology covering all the aspects of sustainability
- To portray some applicability issues of revised guideline

Table 1: Objective- Output Matrix (Author's own analysis, 2016)

Objectives	Research questions	Expected output
Objective 1: To find out the existing gap or limitations of GPRS system	**Question 1:** What are the existing gaps or limitations of GPRS?	Missing indicators, inconsistency with policy documents, absence of operational methodology & case specific example etc.
Objective 2: To develop a revised guideline with clear and define scoring system and operational methodology covering all the aspects of sustainability	**Question 2:** What are the arenas or indicators are absent in GPRS in terms of other international, regional & national indicators?	Analysis of missing branches for sustainability, lists of indicators from ISO and other systems need to be incorporated
	Question 3: What are the other operational outlooks need to be incorporated to make GPRS more comprehensive?	Statement of purpose, clear scoring process and calculation methodology with references
Objective 3: To portray some applicability issues of revised guideline	**Question 4:** What are the extents of revised outputs in terms of local applicability?	Applications of different revised arenas in the local context

3. METHODOLOGY

The paper is based on both primary and secondary materials. The first two objectives are based on secondary materials and the third objective deals with the primary data. Secondary data was collected from different organization's official records, publications, books, internet, thesis, unpublished reports etc. Mainly inside the international standards ISO, Organization for Economic Co-operation and Development (OECD), CEN and Green Globe 21 were analysed. Under the regional framework AGCI and in the interior of national framework LEED from US, BREEAM from UK, Pearl from Abu Dhabi, DGNB from Germany were analysed. Within ISO, relevant prospectus titled ISO 14001- Environmental Systems Handbook, ISO 14004- Environmental Management Systems, ISO 14006- Guidelines for Eco-design, ISO 14020- Environmental Labelling, ISO 14031- Environmental Performance Evaluation Guidelines, ISO 14040- Life Cycle Assessment, ISO 14045- Eco-efficiency Assessment, ISO 14064- GHG Accounting, ISO 14067 and 14069- Carbon Footprint, ISO 19011- Guidelines for Quality and/or Environmental Management Systems Auditing, ISO 37120- City Indicators for Service Delivery and Quality of Life, ISO 37121- Indicators for Sustainable Development & Resilience in City etc. were reviewed. Observational survey, Key Informant (KI) interviews and Focus Group Discussions (FGDs) were conducted to collect the primary data.

The secondary info helps to collect policy reference, operational methodology, case specific example, indicators in several similar national/international systems etc. and the primary data helps to analyse the condition of new indicators at local level with its importance & dimensions.

4. GREEN NEIGHBORHOOD RATING SYSTEM

Different countries have adopted different measures in terms of declaring green construction. These measures include series of criteria according to different contexts. Most of these measures are implementing under public green initiatives. The following map shows in detail:

Figure 1: Different National Rating Systems (EGBC, 2009)

4.1. Green Pyramid Rating System (GPRS)

The GPRS system came into stage to reduce carbon related emissions which has been accounted around 50% of total emissions. Egypt is considered to be one of the countries, most at risk from the impacts of global climate change. In this situation, Egyptian Green Building Council introduced the GPRS system (EGBC, 2009). Though most of the criteria were designed for building purpose but they can be used for neighbourhood related indexing.

Table 2: Green Pyramid Categories and Their Weighting (Neama, 2012)

Green Pyramid Categories	Category weighting	Percentage
Sustainable Site, Accessibility, Ecology	10 points	15%
Energy Efficiency	50 points	25%
Water Efficiency	50 points	30%
Material & Resources	20 points	10%
Indoor Environmental Quality	20 points	10%
Management	20 points	10%
Innovation and Added Value	10 points	Bonus
Sum	**110 points**	**100%**

Under these main headings, there are different other criteria. Some of them are mandatory (have to be fulfilled) and some of them are point based criteria (have to be filled up to receive the point). At the end, the project deserves to be certified based on accumulated credit points.

GPRS Certified: 40-49 points
Silver Pyramid: 50-59 points
Gold Pyramid: 60-79 points
Green Pyramid: 80 or above points
Projects with less than 40 credits will be classified as 'Uncertified'

5. LIMITATIONS OF GPRS

GPRS was issued as a start to realize comprehension of green buildings in Egypt and the application of this comprehension increase its important to apply the complete economic development to go to the desert and to start construction and building and start a complete society in the desert to meet expected increase in the life needs as a cause of population growth and advancement, from that point, the use of environmental management to organize consumption of materials will be the first important need to realize development (Ammar, 2012). But it consists multiple sets of backlogs which need to be fixed to make it SMART (Specific, Measurable, Attainable, Realistic and Time-bound) and applicable. The overall limitations are:

- ✓ GPRS system doesn't contain any separate guideline for neighbourhood development. Though most of the existing criteria are applicable for neighbourhood.

- ✓ The guideline for calculating the points are unclear. The standards need to be smart. There are multiple errors in point calculation e.g. in the energy efficiency section, the total allocated points are 52 but labelled as 50; same state in the management section.

- ✓ Due to absence of case study or case specific example, followers might find the rating tool inappropriate. Again, the evidence based piloting or pre-testing can be a first supporting manual for the relevant stakeholders before going for final certification.

- ✓ GPRS is unable to provide comprehensive measure of sustainable communities due to lack of some arenas like economic efficiency, good governance and so on which portrays the gap of missing indicators but properly addressed in other systems like LEED, DGNB etc. (Please see section 6 for details).

- ✓ GPRS has diversified policy reference which is very appreciable and handy. But sometimes it is really difficult to track the policy reference due to referring different policy documents in the same section. As example, in the mandatory requirement section of Energy Efficiency- it is written that a minimum energy performance level is needed which is 10% above an appropriate simulated base case model. The base case model is to be produced in accordance with the Egyptian Energy Efficiency

Code (EEEC) and using the methods outlined in Appendix G of American National Standard Institute (ANSI) / The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) or Illuminating Engineering Society of North America (IESNA) Standard 90.1-2007. In the same category, under the section 2.3 Energy Efficient Appliances (EEA) has been described: Credit points are obtainable for demonstrating that the building occupier will be provided with formal documentary guidelines on the purchase and use of Energy Efficient Appliances for the building, with reference to rating schemes such as Energy Star (USA) or the Energy Efficiency Labelling Scheme (EU). As there are already existed strategies under EEEC about EEA, so it is contradictory to utilize another system to describe the channel.

- ✓ The operational methodology or the strategies are unclear in many cases of GPRS. Under the section- 2.4 Vertical Transport System of Energy Efficiency, it has been described that All lifts within the building needs to be energy efficient, i.e. operate in stand-by mode during off-peak periods; include a regenerative drive system for buildings over 3 stories; and use LED lighting and LCD display features. Not only that, All escalators and travelators are also need to be energy efficient with an automated stop/start function linked to occupancy sensors to enable standby mode when there is no passenger demand; and use LED strip lighting. But the case for one storied building is not clear here or the buildings which does not belong any lift or escalators are exemption or not, needs to be clarified.

The strategy might be developed according to base case model of EEEC where mainly 3 types of buildings were described which also triggered the question about the other building usage types or the case for mixed use buildings. These things need to be described in details.

These are only some indicative limitations for GPRS. There are many other inconsistencies like cultural heritage under the heading ‘Innovation and Added Value’ is almost same with the point Respect for sites of historic or cultural interest under the heading ‘Ecological Balance’. Though in one case the total numbers of points are 3 and in another case 1. So these problems need to be fixed to make the guideline clear and SMART. The following problem tree shows the cause-effect relationships of different limitations:

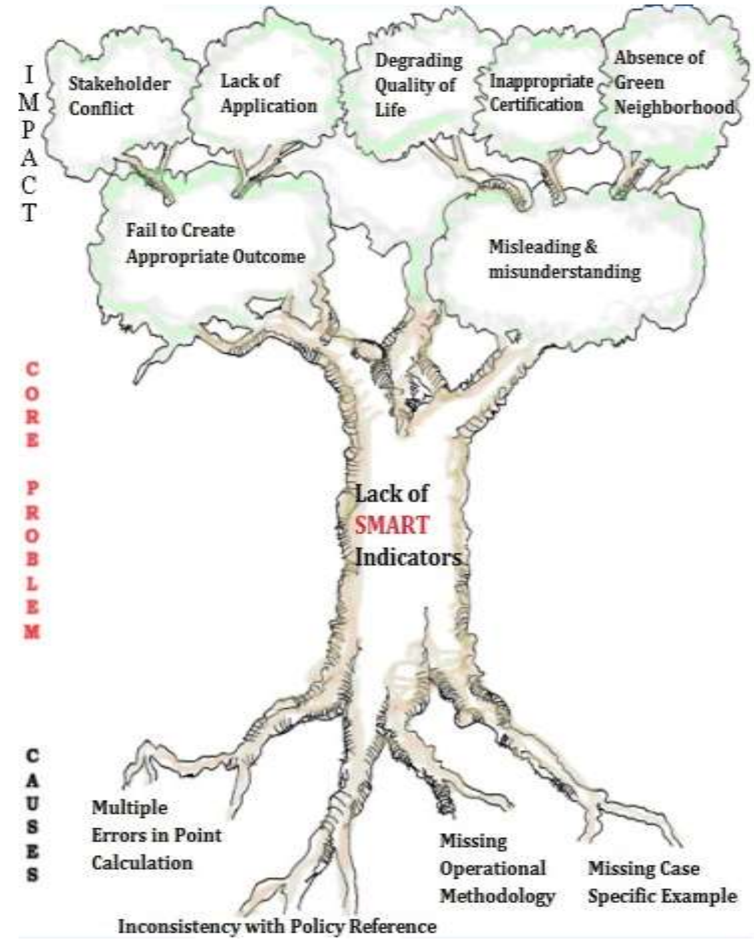
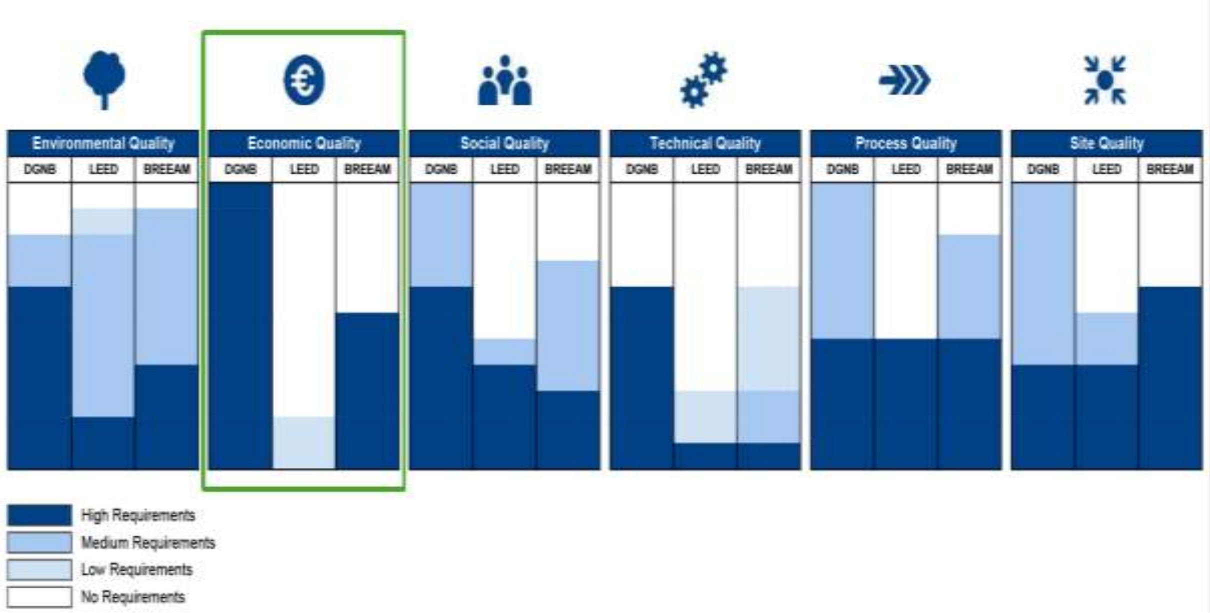


Figure 2: Problem Tree of GPRS (Author's Own Illustration, 2016)

6. BLENDING WITH OTHER NATIONAL & INTERNATIONAL SYSTEM

It is clear that- energy and water efficiency were the top and significant priorities of GPRS. A handsome proportion was denoted under the category sustainable site, accessibility and ecology but still it's not much as three broad spectrums have been covered under one category. This study compares the broad categories of GPRS with other national systems to realize the similarities and dissimilarities which portrays that GPRS does not contain any categories related to Economic Efficiency (EE) or social/neighbourhood quality. DGNB, LEED and BREEAM, all these three categories focus on EE or social quality (Figure 3). Among them, DGNB shows significant requirements on both of these categories. The category social and neighbourhood quality is wide ranging discusses governance process, software (materialistic) development, services and amenities etc. The modern sustainability concept is consisted of social, environmental, economical, ecological and political concepts.



So without these economical and socio-cultural qualities, it is not possible to build up sustainable communities which trigger to incorporate these broad grounds inside GPRS.

Figure 3: Comparison between DGNB, LEED and BREEAM (Becker, 2013)

As economic and social criteria are completely missing inside GPRS and the other criteria have plenty of inconsistencies so multiple sets of national and international indicators were reviewed to blend with GPRS. Most of renowned standards were incorporated inside the study umbrella to create a strong and diversified based of categories and indicators. At first, total 184 new indicators were taken from ISO 14001, ISO 14004, ISO 14006, ISO 14020, ISO 14031, ISO 14040, ISO 14045, ISO 14064, ISO 14067, ISO 19011, ISO 37120, ISO 37121, OECD, CEN (EU), ASTM, ANSI, ASHRAE, CG21, AGCI, LEED, BREEAM, DGNB and PEARL. These national, regional and international guidelines were chosen because these were found most relevant with green neighbourhood system. Some of these guidelines have separate section or manual for neighbourhood development (e.g. LEED has separate guideline for Neighbourhood Development) and some of the guidelines have mixed indicators for buildings and neighbourhood. As this paper deals with the assessment of the green neighbourhoods, so the indicators which can be applied for neighbourhood, has been accounted and analysed. Among these 184 indicators, 98 indicators were selected for further analysis as others are found fully or partly duplicated. The partly duplicated indicators were merged to cover wide arena. As 98 indicators are also too much to blend with existing GPRS system for that reason this study has followed some steps of factor analysis to reduce the numbers of desired indicators. The first step charted weightage of the indicators defining the system in the following way:

Score 10: Indicators exists in ISO

Score 09: Indicators exists in CEN

Score 08: Indicators exists in OECD

Score 07: Indicators exist in American Society for Testing & Material-ASTM/ANSI/ASHRAE

Score 06: Indicators exists in GG21

Score 05: Indicators exists in AGCI

Score 04: Indicators exists in LEED, BREEAM, DGNB or PEARL

Table 3: Indicator Weighting Process Sample (Author's own analysis, 2016)

Name of Indicators	ISO	CEN	OECD	ASTM/ ANSI/ ASHRAE	GG21	AGCI	LEED/ BREEAM/ DGNB/ PEARL	TOTAL
Safe and Secure Community	10		8				8	26
Strategies for prevention of odor related nuisances	10							10
Provision of amenities and facilities	10						8	18
Formulate Eco-plan with EIA	40	9						49
Any previous environmental incidents & emergency preparedness	20							20
Monitoring, Auditing and controlling for Environmental management	50	9				5	12	76

Name of Indicators	ISO	CEN	OECD	ASTM/ ANSI/ ASHRAE	GG21	AGCI	LEED/ BREEAM/ DGNB/ PEARL	TOTAL
Controls on fugitive emissions	10							10
Awareness & Training Programs	20		8	7			8	43
Life Cycle Assessment & reduction of Environmental impact	10						8	18
Any strategies for utilizing degradable materials	10							10
Carbon footprint of utilized materials	10							10
Strategies related to non-renewable resource replenishment	20	9						29
Heat Island Effect and Microclimate Analysis	10						12	22
Noise level & strategies related to reduce effects	10							10
Any strategies to reduce eco-toxicity	20							20
Financial allocation for conducting different pilot projects/Activities	30		8	7				45

The above table portrays the weighting process of the indicators. Here only some indicators have been listed to show the calculation strategy. At the end, total 27 indicators were selected for further processing which are related to neighbourhood and gather more than 10 points in total. These 27 indicators are:

- Safe & Secure Community
- Formulate Eco-plan with EIA
- Economic Efficiency
- Better Governance Process
- Green or sustainable building
- Parking Management
- Community Based Energy Strategy
- Cycling Convenience
- Provision of amenities and facilities
- Heat Island Effect and Microclimate Analysis
- Effective Land use and compact development
- Walkability and better accessibility
- Eco & Vernacular Design
- Improved Lighting Quality
- Community Based Water Strategy
- Awareness and Training Programs
- Life Cycle Assessment & reduction of Environmental impact
- Integrated Development policy with community participation
- Strategies related to growth of agriculture or food production
- Any previous environmental incidents & emergency preparedness

- Monitoring, Auditing and controlling for Environmental management
- Strategies related to non-renewable resource replenishment
- Any strategies to reduce eco-toxicity
- Financial allocation for conducting different pilot projects/Activities
- Any strategies related to efficient use of raw materials
- Risk Assessment and mitigation strategies
- Any strategy for community level GHG gas emission reduction

The most challenging step of this study was the incorporation of the new indicators into the existing system because if the value or the placements of new indicators are not done properly, it might destroy the whole harmony of the GPRS. In this case, the study follows the following steps:

- ➢ At the first step, the indicators which are somehow related or possible to relate with the existing indicators were merged
- ➢ At the second stage, those indicators which are not related but belong to a similar broad category (e.g. community water strategy can be articulated under water efficiency) were incorporated in the same segment.
- ➢ At the third stage, some new broad categories were established (e.g. economic efficiency) as GPRS lacks of these aspects.

The score of new indicators were given proportionately with their represented score and average value of that category of GPRS which currently belongs to. As example: 'any strategy to reduce eco-toxicity'- this new indicator will be placed under the category Ecology. It accounts total score 20, which is 71% of the average value of the new indicators. So in the ecology section, it will obtain 71% of the current average value, which is 0.71 equals to 1.

Finally among 27 indicators, 3 indicators- Safe and secure community, Integrated development policy for community and risk assessment and mitigation process were merged with health and welfare regulations, sustainable site and demolition strategy respectively. 2 new indicators were incorporated under the new category economic efficiency. 9 new governance related indicators were included under neighbourhood development category. 7 new indicators in existing sustainable site, accessibility and ecology section and 1 indicator has been merged with other point; 2 new indicators in resource and materials section; 2 new indicators in energy efficiency and 1 new indicator under water efficiency which bring the following result:

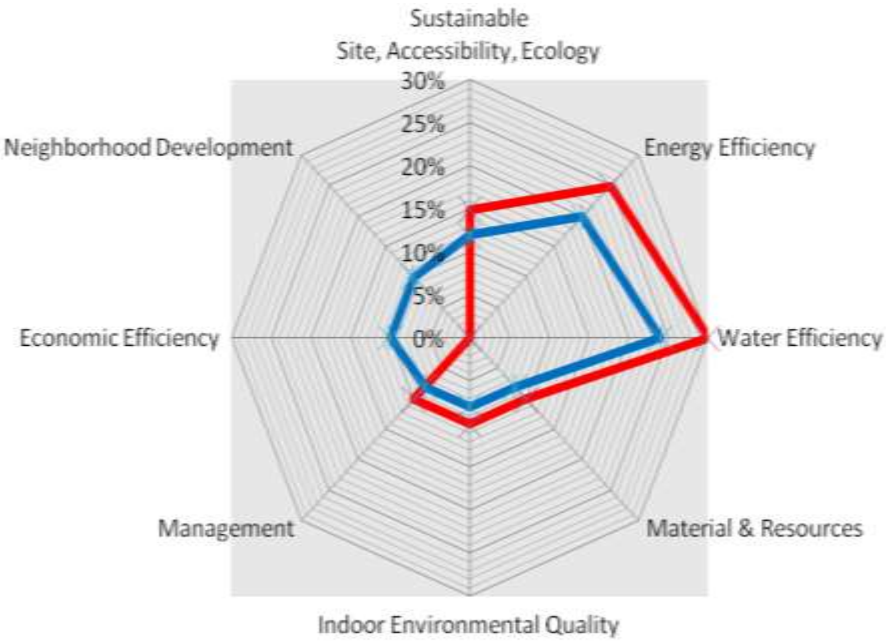


Figure 4: Contrast among Original (red) & Revised (blue) System (Adapted from HBNRC & EGBC, 2011)

It is clear that the revised blue line represents new category titled economic efficiency and neighbourhood development and their significant percentages which will assist GPRS to touch all the aspects of sustainability. Again, it doesn't affect the proportional sharing of existing GPRS in terms of other categories.

7. LITERATURE REVIEW AND DISCUSSION

U.S. Green Building Council mentioned 12 steps to develop a green community which are: create a sustainability path, Increase community Involvement, support regional cooperation, preserve and enhance natural resources, support local food production, implement smart growth strategies, encourage healthy living, increase affordable housing, reduce carbon footprint, support green building and infrastructure, reduce waste and develop efficient network that reduces vehicle use (U.S. Green Building Council, n.d.).

Karim M. *Ayyad* and *Mostafa Gabr* has described in their paper titled 'Greening Building Codes in Egypt' that-

"At the Unified Building Law no.119 released in 2008 and its executive appendix released by the Ministerial decree no. 144 in 2009 was not formulated having green concepts in mind, while the GPRS was not designed to be in harmony with the Unified Building Law nor its executive appendix. However, it is also evident that integration opportunities are existent. The analysis of selected articles and regulations of the IGCC and its compliance option, the ASHRAE Standard for the Design of High Performance Green Buildings, shows possibility

for adopting some of them in Egypt through integration into the Unified Building Law" (Ayyad & Gabr, 2012).

So it is clear that GPRS is not unified with the building law also which also press the urgency of revising it.

A study developed by *Shady Attia* and *Marwa Dabaieh* on "The usability of green building rating systems in hot arid climates: A case study in *Siwa*, Egypt" portrays that

"The examined rating systems are merely usable. Despite that the development of the examined rating systems is intended to facilitate the assessment of sustainable design; they fail to recognize the qualities of local architecture. We conclude that the existing rating system needs to be more comprehensive considering the local environmental and sustainable potentials" (Attia & Dabaieh, n.d.).

It is clear that the rating system needs to be comprehensive and none of the single standard is alone complete. The above literature review findings represent the following remarks to be fit into revised GPRS guideline:

- It needs a sustainability road map which mainly indicates to include each and every aspects of sustainability inside GPRS which has been considered through incorporation of EE and neighbourhood development criteria inside existing GPRS.
- Several literatures stressed on community participation. To achieve this plinth integrated development process has been designed as mandatory criteria under the point sustainable site.
- It was suggested to conserve the natural resources. In existing GPRS, there are already some indicators under the category ecology to address this point but still some new indicators have been incorporated to strengthen the foundation e.g. any strategies to reduce eco-toxicity
- Agricultural practice and local food production have been mentioned. The criteria are already included as new indicator in revised GPRS.
- Smart growth strategies, healthy living and affordable housing these points have been merged under the new indicators safe and secure community, land use and compact development, disbursement of services & facilities and awareness rising.
- Reduce carbon footprint, GHG emission, green building and infrastructure have been also included as new indicators. The waste management dimension is already existed in GPRS.
- Alternative transport mode e.g. bicycling has been already encouraged through the new indicator which was suggested by USGBC literature.
- *Ammar* and *Attiya's* study show the difference between comprehensive rating system and one individual rating which support this study to blend existing GPRS with national and international standards.

- Local and vernacular design has been encouraged by *Ammar* which has been also incorporated as new indicator.

Besides all of these, the revised GPRS attempts to synchronise with the policy documents which will remove the problem of unification and references

8. APPLICABILITY AND FURTHER RESEARCH

The question always arises that the new indicators are applicable in the local context or not. Furthermore, the influence of new indicators in the local arena is also a question. This study examines some of the new indicators in terms of El Gouna to relieve the importance.

El Gouna is a touristic based private town which has been developed on the beautiful Red Sea Coast. It has been started since 1990s by Orascom Hotels & Development (OHD) and gradually developing along the coast line. According to El Gouna website, it offers an unrivalled lifestyle, built on 10 km of beach which consists over 3306 residential units, 16 hotels and 2450 guest rooms spread across islands and lagoons (OHD, 2016).

8.1. Safe and secure community

As a privately developed town, El Gouna has its own safety and security measure. El Gouna has its own surrounded boundary which can be titled as a gated community. People need to show valid permit or document to enter inside El Gouna. El Gouna has its own security forces at the different parts of the city. Due to political condition, different cities inside Egypt were very perilous and under curfew but El Gouna never face any difficulty in any situation due to its unique safety and secure measurement. No doubt, it is a positive aspect for El Gouna and should be treated properly. For certification, it is very important to scrutinize the safety issue of a community to perceive also about the risks and its associated impacts.

8.2. Land use and compact development

The indicator titled ‘land use and compact development’ is an important phenomenon for planning field. It is not possible to design the services effectively if the development is not compact. In terms of El Gouna, the case of compact development is really serious. In El Gouna most of the buildings were developed according to client’s demand which create lots of interior and exterior space. Again, the orientations of the buildings and alignments with the roads create multiple spaces.

Figure 5: 3D View of El Gouna (Author's Own Illustration, 2016)

From the above description it is clear that this aspect is necessary for sustainable neighbourhood design with access to facilities which has been overlooked in existing GPRS. According to the revised system, El Gouna will not get any point under this category.

8.3. Eco and vernacular design

Egyptians have long tradition to build their houses in a traditional way. This is not only about the design of houses but also it is ecologically sustainable and comfortable. In El Gouna, eco and vernacular design have been maintained through different structures like dome shaped roofs, traditional façade and windows etc. El Gouna does not contain one specific type of building design rather it is much diversified according to the zones. To encourage this type of eco-design, this indicators need to promote.

Figure 6: Dome-shaped Building Type in El Gouna (Author's Own Illustration, 2016)

8.4. Heat island effect and micro-climate analysis

There are lots of potentialities of El Gouna in terms of energy saving town. Analysing El Gouna climate in a typical summer day proves that there is heat island effect (Fig. 7; red, purple and purplish marked) in El Gouna which can be solved through different low cost techniques like insulation, shading etc. Again, lots of dusts pass through air which also pushes the necessity of buffering El Gouna from desert zone. The micro climate scenario has been given below:

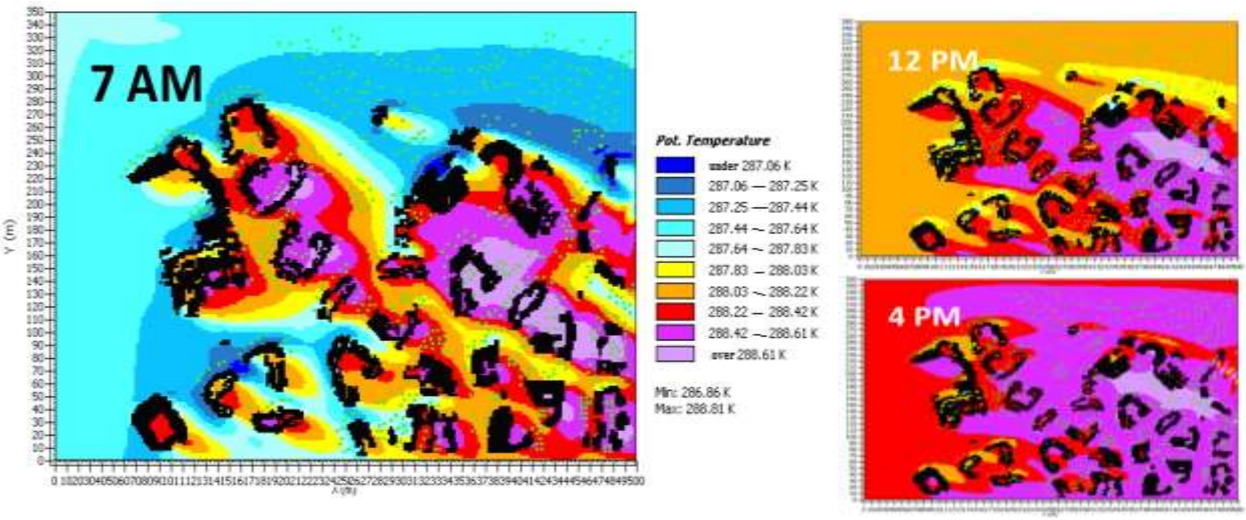


Figure 7: Heat Island Effect in El Gouna (Author's Own Illustration, 2016)

It is very important to analyse the heat island effect and the condition of micro-climate to realize the strategies regarding heating or cooling effect, shading and so on.

8.5. Further Research

In every national or international system, numbers of case studies existed which define the application system more elaborately to assist policy makers, developers and other related stakeholders. So further research can be conducted through applying and comparing the existing & revised GPRS scores in terms of LEED, BREEAM, PEARL etc. Additionally comparing the results of different systems in different cities of Egypt and monitoring system for GPRS can be handy for further study.

9. CONCLUSION

The approach to green or sustainable development through developing Green Pyramid Rating System is no-doubt a milestone for Egyptian Planning system. The multidisciplinary approach accompanying with different key stakeholders represents the promise to achieve the vision. The annual reviewing and monitoring path with the developers, planners and other personals depict the importance and responsive version of progress. To strengthen that ground stronger and to make the national system more comprehensive this study explores each and every particle of GPRS and wrought those with necessary ingredients.

After zooming inside the GPRS, it articulates several backdrops like errors in point calculations, missing aspects of sustainability, absence of important indicators etc. Again, it discovers multiple deficits in the definition of point calculation which all lead this study to develop a revised comprehensive guideline through blending different international (ISO, CEN, OECD etc.) and national (LEED, BREEAM, DGNB etc.) standards. It incorporates mainly economic and governance related indicators which are now completely lacking in the existing system. Furthermore, it inserts 27 new indicators from different perspectives after conducting multi-level scoring process and factor analysis. The study also conducts a sturdy literature review to account several materials which needs to be inclusive in the revised guideline. Still the revised system should be pretested in any corridor before driving it to the application phase though this study attempts to represent the necessity of some new indicators in the context of El Gouna.

Finally looking beyond the courtyard or certification, GPRS needs to forecast some policy advancing tool like PEARL. According to Pearl Executive Council Order of May 2010, all new community developments must meet the 1 Pearl requirements starting in June 2010 which implies the improvement not only for a community but also for all the other communities in the country (Abu Dhabi Planning Council, 2010). It needs also to encourage the planners, developers and other stakeholders to utilize the tool of GPRS for any type of construction or development work. In this case, EGBC can allow only registered contractors, or planners' work for application. Besides these, some other software developments like awareness rising, capacity building, media campaigning etc. are also necessary to promote the system better.

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Theme V

Capacity Building and Education

Learning about sustainability and green construction principles from pilot houses in Zambia

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Abstract: *The Zambia Green Jobs Programme (ZGJP) is a sustainable development programme which facilitates private sector development for inclusive green growth and decent green jobs, especially for women and young people. The focus is not just on the building technology or solution but the use of scalable demonstrations to (1) promote the change in mind-sets, skills, attitudes and behaviour on sustainable construction; and (2) develop markets for green construction by sharing the risk for innovation and product development with private investors and developers. This paper presents the methodology and results of the ZGJP demonstration house project. Three houses were pre-designed in an architectural competition in 2014 and the winning solutions were selected for the pilot phase (2015-2016) at the North Western Province in Zambia. The sustainability aspects in the pilot phase included design aspects (e.g. flexibility in space design, passive solar prevention, daylighting, natural ventilation), technology solutions (solar PV, window technology, energy efficient lighting, local materials), quality aspects in building phase (supervision, material testing) and capacity building issues (business for local contractors, job creation for locals, improved construction practises, contractual practises). The sustainability of the houses was evaluated based on review of the plans, interviews of the stakeholders and on-site visit including 'walk-through' evaluation using the Sustainable*

Building Assessment Tool (SBAT). The first users are moving in the houses before the end of 2016 and user responses will be available after that. The multi-step approach ending up to real houses with real habitants will give valuable feedback for the future design, green technology selections and construction process. The paper presents the project and critically evaluates the process and the final product. The review will be distilled into recommendations for the next phase sustainable green houses, which can be replicated to fill the huge gap in housing needs in Zambia.
Keywords: assessment, capacity building, green construction, sustainability

1. INTRODUCTION

The scale of the housing challenge in Zambia is immense, with a new dwelling required every two minutes of the working day until 2030 to meet urban housing demand (UN-Habitat, 2012). In addition to new housing provision, there is huge need to upgrade existing informal settlements and improve the access to land, as well as to develop a new national housing policy that reflects the need for housing provision which is affordable to the majority. It is obvious that the huge development in the housing sector is needed and this should be done according to green and sustainable principles keeping in mind basic principles of climate change mitigation and adaptation.

The Zambia Green Jobs Programme (ZGJP, 2015) is a sustainable development programme, funded by the Government of Finland and implemented by the Government of Zambia with technical assistance from the United Nations System led by the International Labour of Organization (ILO). The Programme facilitates private sector development for inclusive green growth that creates decent green jobs, especially for women and young people. This is achieved through the promotion of access to finance and business development business development services form micro, small and medium enterprises (MSMEs), as well as changing consumer buyer behaviour to develop green construction markets by sharing the risk of innovation, product development and investment with private developers and investors of sustainable and affordable green housing. The Zambia Green Jobs Programme shares the financial and technical risk of transformative and scalable demonstrations of green building solutions which encompass sustainable construction; water efficiency; clean and renewable energy; as well as integrated waste management. Together with the Copperbelt University, the Programme is also building the capacity of local architects on sustainable or green architecture. This paper presents the methodology and results of the ZGJP demonstration house projects with Barrick Gold Lumwana Mine as well as First Quantum Kalumbira Mine in the North Western Province of Zambia.

Piloting and demonstrations have been recognised to be a good way to show examples when opening the path for new products, ideas and business. Demonstration projects raise public awareness and send a strong signal to the private sector that investing in green growth infrastructure and technologies is feasible (AfDB-OECD, 2013). As part of ZGJP co-operation, Lafarge has started demonstration house projects at Lusaka and Ndola as showcase aiming at 600 affordable and environmentally friendly housing units for middle income families (Lafarge, 2015).

Pilot housing was assessed in terms of sustainability. The assessment aimed to establish the benefits of the approach developed for the pilot housing projects and identify opportunities for improved performance in future projects. It also aimed to capture learning which can be used to contribute to the wider Green Jobs Programme (UNDP, 2013).

2. RESEARCH METHODOLOGY

The concept of localisation and implementation of green sustainable building principles included several steps (Figure 1). In the first phase the architectural competition was arranged to get the local proposals for the green solutions. The winning solutions were selected for implementation phase based on pre-defined criteria. The architect finalised the drawings and local contractors were asked to give offers for the constructing the houses. The tenders were evaluated and compared to model house Bill of Quantities (BoQs) given by quantity surveyor. The Zambian contract models were used in making the contracts between project management and local contractors. The progress of the works was followed by regular site meetings and under supervision by clerk of works. The quality aspects of the construction works were supported by task lists of clerk of works and communication with contractors. During the finalisation phase of the houses the sustainability evaluation was done using SBAT methodology. The experiences during the planning, construction and evaluation phases gave the first feedback for future house concepts, and the final feedback will be got after the end users have lived in the houses for short period. The feedback can be used for improving the details in the model drawings. The optimal result would be realised with continuous running of the pilot house cycle (Figure 1), each cycle giving the better results than earlier ones.

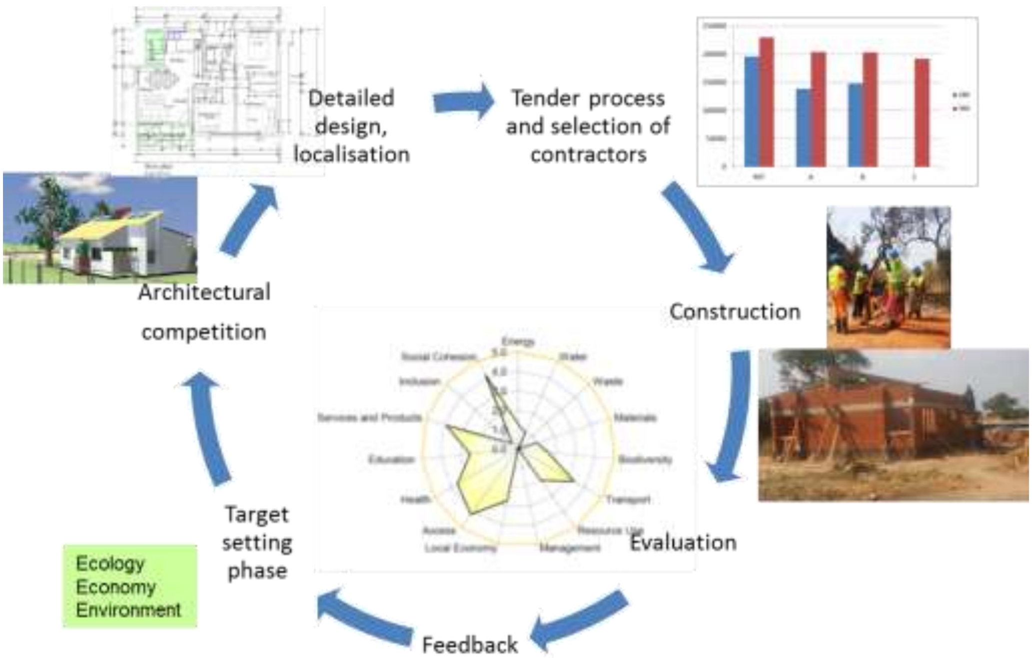


Figure 1: The phases of the pilot project.

2.1. Architectural competition

The Zambia Institute of Architects (ZIA) was mandated to run the design competition on behalf of the ILO and VTT Technical Research Centre of Finland (ILO News, 2013). The competition was open to all registered and student architects. The mandate was to design low cost and medium cost houses using appropriate technology and with utilization of local and sustainable materials, leading to improved eco-efficiency of future housing. The competition looked at the aspects of innovation concept, ecology and positioning of the building site, ecology of the construction phase, building concept itself, ecological building materials, energy savings and use of renewable energy and water solutions.

As a result three winners emerged from the two categories of the houses. The winners were evenly selected as it included both architects who had been practicing for a long time and those who were new as well as students. The result of the competition produced great innovations that were unique to the environment and the people. The competition exposed the participants to think widely and in an innovative way. All the winners came up with different solutions which exploited the recycling of existing materials to make building materials and aimed at reducing the materials that would have ended up at the dump site. Two types of the houses were selected for the following demonstration phase.

2.2. Construction process

The construction process includes several phases and tasks to perform. The path from the target setting phase to the use phase including service and maintenance is described in the figure 2. The target setting phase gave the basis for the pre-design in the architectural competition. The update of the plans was done in planning phase and tender process was performed based on detailed drawings. The evaluation of the offers including cost-benefit analysis lead to selection of the contractors, contract phase and practical construction works. The first performance evaluation of the houses was done based on SBAT methodology. The construction process included several supportive tasks improving the quality of works and materials e.g. planning the programme of works, delivery and storing of materials, protection of the materials on site, quality control actions, inspections, evaluations and valuation of the status of works. The practical works included capacity building for the workers and work safety education and implementation.

2.3. Sustainability assessment

Sustainability assessments were carried out on pilot housing. These aimed to capture the benefits of the approach and identify opportunities for improvement in future projects. The theoretical framework used for assessments was the Sustainable Building Assessment Tool (SBAT) Residential tool (Gibberd, 2005). The tool enables environmental, economic and social sustainability performance of housing to be measured and is based on the following criteria:

- Environmental Sustainability Performance: Energy, Water, Waste, Materials, Biodiversity
- Economic Sustainability Performance: Transport, Resource use, Management, Local economy, Services and products
- Social Sustainability Performance: Access, Health, Education, Inclusion, Social cohesion.

More detail on the SBAT and the assessment methodology is provided later in section 4.

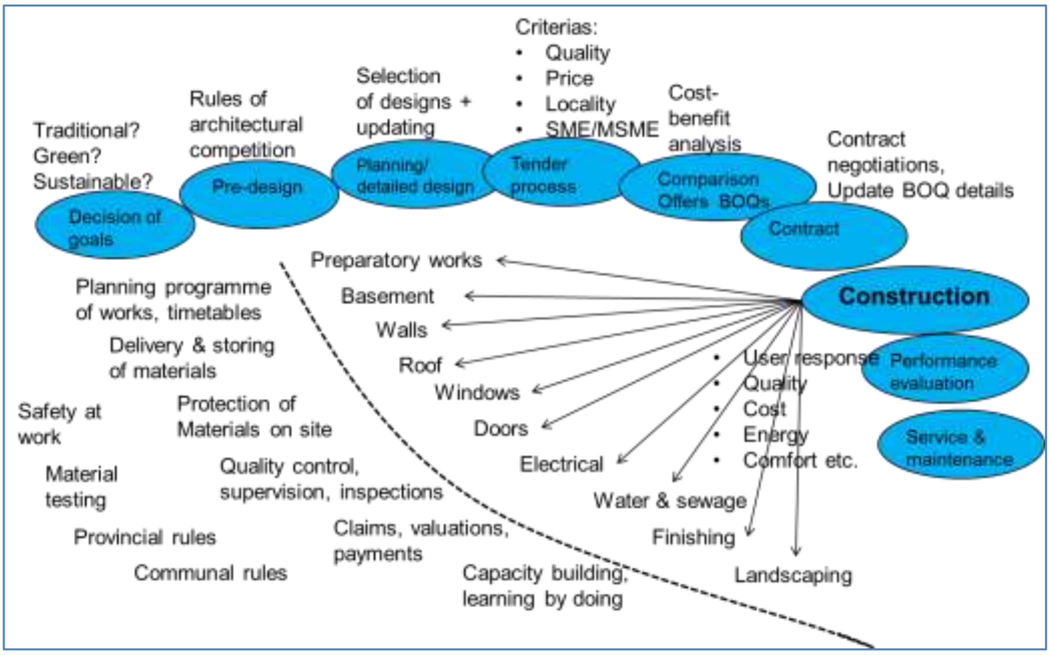


Figure 2: The phases and tasks in the pilot project.

3. PRINCIPLES OF GREEN CONSTRUCTION

The green, sustainability aspects in the pilot project included design aspects (e.g. flexibility in space design, passive solar prevention, daylighting, natural ventilation, water proof details), technology solutions (solar PV, solar thermal , window technology, energy efficient lighting, local materials), quality aspects in building phase (supervision methods and schemes, material testing) and social aspects including capacity building issues (business for local contractors, job creation for locals, improved construction practises, contractual practises), Figure 3. The holistic approach was limited in the pilot house case, because district level selections were not able to do, and the building plots were arranged by the local stakeholders without possibilities to optimise district level issues, e.g. waste handling and transportation issues.

The sections 3.1.-3.3. give a short summary of the design proposals in green sustainable houses. Most but not all of these options were implemented in pilot houses.

3.1. Design aspects

General design principles - The design was an open design to allow for easy flow of light and air. The room designs had no corridor space thus there was maximum utilization of the space.

Flexible solutions in walls /space modifications - The walls were made with thin walls to allow for easy removal and functional changes depending on client’s needs. The design was an open design to allow for easy flow of light and air.

Daylighting strategies - The orientation of the buildings would be north and south to reduce direct sunlight entering the longer parts of the buildings early in the morning and late afternoon. The walls with windows would have recessed facades so that those rooms that receive a lot of sunlight will have sun shields. The internal middle walls have skylights to allow light in the middle of the house. The house will have a ceiling board that is made from recycled materials and the ceiling will follow the direction of the purlins so that the ceiling height is high enough to let hot air rise up and escape through the skylights.

Water proof issues – There will be no water splashing on the wall as there will be gutters to carry off the roof. The eaves of the house will be extended out by 1.2m so that there is no water that will splash on the walls. The plinth is high enough to avoid rainwater causing problems.

Material selections – Different aspects have to be taken into account in selection, e.g. fitness for use and local acceptance, use of local materials, minimised embodied energy, brick vs hydraform stabilised soil brick (SSB), steel roof vs tile roof and wooden vs metal window frames.

Figure 3: Green and sustainable principles in the demonstration houses.

3.2. House technologies

Solar PV - Three solar panels have been positioned on the western side of the house and the largest portion of the roof will be utilized with solar panels. The solar panels will be able to light the whole house and will be able to supply the sockets with sufficient energy.

Solar thermal – The domestic hot water will be produced with solar thermal collector combined with thermal storage tank.

Energy efficient lighting – The lighting fixtures will be selected to have low energy consumption light bulbs using less power than traditional ones.

Roof insulation / low emissivity coated membrane as underlay - The roof will have an underlay membrane that will act as an insulation from the heat of the roof transferring the heat to the rest of the building. The underlay will also protect the roof from leakages.

Ventilation - The rooms will have large windows on adjacent side of the rooms for cross ventilation and to capture the prevailing winds.

Rainwater harvesting - The design will use rain water and it is hoped that this will reduce the cost water by 30%. Water will be captured from the roof, from storm water drains and from the soil water. There will be two storage tanks on one end of the roof. These tanks are 200 litres.

Windows - The windows will be large and placed on adjacent side of the walls. The windows will allow cross ventilation and sufficient daylighting will enter each room. The areas where there is a lot light coming in through the windows will have both vertical and horizontal sun shades.

3.3. Social aspects in green construction

The holistic approach for sustainable green construction takes into account the social aspects including engagement of local workers (direct employment, selection of career based on showcase etc.), capacity building (skills development, education, training), local business opportunities and locality of the materials used in the construction. Engagement of local small and medium size enterprises is an important goal to offer decent jobs in green construction. The pilot house project was working closely with Zambian property developers and investors, architects and designers, and selected micro and small medium enterprises linked to construction project.

3.4. Quality assurance in construction

The quality assurance of the construction works have to be systematic and based on defined procedures. The tender process must be according to pre-defined procedure including requirements for quality of documents, e.g. bill of quantities (BoQ) must be comparable. Using of model BOQ would help and speed up remarkably the later phase valuation process. The agreement can be done based on nationally accepted model. The model agreement is profound and too heavy for small companies and one-cycle client, including 35 conditions and quite complex language. There is need of a short and simple contract model for residential houses and non-professionals as party in contract. As part of quality plan, the organisation and roles and responsibilities and communication plan should be given in written form. The clerk of works at site will safeguard the interest of the client on and around the site of project, and has a remarkable role in supervision of the quality of works. The checklist of tasks and responsibilities will help the systematic performing of actions.

Clear rules for health and safety at construction site are needed, and rules must be supervised. The practical instructions for workers are needed, e.g. agreement on shoes and hats to be worn on site during the construction work. The health and safety sessions/reviews should be held in site meetings regularly. Promoting safe, healthy and sustainable jobs in the building and construction sector is one aim of Zambian Green Jobs Programme (Mukosiku, 2014).

4. EVALUATION OF THE HOUSES

4.1. Methodology

The methodology followed for the assessing pilot housing involved the following tasks. Firstly, drawings, specifications, bills of quantities, product manuals, manufacturers' data sheets, reports and other documentation related to pilot housing were received and analysed. Secondly, visits to the sites were carried out and a visual inspection, field measurements and a photographic record developed. Thirdly, structured interviews were held with role players on the project including relevant built environment professionals. Fourthly, analysis and calculations were carried out on documentation, data captured on site and from interviews. Finally, data was inputted into the Sustainable Building Assessment Tool (SBAT) and performance reports generated. Further detail on the SBAT and a brief description of the assessment results are provided below.

4.2. The Sustainable Building Assessment Tool

The Sustainable Building Assessment Tool supports an integrated and responsive approach to achieving high sustainability performance in buildings. The tool is based on a holistic approach to addressing sustainability and includes social, economic and environmental criteria. SBAT criteria are based on a definition of sustainability found in the Living Planet Index (World Wild Life Fund, 2006). This defines sustainability as the achievement of minimum quality of life standards within the earth's carrying capacity. This is specifically defined as the attainment living standards above 0.8 on the Human Development Index (HDI) and the achievement of an ecological footprint (EF) of less than a 1.8 gha per person (gha, global hectare).

Therefore, the SBAT measures the performance of built environments in terms of its capability to support the achievement of living standards of above 0.8 on the Human Development Index (HDI) and an ecological footprint (EF) of less than a 1.8 gha per person. The assessment therefore provides an indicating of whether built environments have the required characteristics, and the configuration, to enable users (occupants) to live in a sustainable way.

The SBAT Residential tool and manual has a focus on built environments on residential environments, such as housing and apartments and their immediate neighbourhoods. The SBAT can be used to set targets for sustainability performance for buildings and their immediate neighbourhoods. It can also be used assess and validate the sustainability performance of buildings.

Scores in the Sustainability Building Assessment Tool range from 0 to 5. Performance can be related to the objectives of the SBAT (Introduction) and is indicated in Table 1.

Table 1. Key to SBAT scores (HDI=Human Development Index, EF=ecological footprint).

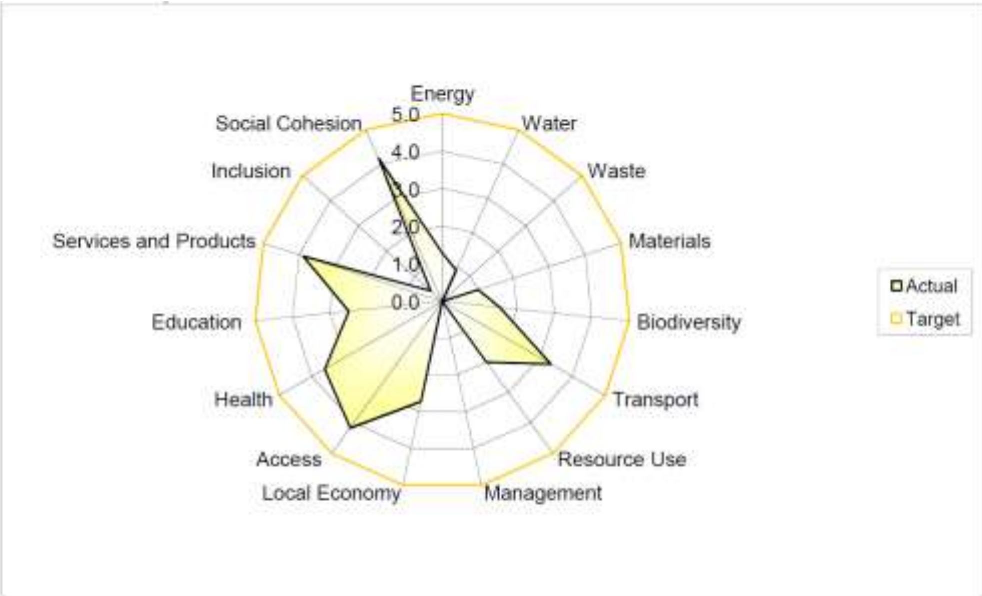
SBAT score	Sustainable built environment performance
5	Built environments provides **full** capability to enable occupants to achieve HDI and EF targets and live in a sustainable way.
4 - 5	Built environments provides **excellent** capability to enable occupants to achieve HDI and EF targets and live in a sustainable way.
3 - 4	Built environments provides **strong** capability to enable occupants to achieve HDI and EF targets and live in a sustainable way.
2 - 3	Built environments provides **partial** capability to enable occupants to achieve HDI and EF targets and live in a sustainable way.
1 - 2	Built environments provides **limited** capability to enable occupants to achieve HDI and EF targets and live in a sustainable way.
0	Built environments provides **no** capability to enable occupants to achieve HDI and EF targets and live in a sustainable way.

4.3. Sustainable Building Assessment Tool Report and Findings

An extract of the SBAT report for pilot housing is provided in figure 4. This shows the performance of pilot housing in terms of SBAT criteria.

4.4. SBAT results

The SBAT report indicates that overall sustainability performance of pilot housing is 2.1. Reference to figure 1 indicates that there is **partial** *capability for occupants to achieve HDI and EF targets and live in a sustainable way*. This means that sustainability performance of housing is well above conventional housing. It also indicates that performance in different areas is mixed. The detailed nature of this performance can be ascertained by reviewing the spider diagram and the scores indicated in figure 4. The more detailed descriptions below indicate performance in the different areas and provide recommendations of measures that could be implemented to support improved performance.



SB4 Environmental, Social and Economic Performance	Score
Environmental	0.9
Economic	2.4
Social	2.9
SBAT Rating	2.1

Figure 4: SBAT Evaluation Report of Pilot Housing

4.4.1. Environmental performance

Environment performance of pilot housing is 0.9. This indicates that there is potential for improved performance. A review of the SBAT criteria indicates that performance could be improved in the following ways. Energy efficient equipment and renewable energy systems could be installed. Water efficient fittings and a rainwater harvesting could be incorporated. In addition, provision for recycling would also improve performance. Performance within biodiversity could also be improved through provision of ecological landscaping and food gardens.

4.4.2. Social performance

Social performance of pilot housing is 2.4. This indicates that performance in this area is better than environmental performance but that there is potential improvement. It shows that, in general, housing has good access to health, education and recreational facilities which support sustainable living patterns. However, provision for more inclusive environments could be addressed. This includes more accessible paths to housing as well as ensuring that circulation, spatial configuration and equipment within the house can be readily used by all occupants, including people with disabilities.

4.4.3. Economic performance

Economic performance of pilot housing is 2.9. This is the best performing area and indicates that construction of housing is supportive of local economic development. It indicates that construction of pilot housing has been carried out by local contractors in a labour intensive way. It also shows that housing is located in areas where there is good access to goods and services that support sustainability, such as access to local produce markets. However, aspects that could be addressed include metering for electricity and water consumption as well as the provision of building operation guidance to support sustainable occupation of housing.

5. FEEDBACK AND LESSONS LEARNED

The feedback from the stakeholders who have visited the demo houses has been very positive. Some development proposals for house designs have been given, e.g. adding of veranda roofs, decrease of the height of the building, lightening some internal walls and small changes for dimensions in toilet and bathroom, and these proposals have been communicated to the architect. During the construction phase some work phases had needs for development, e.g. work instructions for installation of underlay and window frame installations. The success and risk factors based on pilot house project experiences are listed in Table 2.

The implementation of the green sustainable principles in demonstration houses requires knowledge in design principles and availability of the technology solutions. The most of the construction techniques and installations on site belong to normal construction and there should not be any barriers for implementation. Some work phases require high expertise, e.g. installation of PV-system with other electricity system. The big concern is related to service and maintenance of the houses, which requires instructions and responsible person to take care of it.

The sustainability evaluation with SBAT method indicates that overall sustainability performance of pilot housing is 2.1, which means that there is partial capability for occupants to achieve HDI and EF targets and live in a sustainable way. The sustainability performance of housing is well above conventional housing. The best performing area is *economic performance* (2.9) indicating that construction of housing is supportive of local economic development. The construction of pilot housing has been carried out by local contractors in a labour intensive way. Social performance (2.4) indicates that housing has good access to health, education and recreational facilities which support sustainable living patterns, and there is potential for improvement. Environment performance (0.9) needs improvements, e.g.

energy efficient equipment and renewable energy systems should be installed and water efficient fittings and a rainwater harvesting could be incorporated.

Table 2. The success and risk factors based on pilot house project experiences.

Success factors	*Risk factors*
+ Preceding architectural competition for green sustainable houses gave a good basis for the project + Suitable models for Bill of Quantities (BoQ) + Active participation of the local stakeholders in the pilot project, including local consults for Operating Agent + Active support by local ILO office and participation in site meetings and site visits + Interest of local SMEs on construction business + Interest of building sector on dissemination workshops + Enthusiastic and motivated clerk of works + Systematic evaluation of progress and payment claims with help of local experts (quantity surveyor and clerk of works) + Fluent communication possibilities, e.g. by Whatsapp, supporting delivery of photographs and instant advices + existing instructions for different phases of construction works	- Complex land ownership issues and finding the proper model for land use in case of pilot houses - Poor knowledge on contractual issues, lack of contract model suitable for small residential houses - Lack of liquidity of local contractors – this may cause delays in material delivery and works - Disability of local contractors to give bank guarantees helping the payment processes - Lack of timetable discipline by contractors – this may be partly due to material delivery problems, but can be avoided by better work timetable planning - Capacity building needed for special topics in construction - Poor quality procedures and supervision procedures; there is need of written instructions - Risk of project costs increasing due to big variations in exchange rates and uncertainty in economy - Too high cost for management and supervision of works (clerk of works, quantity surveyor, architect) - Lot of good procedures and principles have been implemented in practise in pilot house construction sites, but the result dissemination should be done more, to get better value for money.

A recommendation for future houses is that explicit sustainability targets should be set for projects at the outset. The SBAT framework can be used for this purpose. This will enable designers and contractors to respond to these requirements and is likely to lead to much higher performance.

6. CONCLUSIONS

The paper gives an example of green sustainable demonstration house built in Zambia. The sustainable principles in building design, technology selection and social aspects are presented. The demonstration project aims at showing an example, which can be scaled and replicated in new buildings. The success and risk factors for the demonstration project and first feedback for the demonstration houses are presented. The feedback from the stakeholders who have visited the demo houses has been very positive. Some recommendations for the changes in technical details have been give and communicated to the architect.

The houses were designed according to principles of green and sustainable construction. The design selections were qualitative and there was no detailed quantitative evaluation of the sustainability including material flow and energy consumption calculations. The sustainability evaluation with SBAT method indicates that overall sustainability performance of pilot housing is 2.1, which means that there is partial capability for occupants to achieve HDI and EF targets and live in a sustainable way. The sustainability performance of housing is well above conventional housing, and based on SBAT evaluation it was possible to give proposals how to improve the performance, e.g. by using energy efficient equipment, renewable energy systems and water efficient fittings.

The most notable achievement during the demonstration house project are (1) capacity building of local architects, small scale contractors and service providers which resulted in jobs and skills development; (2) development of curriculum and course on sustainable architecture which ensures sector sustainability in terms of skills for sustainable architecture; and commercially (3) the inclusion of green building principles, processes and practices into the architectural code of the Kalumbila Town which will, result in thousands of green homes and communities in North Western Province.

The first users are moving in the houses before the end of 2016 and user responses will be available after that. The multi-step approach ending up to real houses with real habitants will give valuable feedback for the future design, green technology selections and construction process.

7. ACKNOWLEDGEMENT

The work related to this paper has been done as part of Zambian Green Jobs Programme (ZGJP). The ZGJP is a partnership between the Government of Zambia, the United Nations (UN) and Government of Finland. The programme is led by the International Labour Organization (ILO) and is aimed at promoting more and better jobs for inclusive and green growth in sectors where goods and services can be produced with an environmental benefit.

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Designing Cycles – Solid Waste Management (SWM)

Case Study Geziret El Dahab

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Abstract: *With an estimated 8,000 inhabitants (see Nazer, 2006), the agricultural island of Geziret El Dahab as one of the protected Nile Islands is a green haven in the middle of the megapolis Cairo. Currently, there is no solid waste management system in place. While organic waste is mostly fed to the animals, an-organic waste is either thrown in the Nile, on its shores, or burnt. Apart from a missing sewage system, this poses the most pressing problem for the island's ecology.*

The action-based research outlined includes

- *A household survey to understand the willingness and preferences of the inhabitants*
- *Potential models of solid waste management on and off the island*
- *A test-run of waste collection in cooperation with Ihlam, a student's environmental group, the islanders and the Zabaleen (waste collectors) of Manshet Nasr (informal city district specialized in solid waste management)*
- *A SWOT analysis of four customized SWM models for the island*

The action-based research evaluates the spatial, legal and socio-economic parameters for the installation of a solid waste management system on the island and is part of the Nile islands Initiative (Nil).

Keywords: *action-research, Nile islands, participation, recycling, solid waste management*

1. INTRODUCTION

1.1. THE NILE ISLANDS INITIATIVE - DESIGNING CYCLES

The Nile Islands Initiative (Nil) is a multidisciplinary open platform initiated to map, protect and activate the spatial qualities of the Nile Islands in the context of increasing urbanization. There are an estimated 144 islands in the Nile of which many are threatened by encroachment and environmental degradation. At the same time their legal status is unclear. Dahab Island in the middle of Cairo is currently serving as a case study for Nil activities. Environmental protection and urban upgrading regarding informal building activities, water quality and supply, solid waste management, engagement of the local community and habitat protection are the strategic aim of the Nil series “Designing Cycles”.

1.2. SOLID WASTE MANAGEMENT IN CAIRO

As any megapolis, Cairo is struggling with the provision of solid waste management services and infrastructure. Many communities and neighbourhoods are either not served or not served adequately by the state collection service currently provided by multinationals. For Egypt, only an estimated sixty per cent of the waste produced is actually collected, of which less than twenty per cent is recycled or properly disposed of (see nswmp.net). According to the GIZ, “despite international support, the institutions responsible for waste collection and disposal are not yet able to perform their complex tasks. The legal framework is inadequate, there is no strategic planning, and the allocation of responsibilities and tasks remains unclear. The sector is significantly underfinanced and there is an enormous need for sustainable investments and services”. The majority of solid waste collection services in Cairo have been provided by the Zabaleen, the mainly informal garbage collectors of Cairo responsible for creating one of the world’s most efficient and sustainable resource-recovery and waste-recycling systems. The introduction of international private sector companies in 2003 is widely considered to have limited success (Wilson et al, 2006; Fahmi & Sutton, 2010). While the formal collection services dispose the waste to landfills, the Zabaleen manage to collect and sort 60% of Cairo’s overall waste and recycling 80-85% of it (GIZ, 2008). The informal solid waste management system of the Zabaleen has resulted in Manshet Nasr, a whole city district of predominantly coptic waste collectors (men) and sorters (women) also known as Garbage City and a number of other neighbourhoods of garbage collectors who have divided large parts of the city terrain among themselves to provide services (see Figure 1).

As of yet, the informal segment that has evolved since the 1950s and the much younger state-run system do not cohere as one works via door-step collection while the other provides centralized roadside collection points that are often scavenged or otherwise torn apart by dogs and cats (see Figure 2). While the formal institutions are directly contracted by the Cairo Cleansing and Beautification Authority (CCBA), founded in 1986, the Zabaleen rely on doorstep payment (Iskander, 2010). In addition, contractual penalties for international companies operating since 2003 and side lining the informal sector are very lax regarding pick-up delays. In a city as dense as Cairo with its hot climate, this leads to great health risks and unpleasant visual and olfactory street conditions. Beyond aspects of corruption, the general lack of awareness regarding solid waste, both as a resource and even more so as a health threat are challenging change.

Currently, a number of initiatives are underway to improve the situation. The National Solid Waste Management Initiative under the auspice of the Ministry of Environment is developing policy, legal and institutional framework and providing capacity building at the national and local levels with support by KfW Development Bank (KfW), the European Union (EU) and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and more recently Swiss Development Aid. However, this program is currently not focussing on Greater Cairo, but on other Egyptian governorates. On a local sale, Geziret El Dahab belongs to the Giza governorate, however the island is not declared a priority area. In parallel, the informal sector, is developing mechanisms to formalize. As the current contracts of the formal sector for Greater Cairo are anticipated to end in 2017, the Spirit Of Youth Organization of Manshet Nasr is supporting informal collection practices to formalize by becoming microbusinesses (see http://soyzabaleen.blogspot.com.eg/). In cooperation with the informal sector, previous governments have provided system proposals on how to integrate a separation practice to differentiate between organic and inorganic waste, so far without execution.

The current situation underlines the need for self-initiative by inhabitants and the inclusion of the informal sector on a path to a more sustainable formal practice.

1.3. THE CASE OF GEZIRET EL DAHAB

Already today, Dahab Island has many qualities other cities are struggling to develop: it is car-free, contributes to local food production and composts its organic waste. At the same time its infrastructural and environmental shortcomings offer a fruitful ground for decentralized cyclic solutions. With an estimated 8,000 inhabitants (see Nazer, 2006), the agricultural, car-free island of Geziret El Dahab as one of the protected Nile Islands is a green haven in the middle of the megapolis Cairo. Currently, there is no solid waste management system in place. While organic waste is mostly fed to the animals, an-organic waste is either thrown in the Nile, on its shores, or burnt (Yin, X., Van Wensen, E, 2010). Apart from a missing sewage system and agricultural pollution, this poses the most pressing problem for the island's ecology.

The island lies within the jurisdiction of the Giza governorate. Apart from the supply of drinking water and electricity, Dahab Island has been neglected in terms of infrastructural provision due to its informal state of urbanization and contesting interests regarding its future development (see for example GOPP, 2009:133, Barthels, 2009). It is one of the three environmental protectorates of Greater Cairo (Ministry of Environment). A large section of the island is owned, but currently not cultivated by the Ministry of Agriculture while the Ministry of Water Resources is responsible for the Nile islands and any waterfront development along the river as a whole. The island is self-organized by a mixed Muslim and Coptic community defined by tribal structures. In terms of capacity building, the island is suffering from a lacking representative body both for the community as a whole as for the three villages. While rising costs are making it increasingly unviable to cultivate the fields, the island's agricultural land is decreasing due to two further developments: urban growth triggered by a growing local population and market-steered real-estate development as land prices are rising. Considering all of these factors: the blurry legal status, the contested land and the informal social structure vis-á-vis the obviously urgent environmental degradation suggest a low maintenance solution that could develop further upon success.

Figure 1: Informal and Formal Sectors – Zones served by Garbage Collectors and Landfills in Greater Cairo (based on students' interview with Ezzat Naem and site visits, graphics: A. Faisal, M. Bargash edited by S. Sherif for "Designing Cycles Waste and Water", elective course, GUC Architecture and Urban Design Program)

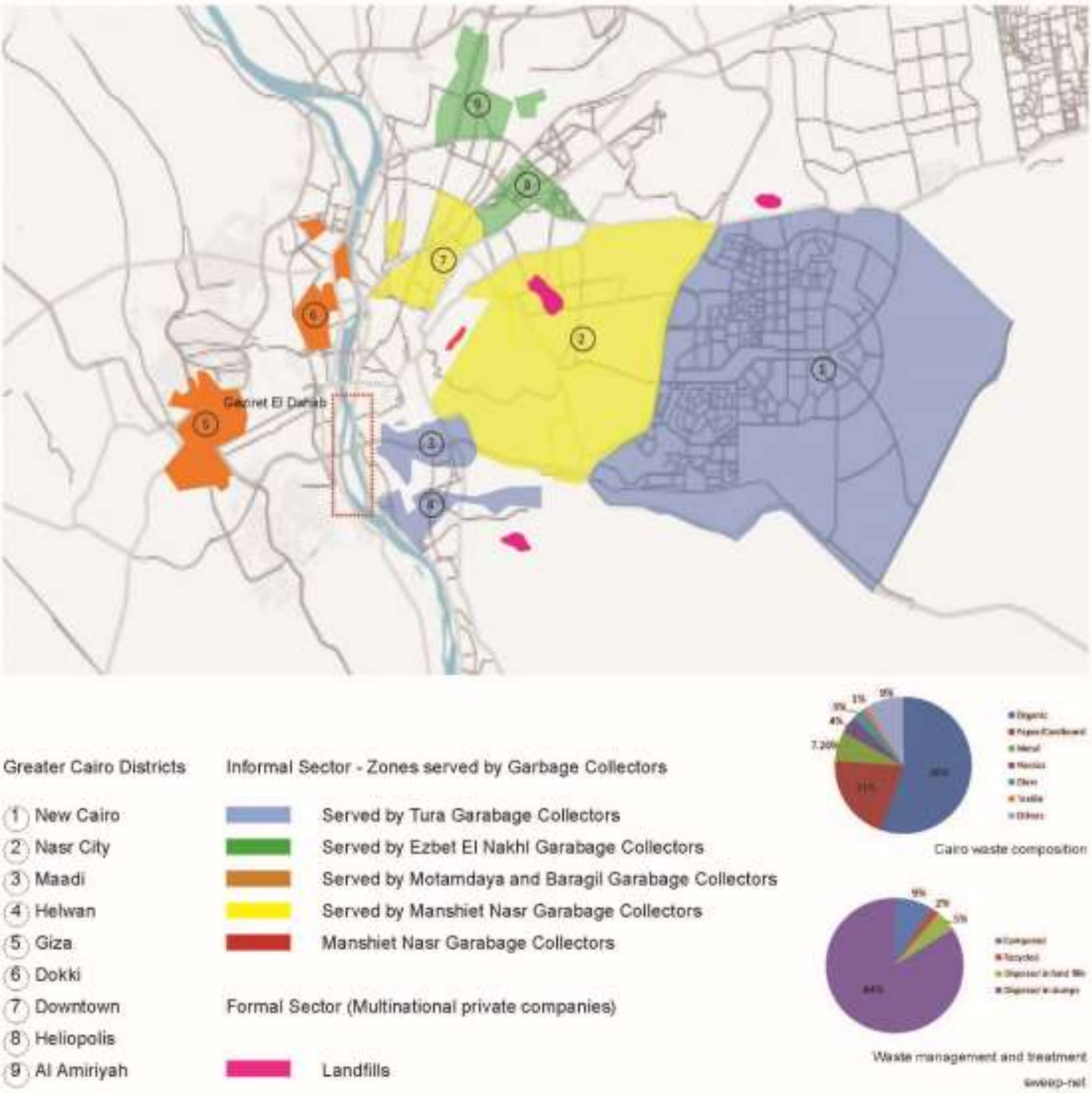
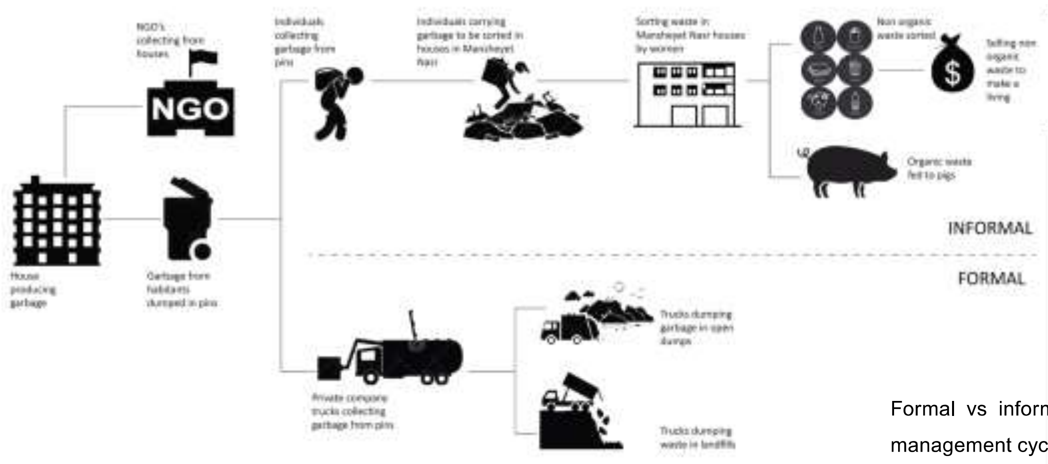
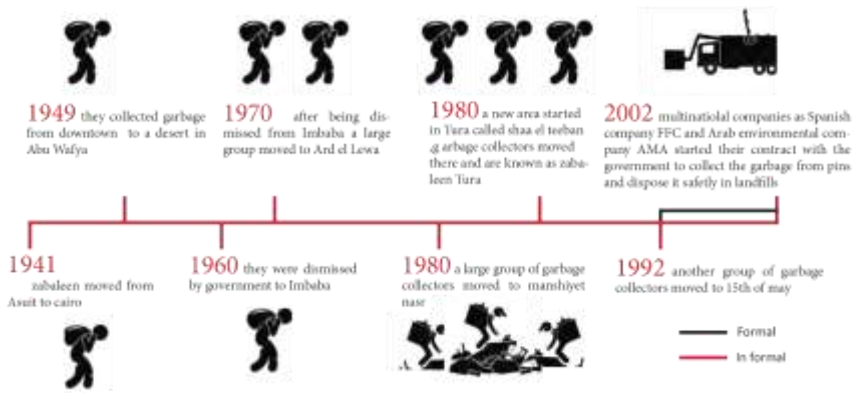


Figure 2: Evolution and Building Typology of Formal vs. Informal Waste Management Cycles in Greater Cairo (based on students' interviews with Ezzat Naem and site visits, graphics: A. Faisal, M. Bargash edited by S. Sherif)



Formal vs informal waste management cycles in Greater Cairo

Manshiet Nasr housing typology



Evolution of formal / informal waste management system in Greater Cairo

1.4. RESEARCH METHODOLOGY

The action-based research outlined is a collaborative project by the GUC Architecture and Urban Design Program and Fayoum University of Geography under the umbrella of the Nile islands Initiative and includes

- A household survey to understand the willingness and preferences of the inhabitants
- Potential models of solid waste management on and off the island
- A test-run of waste collection in cooperation with Ihlam, a student's environmental group, the islanders and the Zabaleen of Manshet Nasr
- A SWOT analysis of four customized SWM models for the island

It aims to evaluate the spatial, legal and socio-economic parameters for the installation of a solid waste management system on the island and is part of the Nil based on the hypothesis that a community-based participatory research approach provides multiple benefits in the public health sector (Minkler, 2005).

1.4.1. Case study Bahareya village

For this research, the village of Bahareya to the North of the ringroad with an estimated 200 households, serves as a case study. The village hosts one of the islands' main mosques and its only Coptic church. It is connected to the city by a falucca, or motorized ferry when there is no wind, mooring at Maadi Corniche around the clock.

1.4.2. Household survey

The household survey was conducted in the winter of 2015-16 by students of the geography department of Fayoum University covering 100 households in Bahareya village. It aims at providing a better understanding of the inhabitants current awareness and willingness to participate.

1.4.3. Model development

The different models were developed by GUC architecture and urban design students under the supervison of Prof. Cornelia Redeker as part of the course Sustainable Urban Development in the winter term 2015-16. It involved a human-centered design approach including the formualtion of a joint framework and questionaire and resulted in different proposals that were visualized in process diagrams and graphic representations pairing the inhabitant's feedback and the spatial survey on the island with expert consultations off the island. These models informed the four alternatives discussed in this paper: Model 1 Door-Step Pick-Up, Model 2 Central Collection Point, Model 3 Central Boat, Model 4 Garbage Sorting Plant on the Island

1.4.4. Test run

A 24-hour test run was conducted in cooperation with the villagers to

- challenge the general opinion that people do not mind the garbage and
- evaluate the willingness of the inhabitants to participate in solid waste management as a household
- estimate the level of awareness to differentiate between organic and anorganic waste

It further tested the the ferry operators' willingness to move the collected waste from the island to the mainland on the given ferry, as well as the Zabaleen's to collect it from the mainland ferry stop at a given time. The test run was carried out by the GUC architecture student environmental group Ihlam with a group of international students from AIESEC, a global student-run initiative addressing world problems, leadership and management (see http://aiesec.org). It involved

- preparing a flyer to inform inhabitants
- door-to-door briefings including bag sales
- collecting the bags at the doorstep the next day
- transporting it to the mainland by falucca by the ferry operators
- pick-up by the Zabaleen from the Corniche

The test run most adheres to Model 1.

1.4.5. SWOT analysis

The SWOT analysis looks at the four proposed models based on the insight gained from the household survey and the test run to evaluate a short and possibly a long-term solution and the demanded commitment by all in terms of self-organization.

2. FIELD AND ACTION-BASED RESEARCH

2.1. HOUSEHOLD SURVEY

Field results showed that 75.8% of the sample are willing to participate in solid waste management of which:

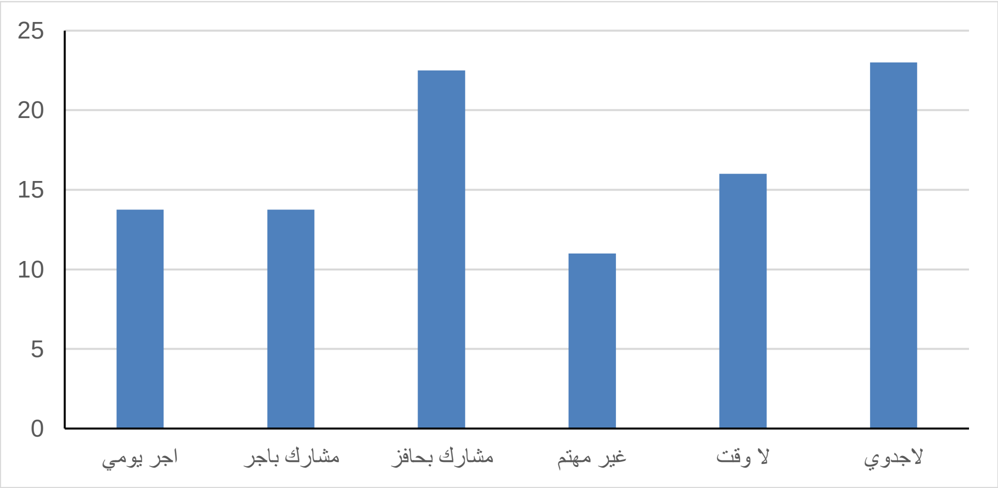
- 59.4% limit their participation to collecting their waste at home and leaving the rest of the process to someone else
- 27.4% are willing to collect and separate the waste
- 13% are willing to help throughout the process, from collecting, classifying to selling the waste
- Some other inhabitants showed no interest and unwillingness to participate in the whole process

58% of the sample are willing to participate for money in return, and this value varies:

- 45% wants ration goods in return (which may again be incorporated in a cyclic model)
- 27.5% wants to get more than 100 LE per month
- 27.5% wants to earn between 50 to 100 LE per month
- While one case only is satisfied with 50 LE per month

Figure 3: Participating to non-participating ratio of inhabitants in SWM measures

(Nazer, H., 2016)



Paid daily / paid participation / participation with encouragement / not interested / no time / indifferent

2.2. TEST RUN

2.2.1. Process

The test run took place over a period of 24 hours and involved passing out 130 70l plastic bags to the individual households after prayers on Friday to be filled with anorganic solid waste by the inhabitants until the next day at 2 PM. This makes up about 65% of the village households. According to GIZ estimates in this context one can count 0.25 kg of anorganic waste per inhabitant amounting to 2.5-3 kg per household on average and 600 kg in total per trip. The test run further involved a door-to-door briefing supported by a flyer. Everyone who wanted to participate was asked to pay 1 pound upon receiving the bag as a symbolic price to signal that this service would not be for free in the future.

2.2.2. Outcome

All 130 bags that were handed out were found in front of the doors at 2 PM the next day as demanded. The transport from the island by the ferry operators was not previously announced, but worked smoothly without any extra fees. The Zabaleen were on time on the Corniche side to pick up the collected bags. Unfortunately, not all bags were exclusively filled with anorganic waste. The test run showed the willingness of the inhabitants and the need for awareness building regarding waste as a resource (not to mix anorganic and organic waste).

2.3. POTENTIAL MODELS

The four alternatives compared were extracted from a number of models according to their potential for realization. A model previously discussed by the islanders and the Ministry of Environment that would lift the collected waste up to the Ringroad Bridge for pick-up was not considered as a truck stopping on the bridge would produce a severe bottleneck for the already stagnant Ringroad traffic. The following figures 4-7 elaborate the tasks of the different actors followed by Table 1 that summarizes the estimated demands in terms of infrastructure, manpower, initial costs and running costs, the potential business models and the expected fees for the inhabitants (not including initial costs) of Models 1-4.

2.3.1. Models 1-4 Responsibilities

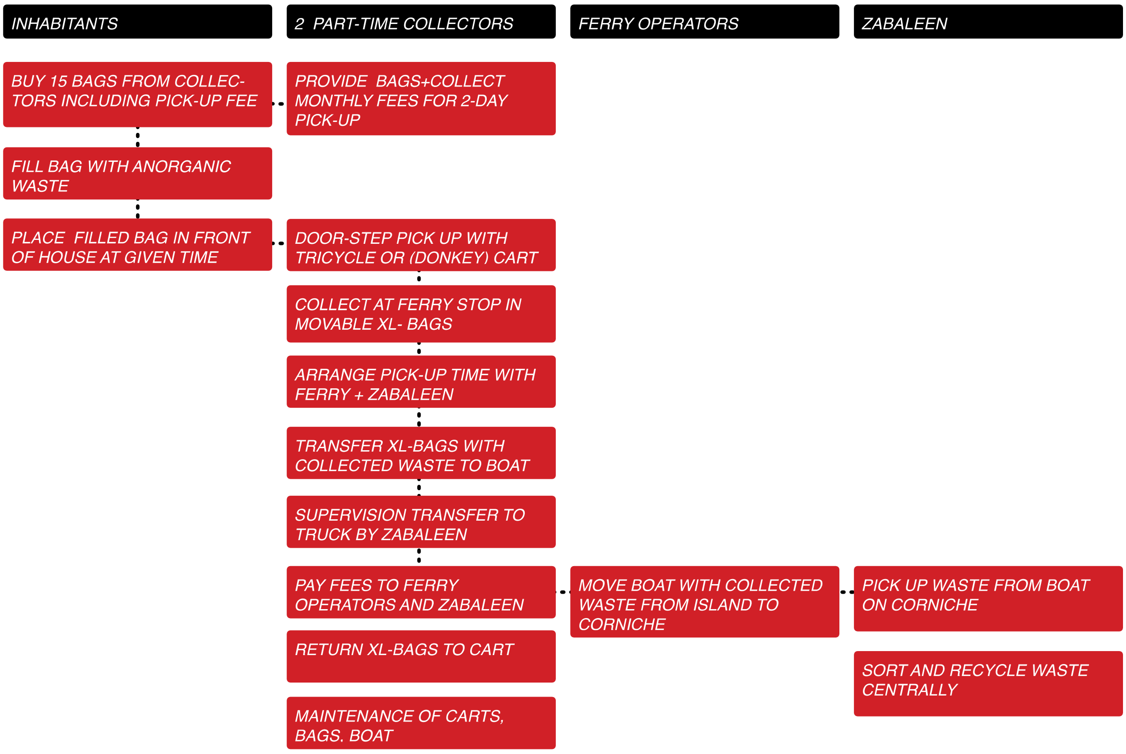


FIg 4: MODELS 1 DOOR-STEP PICK-UP (Redeker, C., 2016)

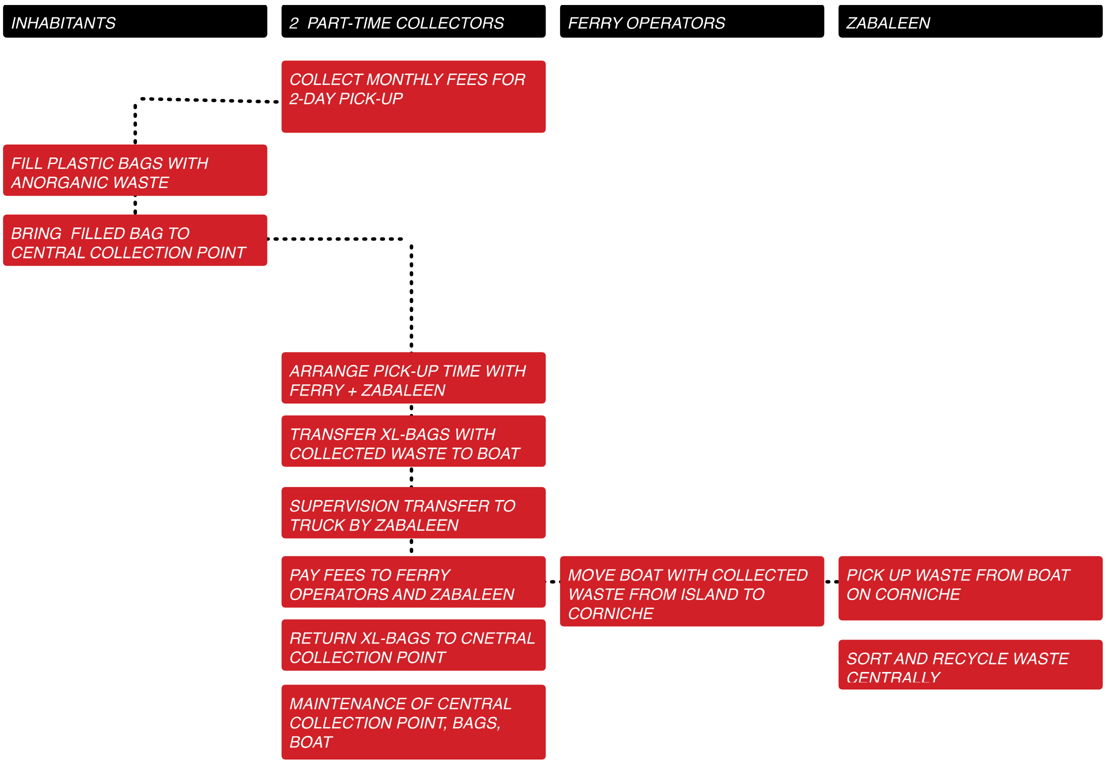


FIg 5: MODEL 2 CENTRAL COLLECTION POINT (Redeker, C., 2016)

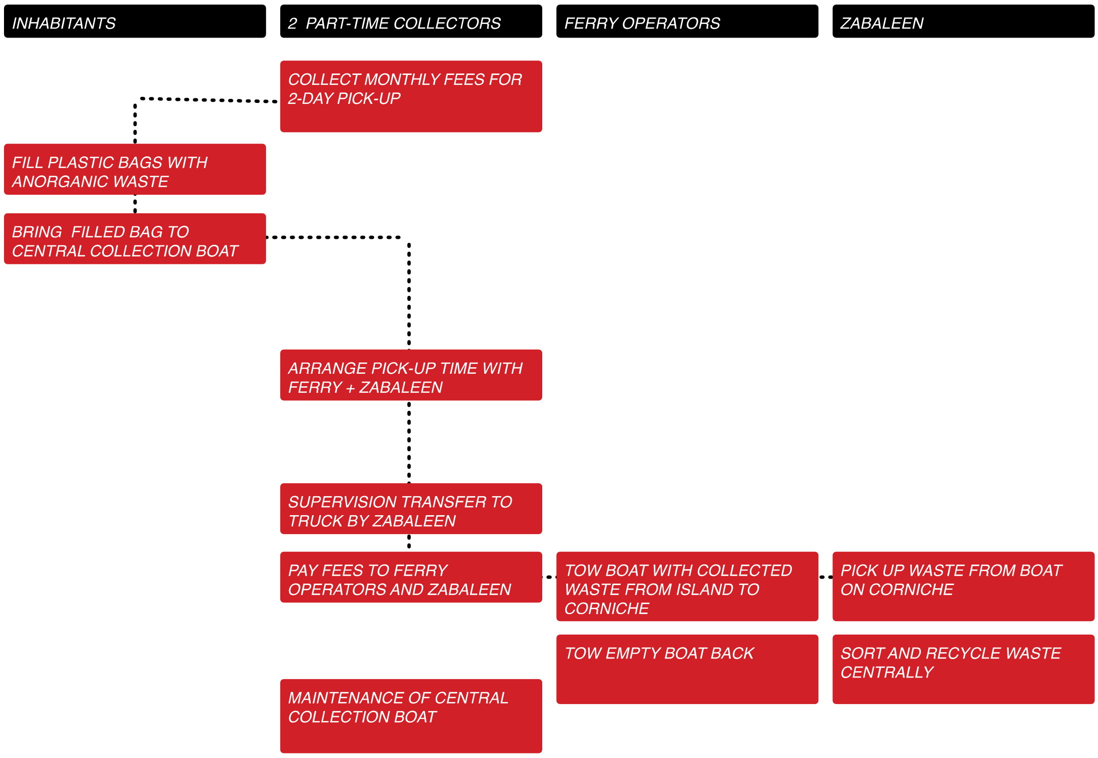


FIg 6: MODEL 3 CENTRAL BOAT (Redeker, C., 2016)

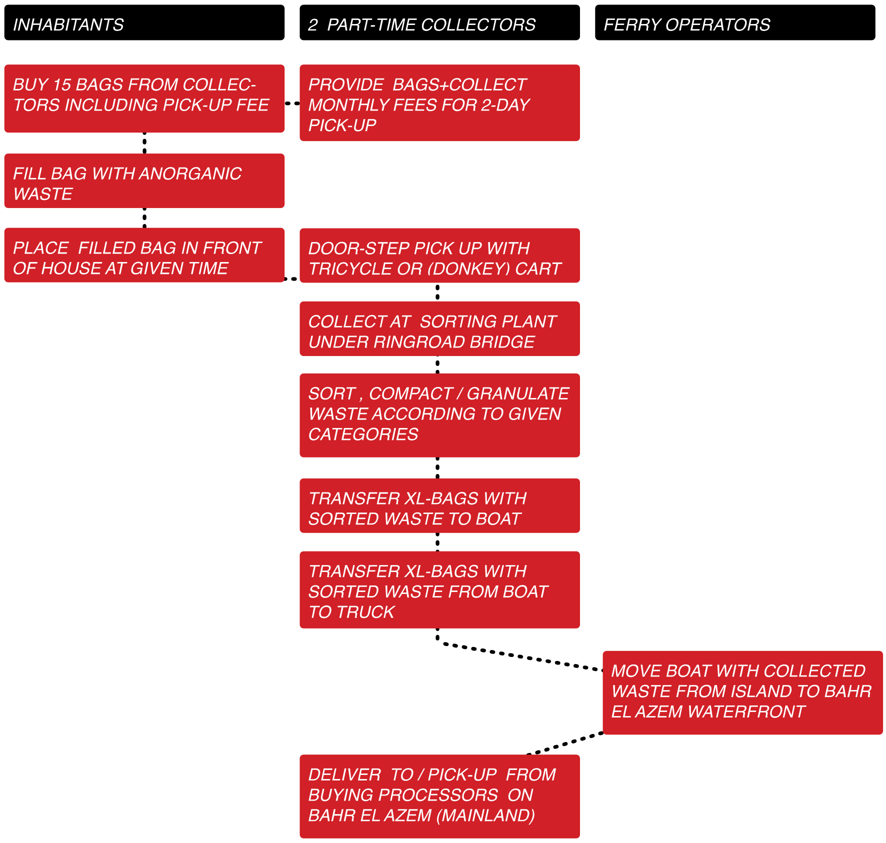


FIg 7: MODEL 4 GARBAGE SORTING PLANT (Redeker, C., 2016)

2.3.2. Model 1-4 Needed resources

MODEL	Infrastructure	Manpower	Initial investment	Fees inhabitants/ household/month	Organization	Permission
MODEL 1 DOORSTEP PICK-UP	donkey cart or tricycle XL-bags existing ferry use	2 part-time collectors and movers	donkey cart or tricycle 2000 egp	20 EGP / household / month	microbusiness	no permission
MODEL 2 CENTRAL COLLECTION POINT AT FERRY	central collection unit XL bags existing ferry use	2 part-time movers	initial investment 800-1000 egp	15 EGP / household / month	microbusiness	no permission
MODEL 3 CENTRAL BOAT	falucca with collection units XL bags existing ferry for towing	2 part-time maintenance worker	9000 egp	15 EGP / household / month	microbusiness	Ministry of Water Resources and Irrigation
MODEL 4 GARBAGE SORTING PLANT ON THE ISLAND	donkey cart or tricycle XL-bags sorting station existing ferry use	min. 10 full-time collectors and sorters	200,000 egp	20 EGP / household / month	Small-scale enterprise	Ministry of Water Resources and Irrigation Ministry of Environment Ministry of Transportation Giza Governorate

3. SWOT ANALYSIS

3.1. Based on the current conditions in Cairo, and the specific situation of Dahab Island, the survey results and the test run and model development, we can conclude the following parameters for the SWOT analysis:

- self-initiative friendly involving inhabitants and informal sector
- low maintenance solution
- job creation
- low demand on resources
- potential to develop further upon success

Table 1: SWOT Analysis SWM models Bahareya, Geziret El Dahab, Cairo (Redeker, 2016)

MODEL	STRENGTHS	WEAKNESSES	OPPORTUNITIES	THREATS
MODEL 1 DOORSTEP PICK-UP	no land needed more service for inhabitants cores-ponding to survey results no permission	costs for inhabitants higher than M2, M3 garbage bags in the street attracting vermin	microbusiness model could be applied to Ringroad bridge site to serve other two villages	animals tearing bags apart reliance on households to place bags in time
MODEL 2 CENTRAL COLLECTIO N POINT AT FERRY	less costs for inhabitants than M1+M4	land needed potential smells, etc.	microbusiness model could be applied to Ringroad bridge site to serve other two villages	negative impacts on central location (Smells, etc.) but also hindrance to manoeuvre other goods
MODEL 3 CENTRAL BOAT	1 step less in moving waste no land needed away from land to avoid conflicts	initial investment higher central mooring site needed	microbusiness model could be applied to Ringroad bridge site to serve other two villages	Nile Authorities may respond negatively as this model is unprecedented
MODEL 4 GARBAGE SORTING PLANT ON THE ISLAND	larger scale job and income generation more independence costs for inhabitants if not participating in initial investment same as M1	initial investment highest long-term development complex permission process (Ministry of Water Resources and Irrigation, Ministry of Environment, Ministry of Transportation, Giza Governorate)	small-size enterprise expandable: use of derelict land under Ringroad could host further programs for example to produce biogas	lacking value of island waste to ensure economic viability

The SWOT analysis shows that M1 provides the biggest service to the inhabitants and avoids the potential conflict of installations in the limited public space (M2). M2 and M3 provide more economical solutions with a lesser job creation. M4 may be a long-term solution that is most adherent to become an expansion of M1. Legally speaking, M1-3 could probably be brought to practice without any permissions as long as the Nile Authorities accept the boat use. For M4 the permission procedure is complex due to the number of authorities involved, the unclear legal framework and the unprecedented situation. It would need further evaluation, maybe as one of M1-3 has been installed, to estimate cost-benefits of the islands produced waste. As it may provide a number of jobs on the island and serve all three villages centrally, M4 should be taken into account as a further solution. With the current governmental focus on business development, the formats of Community Development Association, NGO or PVO (private voluntary organization) registered with the Ministry of Social Affairs (Iskander, 1994) may not be the right format, therefore the focus lies on microbusiness and small-size enterprises.

4. CONCLUSIONS

The research carried out looked at a limited number of parameters to evaluate ad-hoc solutions to solve the current waste management problem on Geziret El Dahab. An action-based research approach was chosen to challenge a number of preconceptions. Many endeavours in the informal context fail due to unexpected banalities based on human shortcomings and lacking frameworks to ensure reliant services. Although not included in this research, all solutions would need an awareness-building and communication initiative to educate and brief the inhabitants on their benefits and role in order to function. As a next step, the religious institutions would be asked to get involved in order to present the proposed models and to ask for funding of the needed initial investment.

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VISUAL ABSTRACTION

A MAGIC TOOLS FOR CREATIVE SUSTAINABLE BUILDING PROCESS

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Abstract: *Visual Abstraction has a great power that opens gates for synergetic creative processes. On a personal level, it was seen how it smoothly integrates the oddest parties to produce amazing outputs.*

Visual language is a common language that anyone can understand, regardless of their verbal language or academic level. On another level, abstraction breaks the barriers between one and his creative thoughts, it opens the doors for options and divergent thinking as it frees the mind from preconceived ideas. When both combined together as 'visual abstraction' even deeper impacts may be achieved, as it highly motivates thought integration. All levels of people are able to integrate in a single creative process. It was found for process to act as a catalyst for creativity it should be visual, active, social, fun and event like. To keep it creatively flowing it should be kept spontaneous and free, more like a hands-on 'design while you build' process. In this process the community, architecture students, and lecturers, share and implement their ideas, helping the students to feel their community, and the community to feel the building process once again. Hence everyone becomes the owner of the outcome, ensuring sustainability. In this process, technology is used only to present, integrate sensors and to detail. The outcome of this synergetic process is uncountable. Sustainability becomes beyond the environment, it is inside the participants. In this complex diverse world, future students should be prepared to creatively integrate through educational channels.

Keywords: Visual abstraction, creativity, building process, community, architecture students, education

1. Introduction

Abstraction is a global method of thinking. Everybody uses abstract thinking at one time or another. Abstraction is a level of mental functioning that allows flexible creative thinking and multi dimensional communication . It is an essential level the brain goes to, when open innovative thinking is required. There are several levels of abstract thinking that a person mentally selects as the level to think with, depending on the situation(Michalko,2001). Visual thinking is an effective tool for creative thinking that allows imagination and provides a shared common language, especially in participatory projects (Kheir,1999). From live experience, when visualization is shared with abstraction, the communication and innovative level goes to another deeper dimension.

In a world where technology and diversity is rapidly growing, the need for innovative multi disciplinary communication is becoming undeniable. There is a need for a process and tool to enhance and empower multi levels (educational, social, etc) to flexibly and effectively interact. This would help ensure an outcome that is more satisfactory and sustainable for this massively multi dimensional changing world.

In the field of architecture and planning there has been increasing complaints that the built environment is becoming less and less satisfactory for the user. Even with the use of visual tools, calls have increased demanding more effective participatory approaches, and to relook educational approaches in architecture and planning(Saki,2008). Some approaches have discussed teaching children architecture from school level (Judith and Cox, 2003). Some argued that architects should be trained to design/build their projects with the community(Carpenter,1997). Others have discussed visual tools to help the community interact with their ideas(Kheir,1999). Another approach focused on the architects' education to become innovative and multi-disciplinary(Nowark,2007).

From the author's view, studies and explorations, all the previous points can become more feasible if integrated in a single flexible visual frame work that focuses on the use of visual abstraction, using the proper level of abstraction in relation to the situation and triggering synergetic creativity .This process can be enhanced through education channels to prepare both the community and architecture students to be able to communicate creatively using abstraction. ***This paper addresses this process questioning which level of abstraction to use with who and how?***

2. Literature review

On an International level, lately participatory projects showed that professionals fail to understand the user and explore the psychological and sociological aspects of their built environment (Marcus,1998). It was suggested that a step preceding integrating the community in a creative building process is required, namely architecture education. There has been a global action for architecturally educating the community for two reasons. The first is to help sustain this environment, especially by addressing children, and increase positive participation of the community. The second, is to raise perception, learning abilities and creativity of youth(Saki, 2008)***.*** Actions taken around the world, follow three main paths. The first is directly through schools' curriculum, especially elementary education, integrating architecture students/professionals and artists with the school students. The second is through integrating universities and faculties of architecture in experimental research and education programs with the community through design/build programs between architecture students and community(Carpenter, 1997). The third alternative is through community based art programs by municipalities, integrating youth/ artists, fine arts and architecture students with community (Nowark, 2007)

Although abstraction is the preliminary level for open communication and creative thinking (Mickalko,2001), only a few humble attempts from the previously mentioned approaches have used it. In the first alternative, mixing architecture students with children at school, In an experiment by 'Connection' the children were given a project titled 'Designing a Personal Space'. In the first step they were asked to explore 'feelings behind a space' using spontaneous approach that relies on no preconceived ideas but on abstract paintings. These abstract paintings were translated to three dimensional clay models of a 'habitable space'. Evaluation stated that the level of understanding that emerged from the project was impressive, showed high understanding of meanings and feelings of space, and in relation to other projects that did not use abstracts was deeper(Judith and Cox, 2003).

In the second alternative, through community based art programs, there were several attempts. Using lower levels of abstraction, artists and designers were engaged with communities through festivals and art activities in a place(Nowak, 2007). There have been several programs to support such activities like 'Philadephia Mural Arts Program' , 'Re-imaging Communities Program' and 'Bario Center Murals'. The outcome shows high integration and motivation.

In the third alternative, in the field of architecture education, some attempts have focused on architecture students using visual abstraction. In an attempt educators use abstraction to turn verbal thinker to visual thinkers using abstraction, by using open ended words (Habib and Jafari, 2006). In another attempt educator uses abstract clay modeling to provoke each student's personal subconscious thinking and personal mental images to be the base for creating new conceptual ideas. In this approach students are given open conceptual titles for a project (a single word concept that does not have any preconceived ideas) that they are supposed to reflect on his/her own understanding using flexible material .This is first expressed verbally then transformed into a visual abstract. Educators concluded that this open the door for architecture students to think openly and divergently, and proved to help them shape their own views and opinions(Ozek, 2007). In another attempt educators rely on another level in abstraction, symbolism and metaphors, transforming later to higher level of abstraction using generative processes. Educators emphasize that the focus in early architecture education should be on the process not the outcome. They argue the need for multi disciplinary and generative pedagogies in architecture education and that it should be flexible, self motivated. They start their approach with a diagrammatic exercise to promote conceptual and metaphoric visualization. Out of a pattern in nature, students are to induce a 2D pattern through layers of diagrams and change it to 3D form. With the help of small scale modeling and computation, the forms produced are transformed into real units out of malleable materials. Assembling them through a generative hands on design/ build process, using multi materials. The educators conclude that experiments showed that generative process motivates the students to be actively creative and allows both the educator and student to be at a state of continuous research, provoking their imagination and visualization (Jackson and Marinic ,2012).The same method is used in Ball and Nogues studio, in which students create together an abstract useful construction, using high level of abstract visual creative synergy hands-on process, out of a unit made of flexible material. The outcomes are creative, homogenous, of value products, that show high integration and synergy (Van Klot, 2006).

Abstraction is a process of conceptualizing ideas, making them more general. It uses a strategy of simplification, details become vague and undefined. It is the basic theory for restructuring a problem, looking at it from a new perspective. This is why it is an essential preparatory stage of any creative process (which is known as the making of something new from old, original, of value, imaginative and purposeful). In the preliminary stage of creativity, the mind has to be liberated from preconceived ideas, removes obstacles, trigger emotions, and becomes capable of thinking in a divergent manner, which abstraction does (Mickalko, 2001). In this step verbal abstracts have to be turned to visual abstracts in the subconscious (Buzan,2005). Creativity is a very complex internal/external process made of several stages (Bytterbier *et al,*2007). It is closely linked to visualization(Allen,1999) which forms a major key to creativity (Sasson2011). Visualization is defined as the ability to see in one's mind (Runco, et al,1999). Visual Tools are tools that promote visualization using visual language and are positive creativity promoters that enhance communication (Graines *et a*l, 1993). They are nonlinguistic symbol system used for graphically linking mental and emotional associations to create and communicate rich patterns of thinking(Hyerle, 2009)

One can always look at things from different levels of abstraction. More specific stated problems lead to quicker solutions but less conceptual creativity than generalized statements. To think more open and to derive deeper solutions and new horizons from the old, it is essential to spend more time at selecting the right level of abstraction required. Einstien, Galilio and other thinkers chose high levels of abstraction to think with. Restructuring problems by making it more abstract helps to eliminate barriers that result in preconceived notions of what an idea or a solution should be like. It forces you to test assumptions and explore possibilities(Michalko, 2001).

One of the mental principles used to promote creativity is synergy. Collaborative or group work promotes creativity. In a synergetic system the whole is greater than the sum of its parts; in other words one plus one does not equal two, but more.. Being able to collaborate creative ideas magnifies the positive outcome of creativity (Buzan,2005).

In the field of sociology and psychology, abstraction has been looked at from the point of view of how it can combine people and the importance of intermediate levels in abstraction in achieving that (Fernandez1990).Communities and total strangers can be combined when abstraction is introduced.(James,2006) . Abstraction is a good tool for effective group communication and group thinking. It helps reaching synergetic creativity. In the process of using abstraction in a group, it starts from the highest level of abstraction, going gradually down step by step, till four levels below are reached. The solution comes by collecting all the outcomes they have gathered together in the five steps of abstraction and then getting an inspiration for the real problem definition and solution (Michalko, 2001)

Since ages ago, the language of art and visual expression has always been a simple tool for communities to communicating and express their emotions. Expressing emotions and feelings helps forming communicative languages and reaching creative visions.(Langer, 1953). Simplifying these symbols into metaphors and abstraction empowers everyone to communicate and express themselves (Ylvisaker, 2006). The visual language has been for long thought of as the tool for participation, yet the correct visual tool has not been always used with the right group (Kheir, 1999).

From the previous literature, when abstraction is mixed with visualization, can become a powerful visual tool for creative group work and synergizing creativity. Yet, it has been introduced on a humble level. The author, from research and explorations, observed that it's a powerful visual tool that should be taken to a deeper level. Abstraction is not simply a tool to use with children, but has multi dimensional impacts on any level and empowers literally anyone to express and communicate ideas and synchronize creative thinking to uplift the quality of the out-product. Everyone becomes a real partner. Without feeling empowered, and reaching sense of belonging, sustainability cannot be discussed.

The author in her work in teaching architecture, research, and field work as a creative designer of socio-physical educational environments and a visual socio/physical developer and consultant, has focused on creativity as a process and visual tools as enhancer for creative building process for the last eighteen years. Although visual tools have shown effective results, but abstraction in specific has lately triggered personal attention and focused explorations and research. It showed to be effective in communicating more creatively any social, academic, educational, cognitive or economical group, and in any course related to architecture. Boundaries seem to ease and mutual understandings seem to be enhanced, and a creative out-product with a deep insight is the usual outcome.

3. Research Methodology:

In this paper, building on my PhD and post research, I am trying to explore, analyze and put together in a complete frame work, a visual abstraction educational process and practice for commutative multi-disciplinary creative building process(Abdelatif, 2013). This process is meant to empower future planners and architects to work in participatory multi disciplinary projects that empowers the users to express, create and implement a built environment that reflects his/her real needs, and integrate different fields in the process, using abstraction. The complexity, prolonged research time and page limitations, did not allow the author to present all the explorations done and show the complex integrated relations to different scientific background.

The first question is: which level of abstraction to work with *who* and *how*? The second question: *how should the process go?* Backed up with literature review and research, and time(fifteen years) the process of exploring has taken two layers.

The first layer explored in the field of *development and creative design*, trying to explore how effective is abstraction of different levels with different categories (social , academic, economic, educational and cognitive) in communicating effectively and provoking creative work. Also which level of abstraction should be used with each category or set of people, and how effective would that be in reaching sustainable development. The second layer explored in the field of *architectural education*, further exploring and implementing the outcome of the first layer. Here the topic to be explored was how is visual abstraction effective as a tool for promoting creativity in architecture students, and how it would enhance creative synergy between lecturer and architecture students, architecture students and each other, architecture students and non engineer students, and finally architecture students and different community levels.

What was tested? For both layers what was tested was, *which* level of abstraction, to use with *whom*, and *how*? In both layers two things were tested; the level of abstraction required, in relation to the category studied, and how effective and creative the communication has been through the out-product produced.

How was it measures? Unlike many researches in the field of architecture, the outcome is more qualitative than quantitative. The outcome is more integrated with fields of psychology, neurology and creativity, hence the methodology of measuring, as in fields of psychology, depended on 'repetitive patterns' and 'Torrance test of creativity'. Torrance tests used were figural tests of creativity; 'suppose that' and 'design task' tests which are up to this date the most reliable tests in creativity (Torrance ,1960).When one categories was measured the other categories were kept constant.

In the first layer; work was done on informal settlement communities in Great Cairo (namely; Boulaq, Agouza, Mansheyet Nasser, El Wayeli),working with CARE, GTZ and Future Foundation. The work was either targeting designing/building or renovating creative educational spaces and visual nodes (schools, open theatres, libraries),or simply enhancing creative abilities in a community for them to be able to take creative decisions and actions regarding developing their own built environment. The groups targeted were: children (school and street children) of different cognitive levels, youth,, women and teachers. At all cases the economic level is constant and is considered low.

The process of exploring was always guided by the stages and details of the process of creativity. It always started from very high levels of abstraction to remove fear of not knowing or being up to the level. The work of abstraction starts with them as individuals, each painting a two dimensional abstract individual painting that expresses them, then moving on doing the same but as in three dimension, using a flexible material as clay or dough. The step after was to analyse each character through their abstracts, and relying on studies related to abstraction, creativity, colour therapy, electromagnetic fields and water therapy, remove obstacles hindering creative interaction(Abdelatif,2013).The process carries on in descending manner with abstraction, working mainly in middle levels of abstraction, till results are satisfactory enough to be turned into a physical out-put or renovation through a hands –on process, or intermediate level abstract models and drawings that may be transformed into a professional output using different CAD software. The process is kept fun and self motivating (Abdelatif,2013).

The flow of the process varied with each category. Children required less time to be ready to implement creative team work. They did not need the step of character analysis and obstacle removal. Youth and women required longer periods as there is usually a layer of obstacles, and negative impacts from the socio/physical environment, blocking creativity. Preparatory steps previously explained have to be done before creativity may be released and they get prepared to forget their differences and integrate in a single creative abstract synergetic work. Depending on their socio/physical environment and its impacts on them, preparation time required may range from one to two years. Figure 1 shows samples indicating the process flow on the different categories.

Figure 1.Samples of the flow from high level abstraction to intermediate level on the different categories in informal settlement

What about if no preparation has been done, may they still communicate in an effective creative product that expresses their real needs using abstraction? In an experiment done with GTZ in Boulaq, random groups were selected from the street, three groups made of 5-6 people per group from each category. Categories resembled children, men, and youth (women were more difficult to collect randomly due to cultural habits). Figure 2 shows samples of working with unprepared groups from different categories using intermediate visual abstraction.

Figure 2: Working with different unprepared spontaneously selected groups from a single category using intermediate visual abstraction

The results showed that children develop more positive and imaginative outcomes, in intermediate levels of abstraction. Youth showed a lower level of abstraction and imagination, while men showed rigid reactions at the start and inability to integrate that soothed down as they touched and shaped the clay and got motivated by the process. Men showed the lowest level of abstraction giving more rigid details. All groups showed an ability to communicate within intermediate level of abstraction and flexible material. When trained through the previously mentioned process, it improves the quality of the interaction and synergetic creativity, and reduces conflicts. The models produced then, or renovations, are imaginative, original and homogenous and have story telling as stated in Torrance tests. The resultant renovation or built environment was followed up for three years. It was found that it was preserved, protected and developed by the community as they felt it was theirs and they were proud of what they have thought of and achieved with their own hands. The door to sustainability was opened. Figure 3 shows samples of the outcome of different categories.

Figure 3. Samples of the final steps and outcome by different categories, models and renovations.

In the second layer; work was done through educational channels, targeting architecture students, to enhance their creative abilities and their communication skills for better and more sustainable out-products. Same process used with the community was followed with architecture students. The process was repeated in relation to the course (Design 1,Design 2, Design 3, Visual Studies, Acoustic and illumination, Illumination Design and Feasibility in Urban Projects were the courses attempted). According to the course, levels of abstraction were chosen (in courses that required an integration between creativity and technicality, like feasibility and illumination, the process went to lower levels in abstraction).The universities selected ranged from high economic level to lower economic level (Modern Academy, Fayoum University Science Valley Academy, Arab Academy for Science and Technology, Misr University for Science and Technology, and the Canadian International College).

The process tested students as individuals, students with students, architecture students with students from non engineering departments and finally architecture students with community. The process was always related to outdoor events to keep it a motivating fun process, that benefits from open visual fields and greenery for triggering creative thinking. The first step always consisted of an individual abstract painting. This abstract painting was found to allow the lecturer to understand each character (over time a 'repetitive pattern' appeared that describes the type of character and problems its has). This abstract painting also allows each student to be able to become open thinkers in whichever course, free them from fear and build their self confidence, break borders between the lecturer and students, and helps the lecturer to understand the composition of the students and accordingly set the levels of abstraction required in the process. Again the process goes from2d to 3d abstracts, releasing emotions and mental images, till it is felt that their souls and minds have become free. Figure 4 shows samples of the first step.

Figure 4.Samples of the first step with architecture students, 2d and 3d high level visual abstracts

The second step is to get them to work as groups ,using levels of abstraction from high to intermediate. Abstraction is used to emphasize the meaning of conceptualization and having a value in each person's project, to reflect back on the community. It is done using plactecine(mixing touch and vision triggers images from the memory, with the aid of abstraction that helps imagination flow with the use of images retrieved from memory /reticular system). As they work in groups with time, each project has to start with a high level of visual and mental abstraction to reach open thinking, then goes down to less abstract levels. Metaphors and symbolism (that are also intermediate levels of abstraction) has been used in more technical courses that required lower levels of abstraction. Figure 5 shows some samples from the second step.

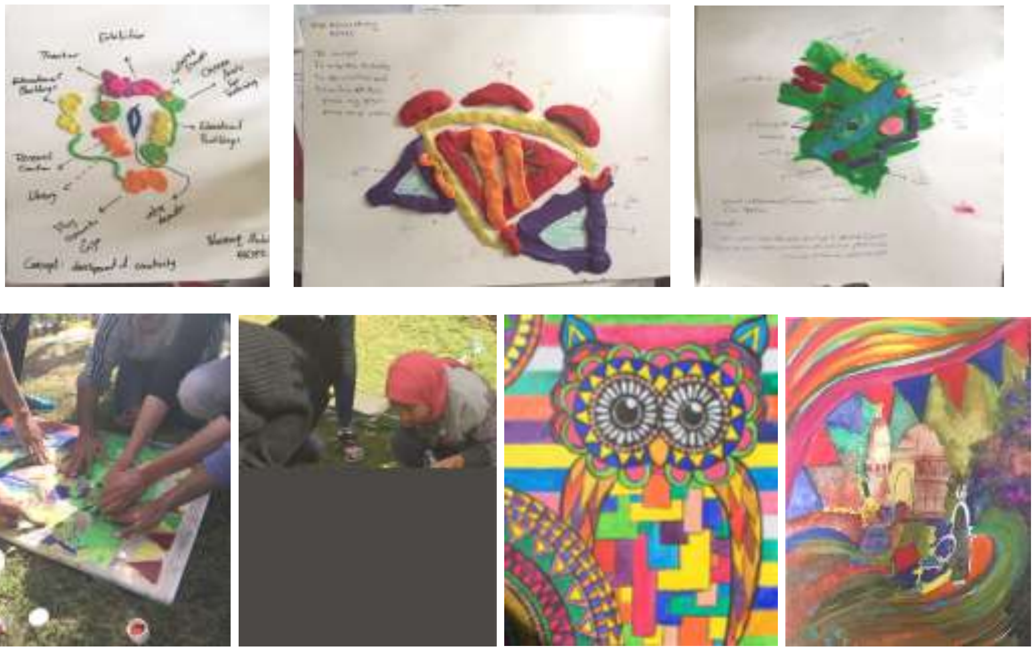

Figure 5: samples of the second step with the students, mixing them in groups using intermediate levels of abstraction, like symbolism and metaphors to reflect concepts and values

The third step is to engage them in a real hands-on abstract event that allows them to engage and think spontaneously together on very free basis, as in figure six. The out-product is a 1:1 creation that they can all see and value. The more homogenous the out-product, the more it describes how abstraction has succeeded with the group to help them think commutatively using synergetic creativity. This live group abstraction event is a turning point. It triggers high communicative and creative synergy inside them, and all the coming shared group projects escalate to another dimension, refer to figure 6. In some courses like feasibility studies, the lecturer may refrain from using abstraction and assign real group projects. The architecture students automatically from now on are capable of synergizing and mentally abstracting their thoughts together.

Figure 6: The final step of the live hands-on visual abstract event boost their ability to synergise their creative ideas and work together homogenously

The fourth step aims to turn them to work in multi disciplinary projects. Architecture students were required to find out the image of the university that students from non engineering departments dreamt of using abstract modeling. The non engineering students usually refrained at start, afraid as visual language is not their tool, but the abstraction helped them integrate their thoughts quickly and smoothly and highly motivated and interested them. Architecture students were asked to present their work with the non engineer students and analyse. Most groups commented that the process was fun for all parties and that communication and expressive levels were high. They were able to feel the real character of the students making the models and their original thoughts. They also states that it is a more effective tool to use than verbal methods.

The final step is engaging architecture students with the community. This step was usually very hard to reach, as by that time the term would have already passed, or because of restrictive rules of the university. The author usually had to do so in the summer time and engage architecture students in her own field work. Architecture students who did engage found it easy to understand a totally different community structure and engage with them using abstraction, regardless of all the background differences, they said they felt something was common. Figure 7 shows samples from the fourth and final step.

Figure 7: the architecture students integrating with students from business and community using intermediate levels of abstraction effectively in the fourth and final step.

Observed results is that abstraction helps students get over their fears, enables them to communicate effectively, triggers their emotions and sense of others and creates an unexplained emotional bond between the students. It enables them to become involved and through their emotions and imagination sense the user and others. It also enabled them to communicate and share thoughts smoothly with untrained students from other departments. Students who integrated in the final stage with the community stated that it had the most effective impact on their lives, and really felt the informal settlement communities. The work of these students on their graduation project and after (masters, designs or even teaching) focused on emphasizing the needs of the community, working with them and for them. On the other hand, following up the teams from the community, participants carried on developing their areas, and protected what was implemented together from intruders. They have become the owners of what they have developed with their own thoughts and/or hands. Real participation has been achieved, and hence empowerment and sustainability.

4. Discussions and Conclusion:

The outcome and reflections by students and other lecturers, indicates the high flexible potentials in using visual abstraction and its ability to enhance creative communication on multi and divergent levels. With the students it empowered them to synergise their creative ideas effectively and when they were integrated with the community after the training process, it showed mutual and easy understandings and communication. As for the community, the feeling of being able to communicate ideas on mutual levels, enhanced empowerment and motivated creative thinking, sense of owner ship and real participation. This in return promotes sustainability as discussed.

Answering ***the first question; which level of abstraction who use with who***; the answer is not so straight forward as attention has to be drawn to educational and economical standard, cognitive stage, and gender. In general higher levels of education and age groups showed a need to start with high levels of abstraction. Lower levels of education, economical level, women and children, showed better results at slightly high levels of abstraction to intermediate. Untrained groups worked best at intermediate levels of abstraction. Men inclined to refrain or use low levels of abstraction. Addressing ***the second question; how***, the process should a need to gradually flow from the starting level of abstraction to lower levels, taking the convenient time required to reach satisfactory results. It should start on an individual level gradually into small groups, then larger groups from the same category, then to larger divergent and multi-disciplinary categories and communities. The process should be kept a fun, motivating event like, and generating '*as it goes'*. The material used should be flexible and malleable, and preferably vivid. With untrained groups, visual abstraction should be kept at an intermediate level, and would still work effectively, giving homogenous and deep synergetic ideas, regardless of which categories get integrated. Children reach satisfactory results in much less time.

Experiencing the divergent power of visual abstraction, it is recommended to train architecture students by using visual abstraction, and how to use visual abstraction. This would enable them to communicate effectively with each other, in multi-disciplinary groups, and with their community for a better quality of the socio/physical environment and sustainable participatory development.

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Integrating Environmental Control Systems in Architecture Design Studios

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Abstract: *Linking Environmental Control Systems and Architecture Design is an important issue in the education of Architecture. It is important to raise awareness among architecture students to the seriousness of having climate responsive buildings as the next future direction for Egyptian buildings. The curriculum has been changed in 2014/2015 at the October University of Modern Sciences and Arts (MSA) to include teaching the Environmental Control Systems course (GSE 261) to architecture students during the 1st year instead of the 4th. This paper provides an outline of the motivations, practices, challenges, and success associated with integrating environmental studies within the Architecture Design Studio. A case study of Design II (ASE261Spring2016) is presented showing how students succeeded in applying the environmental strategies into their design project. The methodology used to assess and measure the success of integrating environmental principles in the design studio is applied through a checklist of assessment criteria that evaluate the students' final design project. An architecture design studio model is proposed and principles of environmental control system are used in this model as a design checklist. This paper serves as a guide for the development and improvement of existing and future programs. Integrating the concept of environmental performance of buildings into the thinking and teaching of architecture during the early design studios will give students the chance to practically utilize their studies of environmental control systems in the architecture design studios.*

Keywords: Architecture Design Studio, Curriculum, Environmental Studies

1. INTRODUCTION

Architects are responsible for designing and constructing buildings that consume energy, resources, and produces wastes. Recently, designers realized the complexity of their role and the environmental consequences of their decisions. These decisions affect the health of current and future generations, as well as the planet on which they live and work (Jones, 2008). Accordingly, instructors of architecture design studios focus on how to educate future architects by showing them the importance of considering environmental aspects while designing, and that sustainability will no longer be an option, but a standard practice. It is crucial that graduating students are prepared to meet this challenge for environmentally conscious design. For that reason many architecture schools have included theoretical environmental design courses in their curriculum. However, theoretical courses alone are not enough to teach students how to apply environmental control strategies in architecture design studios and professional practice. In this context, this paper aims to present the experience of integrating environmental studies within the architecture design studio of Design II, Spring 2016 at MSA University in Cairo. It provides an outline of the motivations, practices, challenges and success associated with this integration. The research also aims to propose a model for integrating environmental control systems in architecture design studio, which is an initial experience for real life situations, and it is also the core of architecture education. The research methodology consists of four parts. The first part demonstrates the princwniples of climate responsive design that were found relevant, and appropriate to be added to the design course outline for first year architecture students. The second part presents the experience of integrating these principles within the architecture design studio at MSA University during the Spring 2016 semester. The third part presents the methodology used to assess and measure the success of integrating environmental principles in the design studio. The fourth part proposes an architecture design studio model where the principles and aspects of the environmental control systems and climatic design defined in the first part of the paper are used. Within this model, a design checklist for environmental aspects was developed in the aims of being integrated within design studio outlines during the early stages of architectural design education. Finally, conclusions and recommendations are presented.

2. LITERATURE REVIEW

Global energy and environmental concerns have driven a paradigm shift in the way that architecture is practiced and taught all over the world. Within the last decade, university faculties and administrators have further stressed calls for introducing environmental conscious design and sustainability into architectural education. Today, an increasing number of architectural departments are revising their curricula in order to define environmentally conscious design as a priority (Iulo, L.D. et all, 2013). Many authors provided considerable contributions to the history of environmentally conscious design education. For example, Garib, B. and Garib, E. discussed the structure of interior architectural studios and the significance of environmental design through the experiences gained in the design studios into different architecture departments in Istanbul. They examined the reflections upon developing the knowledge of “environmental consciousness” and establishing the dialogue between different scales of environment on student work. They concluded that in all areas of design, interior architectural design problems can not be considered independently from the environment (Garib, B. and Garib, E., 2012).

The project of Environmental Design in University Curricula and Architectural Training in Europe (EDUCATE) aimed to promote the effective integration of environmental design and energy efficiency in the education and practice of architecture and urban design. A sustainable reconsideration of pedagogical methods is needed to facilitate the transfer of knowledge between sciences of environmental systems and building application and foster the implementation of environmental issues within creative design. One of the important modules in this program is “Environmental Science for Architects 1 – University of Nottingham”. This year-long module is delivered in the first year of the architectural and the engineering curriculum and introduces students to the environmental agenda as it applies to the architectural profession. The module encourages consideration of environmental issues from the outset of a project and explores the key bioclimatic strategies used to maintain appropriate conditions for the occupant of built spaces, tying together occupant comfort, building program and climate. It also introduces students to simple analytical tools and techniques to explore and understand the proposed environmental strategies within their design projects. The pedagogical method is centred on learning by doing approach, where principles are presented simultaneously with their application in practical exercises. In the first semester, lectures focus on issues of environmental psychology and thermal, acoustic and visual comfort in the context of architecture design. The second semester is devoted to the exploration and application of daylighting in built spaces (Altomonte, S. 2012).

Mansy, K. (2003) reports his academic experience of teaching daylighting to undergraduate architectural students at Oklahoma State University. He suggested simplified procedure, which proved to be user-friendly. Students were capable of visualizing the hourly performance of daylighting systems, and consequently building a comprehensive understanding of the performance of daylighting systems. This hands-on procedure helped architectural students to visualize, further develop and understand the performance of their daylighting designs (Mansy, K. 2003).

Krishan, A. (2002) suggested a new language of architecture where the process of design and projects are designed in response to critical issues. The prevailing environmental conditions demand a radical shift in planning and design paradigm. Accordingly, climate-responsive architecture design and ecological planning become the determinants of energy-source flow and offer a powerful tool for optimization. Therefore, the relationship between built-form and ecology should become the driving force behind the process, based on a scientific methodology leading to climate-responsive architecture (Krishan, 2002).

3. RESEARCH METHODOLOGY

This section is divided into four parts. The first part demonstrates the principles of climate responsive design that were found relevant, and appropriate to be added to the design course outline for first year architecture students at MSA University. The second part presents the case study (Architecture Design II Spring 2016) showing the experience of integrating the principles of climate responsive design within the design studio. The third part presents the methodology used to assess and measure the success of integrating environmental principles in the design studio. The fourth part proposes an architecture design studio model where the principles and aspects of the environmental control systems and climatic design defined in the first part of the paper are used. Within this model, a design checklist for environmental aspects was developed in the aims of being integrated within design studio outlines during the early stages of architectural design education.

3.1. Part One: Course preparation

Designing a climate responsive, and energy conscious building is not an easy task for an architect, as it requires a certain knowledge level of a variety of environmental and scientific principles. Taking that into consideration, teaching design courses that aim to reach a functional climate responsive design needs to prepare and gradually introduce these principles to the students along a series of design courses. The outline preparation of Design II studio was considered the first step towards the integration of climate responsive building design and environmental control. A checklist was created using the fourth year graduation project environmental control requirements and from there a methodological approach was taken to identify the aspects which could be included within the Design II course that would be appropriate to the level of knowledge of the students taking the course.

After the graduation project list was compiled and reviewed, the large list of required aspects that ranged from basic building principles to technological active systems and regional impact requirements needed to be narrowed down. At this point the three-tier approach to the sustainability design of heating, cooling, and lighting (Lechner, 2001) was used to narrow down the requirements. This approach divides most relevant environmental control aspects into three levels as per Table 1.

Table 1: The Three-Tier Design Approach (Lechner, 2001)

	Heating	Cooling	Lighting
Tier 1	*Conservation*	*Heat avoidance*	*Daylight*
Basic Building Design	1. Surface-to-volume ratio 2. Insulation 3. Infiltration	1. Shading 2. Exterior colors 3. Insulation 4. Mass	1. Windows 2. Glazing type 3. Interior finishes
Tier 2	*Passive solar*	*Passive cooling*	*Daylighting*
Natural Energies and Passive Techniques	1. Direct gain 2. Trombe wall 3. Sunspace	1. Evaporative cooling 2. Night-flush cooling 3. Comfort ventilation 4. Cool towers	1. Skylights 2. Clerestories 3. Light shelves
Tier 3	*Heating equipment*	*Cooling equipment*	*Electric light*
Mechanical and Electrical Equipment	1. Furnace 2. Boiler 3. Ducts/Pipes 4. Fuels	1. Refrigeration machine 2. Ducts 3. Geo-exchange	1. Lamps 2. Fixtures 3. Location of fixtures

Table 1 was compared with the graduation project checklist proving to incorporate most aspects within it. The next step was to cross-examine the three tiers with the environmental courses outline as well as the technical systems courses. The result of this examination showed that up until Fall 2015, no courses that preceded Design II did actually cover the fundamentals or principles of any of the three tiers. However, with the new change in curriculum that occurred in Fall 2015 which included teaching environmental control systems 1 course during the students' first year, now most of the first tier strategies along with some of the second tier strategies were available to students before they enrolled in the Design II course. This change offered a knowledge base to enrolling students and an opportunity to include environmental aspects within the course in a more prominent way.

3.1.1. Principles and aspects of environmental control

The fundamentals of the environmental considerations include natural lighting, natural ventilation, solar geometry, human thermal comfort, climatic and microclimatic design for creating healthy environments and environmental determinants of building form. The following show some of the environmental considerations that were included in the design outline to be set as requirements for students in their designs:

- Natural lighting: Increase the performance of daylighting within spaces by utilizing sky gardens, skylights, atriums, using light shelves, proper window dimensions to room depths and proper orientations of different space windows to relevant space functions.
- Natural ventilation: use of passive cooling systems and comfort ventilation, proper orientation of openings in according to site analysis and prevailing weather conditions, dimensions of openings in regards to natural ventilation, and use of landscaping and water-bodies to increase human comfort levels within spaces.
- Shading: through appropriate orientation of shading devices as well as design guidelines for shading device design based on their orientation. Also taking shading into consideration while designing the form in the efforts of providing building self-shade while needed based on the climate analysis.
- The thermal envelope: staying cool and keeping warm. The use and consideration of passive strategies such as appropriate building colour, form, surface to volume ratio, infiltration, use of thermal mass, and using other passive energy conservation measures.
- Encouraging students to incorporate design elements such as wind-catchers, sunspaces, solar chimneys, etc. in their designs

3.1.2. The relationship between environmental control systems and architecture design

The energy conscious design is an important issue that should be taken into consideration while designing and constructing buildings that will not have a negative impact on the environment. Climatic-responsive buildings not only minimize the use of energy but also allow people to have a greater degree of interaction with their environment. This person-centred design approach can create comfort and delight within the indoor environments and be healthier and more connected to place and nature. During the schematic design stage key decisions are made. Building's cost and environmental impact are mainly established at the schematic design stage. The most basic decisions of size, orientation, and form often have the greater impact on the resources required both during construction and operation (Lechner, 2001).

3.2. Part two: Case Study

First, a review of the procedure of activities and topics explored in Architecture Design II studio in Spring 2016 is presented. Then, a sample of students' environmental studies and drawings are presented showing students' capabilities of applying environmental principles in their design project.

3.2.1. Case study review

The case study presents the experience of integrating the environmental aspects in the architectural design studio in the first year in the architecture department in MSA University

(ASE261Spring2016). The department is keen to raise students' awareness of the environmental impacts of buildings. Its aim is to equip students with tools necessary to design projects to substantial complexity, and to integrate to a professional level advanced technical and environmental knowledge in the resolution of such projects. One of the main requirements in the graduation project is to fulfil sustainability principles, which are not optional but should be a standard practice. To prepare students to reach this level, they have to be early engaged in applying environmental consideration in the first level of design studios. Accordingly, since Fall2015, the environmental control system course has begun to be taught early during the first year instead of the fourth year to allow students to have the chance to apply climatic design in their design projects.

The Design Studio II Spring 2016 offered an important opportunity for students to apply the environmentally conscious design in their project. The purpose is to engage students in experiencing the process of designing with the help of environmental design measures. Table 2 shows a review of the procedure of activities and topics explored in Architecture Design II studio in Spring 2016.

Table 2: Review of the procedure of activities and topics explored in Architecture Design II studio in Spring 2016 (Authors, 2016)

1.Lectures	Environmental aspects were emphasized in studio through lectures on the following topics: Natural lighting - Natural ventilation - Shading devices - Thermal envelope -
2. Research	During the first stage of the design studio, students made a research and presentation on how environmental and climatic aspects were considered and achieved in local context.
3. Field Trips	Students visited old traditional houses in Old Cairo. By moving inside these houses students were able to experience how natural lighting, natural ventilation and thermal mass achieved human comfort.
4. Environmental Analysis	Students analysed the old traditional house in terms of orientation and cross ventilation using wind towers (Malquaf) to grab cold air and release hot air through clear story windows (Shokhshikha). They studied the benefits of the other architectural elements as the mashrabia, maquad, takhtabush in terms of being climatic adaptive features. Students also analysed a contemporary building where the designer succeeded in applying the environmental principles in the design.
5. Site Analysis	The second stage was the phase of the site analysis. Choosing a real site for the project gave the chance for students to visit the site and make a real climate analysis using "Climate Consultant". Students did very progressed sited analysis, as they were able to practically apply knowledge learned in the environmental control system course.
6. Design Phase	The third phase was the phase of the design. Students were asked to design their projects by considering the environmental aspects and the site analysis. Projects are developed according to the instructor comments. Students get feedback on their projects through group critiques (15 student and the instructor). 'User-designer' studio concept was adopted where the instructor acts as the user who passes project critiques to the student/designer through user needs and demands. The instructor undertakes the role of a user demanding an environmentally conscious design from the designer/student. At the end of the term, students submitted their design projects with two and three-dimensional drawings illustrating the environmental aspects.

3.2.2. Samples of students' environmental studies and drawings

Figures 1and 2 show selected students' drawings of the environmental studies.

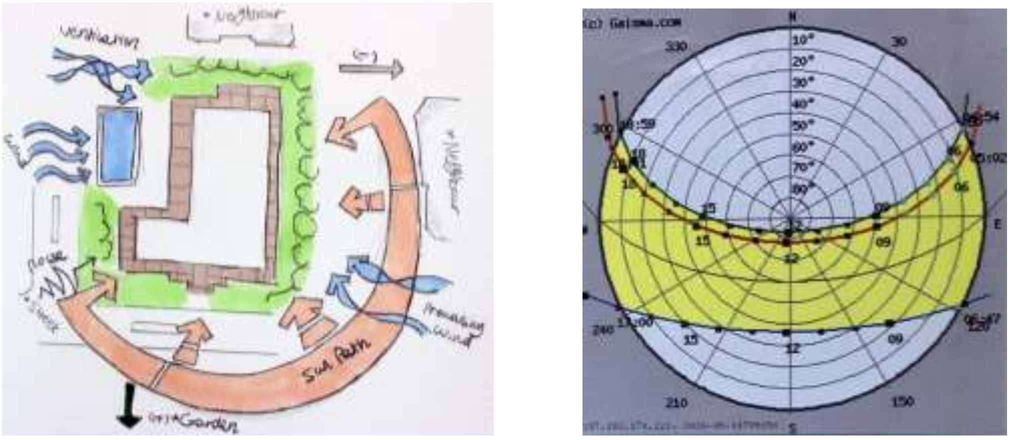

Figure 1: A Student's Environmental Studies in Architecture Design Studio II (Authors, 2016)

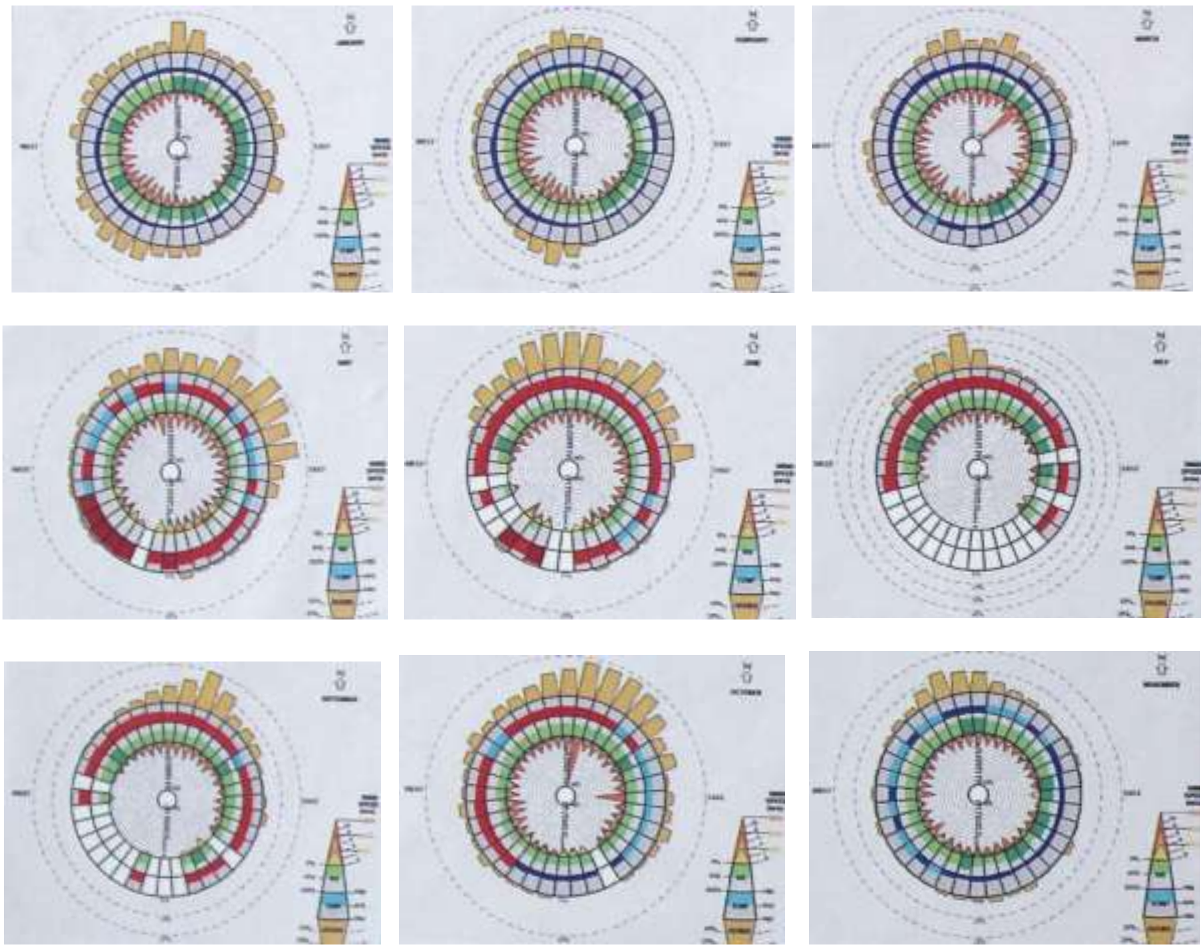

Figure 2: Advanced Environmental Studies in Architecture Design Studio II (Authors, 2016)

3.3. Part three: methodology of student design assessment

This part presents the methodology used to assess and measure the success of integrating environmental principles in the design studio. The checklist in Table 3 was developed in efforts to assess the students' final designs. Each criterion was added to evaluate whether the student has explored, gave consideration to, or effectively included the relevant objective within the design, or accompanied design studies and concept documentation. The checklist included criteria that were found relevant to the current course level and needed learning objectives to provide a sense of awareness of the strategies used; in order to furnish a knowledge base to more advanced strategies and considerations to follow in future design courses.

Table 3: Assessment Criteria (Authors, 2016)

Assessment Criteria	Mark
Daylighting performance based on space function	1
Window/Space proper daylighting based on orientation and function	1
Space ventilation based on climate analysis and function	1
Appropriate surface area/volume ratio building based on climate	1
Appropriate exterior colours based on climate	1
Use of shading devices	1
Use of proper shading device type and design based on orientation	1
Proper and innovative documentation of site and climate analysis data.	1
Sketches (explanation) of used design strategies in concept generation, design progress sketches	1
Overall integration of strategies in a functional design project in relation to site and climate analysis, building code, aesthetic quality of design, and design program outline.	1
Total Marks	10

By using the checklist to evaluate a random sample of student work comprising of twenty projects, the results showed that almost 60 percent of the sample had passed more than 7 of the 10 criteria marks, with an average of 7 marks. The rest of the sample scored between 5 and seven marks with only 3 % scoring less than 5 marks.

These results show how the students effectively included passive climate responsive strategies within the designs at an early stage where usually the focus had been on functional relations, circulation, and mass compositions. The results and final designs showed how the integration of these strategies at this stage resulted in more complex and functional designs, as well as added another line of thinking during conceptual design generation phase and design methodology in general by integrating more requirements to the basic design requirements which were stated earlier.

3.4. Part Four: A model proposal for integrating environmental aspects in Architecture Design Studio

Traditionally, the practice of architecture design is learned through a project-based "studio" approach in departments of architecture. In studio, students themselves generate and evaluate alternatives, make decisions and learn how to design. For educating future architects with a high level of environmental awareness it is very important to integrate the environmental principles in architecture design studio. The traditional educational approach for architecture design studio is defined then a model proposal for integrating environmental aspects in architecture design studio is presented.

3.4.1. The educational approach of traditional architecture design studios

Design is the core subject of architectural curriculum in the university system. The curriculum includes basic courses of arts, courses dealing with professional practice such as building, materials, construction and environmental control system. The major academic work is full of training experiences, which occur in the architectural design studio. A staff member supervises a group of students undertaking a design project in the design studio, which has a great importance in architectural education.

Design is a decision making process that produces plans by which resources are converted into products that meet human needs and requirements. Rittel and Webber (1973) assert that design can be thought of as a problem setting-location, identifying and formulating the problem, its underlying causes, structure and operative dynamics in such a way that an approach to solving the problem emerges. The requirements guide the design process and shape the manufacturing environments like form features, proximities, adjacencies, dimensions, performance related issues as thermal acoustical or lighting expectations and others (Phan, 1991). Design issues can entail varied items such as questions and concerns about procedural aspects of the design, which need to be resolved before progressing. According to Lawson (1980) design problems often define a very wide area and the number of possible solutions is infinite. Usually the goal of design is not clearly set and it changes according to the environment it is situated.

Architectural design studio focuses on “learning by doing” and offers a prime example of a collaborative teaching environment. In the studio space, students spend much of their working lives, at times talking together, but mostly engaged in private parallel pursuits of the common design task (Schon, 1983). The design studio sequence provides the connective tissue that brings together, progressively, the many elements of architectural education (Boyer and Mitgang, 1993).

In architecture design studio students learn by working on projects (Oh et al., 2013). Students are expected to propose solutions to design problems assigned by the instructor. The architecture design studio adopts a learned-centered, collaborative and experiential problem based educational approach. Each studio instructor is responsible from 10-12 students. The instructor establishes the goals of the project, general procedure and the assessment criteria. During the semester, instructors meet students either individually or in groups (desk or group critiques) for developing projects by comments. Students develop their projects according to the instructor and jury’s critiques. Sometimes the role undertaken by instructor and student is the “user-designer’ role. The instructor (user) critics student’s (designer) project according to user demands.

3.4.2. Architectural environmental design studio model

The architecture environmental design studio model has a goal of experiencing an environmentally conscious architecture design process. The instructor undertakes the role of a user demanding an environmentally conscious design from the designer (student). Group critiques give student the chance to share all documentation about the climate-responsive buildings in addition to instructor's and students' comments. At the beginning of the studio, students make a research on the environmentally conscious architecture and collect written and visual documents about climate-responsive architecture. Then they prepare a presentation on the environmentally conscious architecture and make their presentation in a group critique session. After the students finish the research phase, the instructor submits environmental principles checklist, which is shown in Table 4. This checklist will guide students for creating environmentally conscious buildings. Students develop their projects in the light of the environmentally design checklist and instructor's comments.

Table 4: Environmental principle design checklist performed in architecture design studio model (Authors, 2016)

	Environmental Principle Design Check List
1	**Using Natural Lighting** - Increase the performance of daylighting within spaces by utilizing sky gardens, skylights, atriums, using light shelves, proper window dimensions to room depths and proper orientations of different space windows to relevant space functions - Depth of spaces is designed at max. 7m to benefit more from natural lighting.
2	**Using Natural Ventilation** - Use of passive cooling systems and comfort ventilation, proper orientation of openings in according to site analysis and prevailing weather conditions, dimensions of openings in regards to natural ventilation, and use of landscaping and water-bodies to increase human comfort levels within spaces - All spaces benefit from adjustable window, air-holes or natural ventilation opportunities facilitated by channels.
3	**Reducing energy used for heating and cooling** - Passive recovery measure for reducing heating and cooling loads are taken into consideration, e.g. using thermal mass, double-wall application. The thermal envelope: staying cool and keeping warm. The use and consideration of passive strategies such as appropriate building colour, form, surface to volume ratio, infiltration, use of thermal mass, and using other passive energy conservation measures - In order to reduce cooling loads, measures are taken such as sun shades, horizontal overhangs, movable blinds, etc. Shading**:** through appropriate orientation of shading devices as well as design guidelines for shading device design based on their orientation. Also taking shading into consideration while designing the form in the efforts of providing building self-shade while needed based on the climate analysis. - Incorporate design elements such as wind-catchers, sunspaces, solar chimneys, etc. in your design

4. CONCLUSION

Offering the ‘Environmental Control System’ course in the first year in the architectural curriculum, rather than the fourth year, proves to be more beneficial to students as it enhances their understanding of the importance of climate design in architecture. The environmental studies and strategies were well integrated in the architectural design studio. Students effectively included passive climate responsive strategies within their design projects. The environmental principle design check list should be incorporated in the architecture design studio outline and be part of the assessment. It is recommended that the basic ‘Environmental Control System’ course should be a prerequisite for Architecture Design II to facilitate integrating the environmental strategies within the design studio. Learning environmental control strategies is a step before learning sustainable architecture. It is recommended that an additional advanced environmental control system should be incorporated in the curriculum of architecture departments in the third year.

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The Emergent Biophilia

An Exploratory Study on the Impact of Integrating "Biophilic Principles" In Designing Educational Spaces for Childhood

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Abstract: Although, contact with nature is inseparably linked to the well-being of children. Nowadays, children are facing entirely new health threats resulting from being detached from nature, where nature's positive influence is being replaced by staying indoors. In the mid-20th Century "Erich Fromm" coined the term "biophilia", which emphasized the importance of visual connection and interaction with nature, thus appeared as a magical solution. However, in application, architects involved in designing educational spaces for children need to have better understanding on how to enhance children's tendency for biophilia. Hence, this paper begins to explore this growing body of research and emerging biophilic design dimensions, elements and attributes in architectural terms, which could help in drawing connections between fields of study, highlight potential avenues for future research, evolve understanding of biophilic design patterns, and capture the cognitive benefits afforded by biophilia in designing educational spaces for childhood. A research methodology consisting of a literature review, case studies and a survey questionnaire was designed to accomplish intended objectives. Firstly, a literature review was conducted to investigate the concept of biophilia, its design principles, and the factors affecting their integration onto design of spaces for children through a number of analysed worldwide case reviews. Secondly, a one-to-one interview was conducted with a sample of children ranging from 6-10 years old, which aimed at capturing the perceptions and experiences of children in nature and more specifically in educational spaces. Findings of this study indicated that children in early childhood have a positive intellectual and emotional appreciation for all elements of natural environment. Results showed that children enjoy being in, which provides a glimpse into the potentials of integrating nature within architectural context; including offering beauty, freedom, efficient learning, relaxation and a critical life support system.

Keywords: Architecture, Biophilic Design, Children, Educational Spaces, Nature

1. INTRODUCTION

In the last decades, humanity has been facing entirely new health threats resulting from being detached from nature. Nature deficit disorder refers to the phrase coined by Louv, R. (2005) in his book "*Last Child in the Woods",* human beings -especially children- are spending less time outdoors resulting in a wide range of behavioural problems. According to ('EPA',2016), children spend 90% of their time indoors and much of that time is spent in school. In addition, with the advent of the computer, video games, and television children stay indoors, which in turn leads to the production of a new generation subjected to attention disorders and physiological depression. Here comes the role of educational environments in enhancing both health and academic success of children. On the other hand, Unhealthy school environments can affect children's health, attendance, concentration and performance, as well as lead to expensive, time-consuming clean-up and remediation activities. Owing to the fact that young children's relationship with natural environment is a starting point for all future human interactions with the natural world and has a direct impact on the future of the sustainability movement, "Erich Fromm" coined the term "biophilia", which appeared as a solution to this problem, as it emphasizes the importance of visual connection and interaction with nature,(Kalvaitis, D and Monhardt, R.,2015). The biophilic space provides an environment that strengthens life and supports the sociological and psychological components, or, in other words, it is able to unburden the cognitive system, foster the optimum of the sensorial system and support the neuro-endocryne and immunological system, (Caperna, A and Serafini, S., 2013).

Consequently, architects involved in designing educational spaces for children need to have better understanding on how to enhance children's tendency for biophilia. Hence, this research aims at exploring principles of biophilic design, and the impact of their integration onto the design of educational spaces. An important feature of this study is to understand children's perception to define their own relationship with nature by engaging with them to design their dream classroom rather than using them as passive objects of study. The researchers' main intention was to do research with rather than on children by listening to their thoughts and dreams in order to explore "the emergent biophilia" to design their own educational spaces and classrooms.

2. RESEARCH STRUCTURE

For accomplishing the intended objectives of this research, a number of methods were implemented. **Firstly,** a literature review was conducted to investigate the concept of biophilia, its attributes and the factors affecting their integration onto design of educational spaces for children. **Secondly**, Qualitative analysis of a number of worldwide case studies was performed; the objective was to explore the application of the attributes of biophilia. **Finally** an exploratory survey ;a one to one interview, was conducted with a sample of about 30 children, from 6-10 years old, aiming to answer the research questions; *what is the meaning of the child-nature relationship? What are children's perceptions and experiences in educational spaces? How do children describe their relationship with nature?* Findings of this study took the form of guidelines that could help improving design quality of educational spaces for children, meanwhile keeping them attached to their surrounding environment. Figure (1) shows the overall research methodology.

2.1. Literature review

Although the term Biophilia is quite uncommon, however, upon breaking down the word, it becomes clear and simple enough. *Bio-* is *"of or relating to life,"* and *-philia* is *"denoting fondness, especially an abnormal love for a specified thing*", (New Oxford, 2016). Thus, the basic definition for 'Biophilia' is the love of life. In the next section, the concept of Biophilia and its application in architectural context will be discussed in detail.

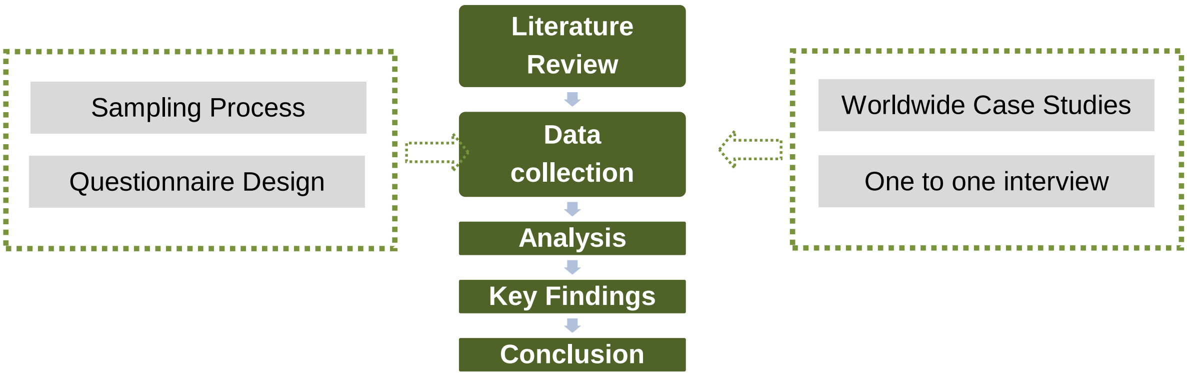


Figure 1: The research methodology for the paper (by the authors, 2016)

2.1.1. The Emergence of Biophilia

The idea of biophilia has originated since the beginning of human history; where homo-sapiens; the modern species of humans, evolved and lived in intimate connection with the natural world, (Homosapiens, 2016). Table (1) summarizes briefly the development of the term "Biophilia" and its conception in the last century. In this sense, the biophilia hypothesis can be used as a valuable framework to help further the interdisciplinary investigation of human's affiliation with nature.

Table 1: Timeline for the contribution to the emergence of "Biophilia" (by the authors, 2016)

Year/Author	Contribution to the emergence of Biophilia
1945 ***Erich Fromm***	• The social psychologist coined the term "Biophilia" to describe the innate bond that humans share with other living species. • In his book '"The Anatomy of Human Destructiveness" he redefines it as *'the passionate love of life and of all that is alive'.*
1979 ***Edward O. Wilson***	• The evolutionary biologist first used the term biophilia in the field of biology (particularly *sociobiology*) in an article titled "Biophilia" (Wilson, E. 1979)
1984 ***Edward O. Wilson***	• He developed the concept in an entire book once again titled "Biophilia", describing how positive feelings towards nature are inborn in human beings.
1993 ***Edward O. Wilson & Stephen R. Kellert***	• Wilson teams up with the Social Ecologist *Stephen R. Kellert* to edit a book, entitled *The "*Biophilia Hypothesis*"* (Kellert, S and Wilson, E. 1993), stating that biophilia became biologically encoded in our DNA because it helped enhance our existence and survival through physical, emotional and intellectual fitness (Davidson, D. 2013).

2.1.2. Biophilic Design

Throughout time, humans have not only relied on nature, but we have copied it. Biophilic design is presented as an innovative approach to design that fosters the positive connection with the natural world through the built environment to create a healthy human life and well-being. At the building scale, biophilic design can inspire architects to build connection with nature. At the human scale, following biophilia can enhance physical fitness and improve health. Mental and behavioural benefits range from increased satisfaction and motivation, less stress and anxiety, improved problem solving and creativity, enhanced attention and concentration and improved social interaction (Kellert, S. 2005).

However, biophilic design should not be confused with sustainable design. The focus of sustainability is on how to mitigate the negative impacts of a building on the environment and how the degradation of resources will affect the next generations. This has been argued by (*Kellert, S, J. Heerwagen, M. Mador,* eds, 2008), who addresses it by “*the missing link in sustainable design*”, where they claimed that there is little focus on enhancing the user’s access to nature, resulting in experiential and aesthetic impoverishment. Whereas, designers who use biophilia in their work not only consider the basic tenets of sustainability, but also take things a step further by designing to create a potentially positive impact on the environment, as well as fostering beneficial relationships between people and nature within the built environment.

To assist designers and developers in the practical application of biophilic design, (Kellert 2008) has broken it down into two dimensions, six elements, and 70 attributes. The first dimension of biophilic design is "organic or *naturalistic dimension*", which represents forms in the built environment that directly, indirectly or vicariously illicit human’s affinity for the natural environment. The second dimension is the *"place-based or vernacular dimension*", this helps connect people to the culture and ecology of their locality or geographic area to give a sense of security. The six elements and some of the 70 corresponding attributes of biophilic design are briefly described in figure (2). These attributes can be used in different combinations to achieve successful biophilic designs for various targeted users.

Figure 63: Kellert's six elements of biophilic design and their attributes (by the authors, 2016)

2.2 Integrating Biophilia into Educational Spaces for Childhood

The way children learn is completely different than adults. To be effective and engage children based upon their abilities and ways of learning, their hands-on sensory experiences need to be immersive and open-ended. Concerning the natural environment, children experience differently than adults as well. Adults usually see nature as background for what they are doing, whereas children experience nature holistically as a stimulator and experiential component of their activities. Children judge nature not by its aesthetics, but rather by the manner of their interactions and sensory experiences with it (White, R and Stoecklin, V. 2008). However, the problem with most young children's environmental education programs is that they approach education from an adult's perspective. In his book "Children and Nature: Design principles for educators", David Sobel mentioned the three basic stages for children's development of their environmental education (Sobel, D. 2008). Some of these tips that strengthen the children-nature relationship were shown in figure (3).

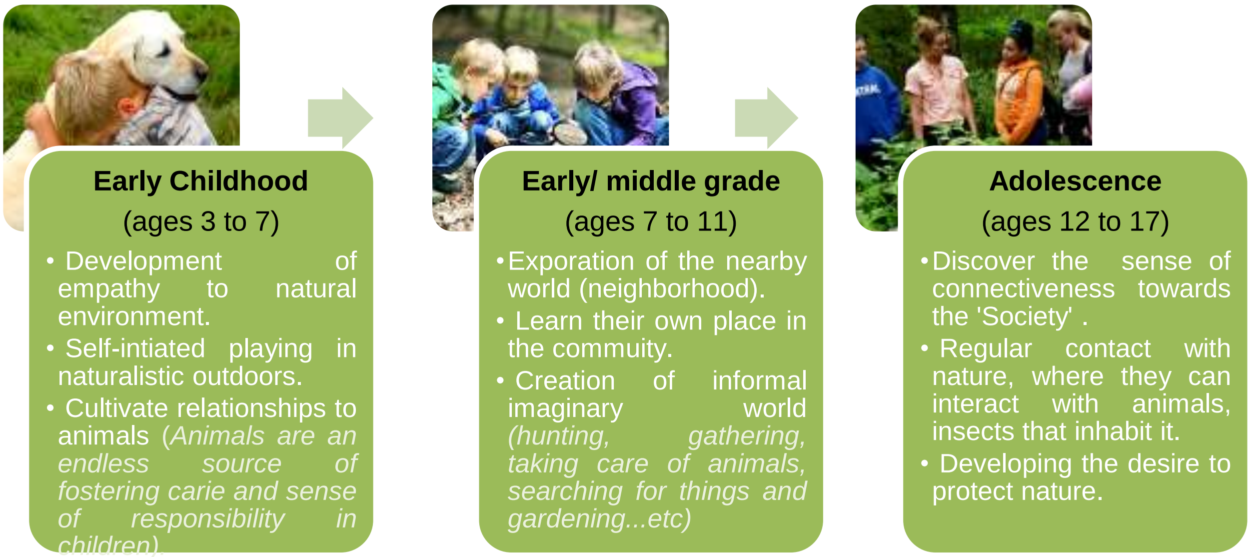


Figure 3: Illustration for the main tips to strengthen the child-nature relationship on the three basic stages of childhood (by the authors, 2016)

This study targets the (early childhood) and (early grade school children), where recent research strongly suggests that the opportunity for children younger than age 11 to explore in wild, natural environments is really important for developing their biophilic tendencies and that the type of play should be child-nature play. One of the best environmental education examples that target these age group early are the "outdoors-in-all-weather nursery schools" and "forest kindergartens." Since the 1990s, parents and educators in Germany have established 700 *Waldkindergärtens* where children ages 3 to 6 spend their entire day in the outdoors in all but the most extreme weather. Forest kindergartens are now found in many other countries including Scotland, Scandinavia, Switzerland and Austria (Cohen, S and Wingerg, D. 1993). The closet equivalents in the US are nature centre-based preschools, such as The Nature Preschool at the Schlitz Audubon Nature Centre (Shackell, A.,Walter, R. 2012).

3. ANALYSIS OF WORLDWIDE CASE STUDIES

As discussed before, based on recent studies, incorporating key principles of biophilic design can make dramatic improvements to educations spaces, improving experiences for children, students and staff alike. This part of the paper follows qualitative analyses of three worldwide educational spaces that applied biophilic principles either partially or totally. The case studies were analyzed based upon the six elements of biophilic design outlined earlier.

3.1 Case 1: *St. Mary's Infant School*

Allocated in Oxfordshire ,UK, St Mary's Infant CE School's new foundation stage classroom consists of three elements, the buff brick main classroom, an additional teaching space and amenities, and cedar clad external covered play area accessed. This school incorporates many Biophilic Design principles described in table (2):

Table 2: Biophilic design principles in Case 1 (Human spaces, 2016)

Environmental features	• The form created an enclosed 'secret garden'.
Natural shapes and forms	• The form of pitched roofs is reflected in a playful and simple way.
Natural patterns and processes	• Natural materials used in the structure *(Wood)* • Many views out to nature and splashes of uplifting colors such as green, red, yellow blue (all indicative of nature).
Light and space	Internally the main teaching space provides a light environment created by: • Multiple roof lights, strip windows along the south elevation. • Large high-level windows which all help to capture light throughout the day.
Place-based relationships	• It offers a variety of spaces through the use of extruded window bays and a raised play area to create an engaging environment for the children.
Evolved Human-Nature Relationships	• The threshold between the interior of the classroom and the outdoors has been blurred *(improving the perception of access to nature).*

3.2 Case 2: *St. Paul Chevallier Complex*

The wooden nursery and elementary school complex in Lyon, France was designed with the intension of establishing robust relationships between architecture and nature, moreover to allow nature to get the upper hand as shown in figure (4). This school incorporates many Biophilic Design principles described in table (3):

Table 3: Biophilic design principles in Case 2 (Dezeen, 2016)

Environmental features	• The school has hilly rooftops carpeted with plants.
Natural shapes and forms	• The design takes account of the sloping terrain. • The inclined roof planes energize the silhouette, and attenuate the massiveness of the blocks
Natural patterns and processes	• The volumes in wood are separated by the broad, planted-out roofs, with their waves of color. • *Timber cladding* covers most of the building's interior and exterior, but is interspersed with a few *yellow-painted panels* on the walls and ceilings. • The ground plan is simple, so that the children can easily find their way around.
Light and space	• Spacious corridors run between classrooms and feature floor-to-ceiling windows to increase natural light.
Place-based relationships	• The inner perspectives are telescoped or attenuated; views onto the outside world, and superimposed spaces, are always different. • There are multiple, changing, irregular facets. No two façades are the same.
Evolved Human-Nature Relationships	• The plant-covered rooftops appear to emerge from the ground, created a series of slopes and pathways that children are encouraged to investigate. • The landscapers have provided places of discovery and experimentation. *(a vegetable garden beside Rue Salignat, and a discovery path on the way to the canteen in the northern wing).*

Figure 4: The plant-covered rooftops and its integration with the natural environment in Lyon (on the left) - the floor to ceiling windows and its effect on the natural day lighting in the classrooms (one the right) - (Dezeen, 2016)

3.3 Case 3: *Fuji Kindergarten*

Fuji Kindergarten or the Roof House in Tokyo, Japan, is considered one of the most successful educational biophilic designs. It incorporates most of the Biophilic Design principles as described in table (4), and shown in figure (5):

Table 4: Biophilic design principles in Case 3 (TED Ideas, 2016)

Environmental features	• There are three *zelkova* trees projecting through the roof deck. • Water wells in the nursery rooms, where children can casually chat, gather together, cheer and shout around these wells.
Natural shapes and forms	• The shape is an oval (a giant halo) form with a perimeter of 183m. It is conceived as a single village with endless circulation.
Natural patterns and processes	• There is no control on children *(they can run with no dead ends).* • Children can climb the trees to the classroom.
Light and space	• The basic state is with open windows allowing max day lighting
Place-based relationships	• The ceiling is merely 2.1 meters (child scale) • The roof is easily accessible and has slides. • There are no boundaries between classrooms (*The no-barrier concept allows total freedom to kids to move and mingle around).*
Evolved Human-Nature Relationships	• There's no boundary between inside and outer playgrounds *(Completely open most of the time)*

Figure 5: (from the left) the oval-shaped form of the kindergarten– The no dead ends concept in the kindergarten spaces allowing children to move freely - The three *Zelkova* trees favorable for children to climb (TED ideas, 2016)

4. Application Of One To One Interviews

Since the motivation for this study emerged from the need to do research *with,* rather than *on* children by listening to their thoughts and dreams, the authors in the coming part of this paper applied a one to one interview on sample children.

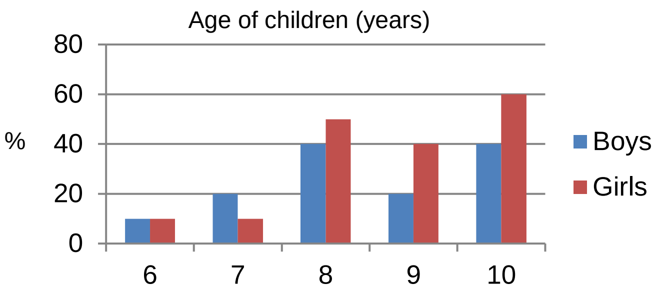
4.1. Sample Population:

The data presented here was collected during the **"**ISCDC Kids Workshop"[1] held in British university in Egypt in June 2016. All participants were of ages 6-10 years old (early childhood and early grade school children); since they form a critical period of cognitive development towards natural environment.. The participants attended the workshop for two sucessive days. A total of 30 children took part in the study, of which 43.3% were boys and 56.6% were girls, as shown in figure (6).

4.2. Structure of the Interview

The overall aim of the interview was to answer the research questions; *what is the meaning of the child-nature relationship? What are children's perceptions and experiences in educational spaces? How do children describe their relationship with nature?* Thus, a composite questionnaire (one-to-one interview) was used to collect these data.
Each participant answered the questions (total 18) individually at the beginning of the first day of Workshop. The questionnaire included twelve structured ''yes'' or ''no'' questions, and six open-ended questions. Children taking part were asked to fill out questionnaires after having some indoor activities and games.
The questionnaire was designed to address the following topics: (Child-nature Relationship), (describing "Nature") and (children perceptions and experiences in educational spaces). By open ended questions, data were gathered to understand children's perception for educational spaces: are they really satisfied with their current classrooms and school outdoors, what are their dream classrooms looks like and finally, the way they would like to spend their day (indoor or outdoor). Additionally, there was a hands-on learning project titled: *''draw then model your dream classroom''*. The assignment was added to analyse the capability of children to illustrate their ideas and dreams, and give additional information about nature perception in educational spaces.

[1] "The ISCDC Interactive Sustainable Child daycare Center" is a two years Research project funded by the YIRG Young Investigator Research Grant as part of the BUE British University in Egypt research initiatives.



Boys	Girls
13	17
43.3%	56.6%

Figure 6: Age & gender of the children taking part in the study (by the authors, 2016)

5. GENERIC FINDINGS

Based on the analysis of the worldwide case studies for educational spaces for children and one-to-one interviews with a sample of children of the targeted age group, the authors extracted some findings that underscore the objectives of the research, which can be described as follows:

5.1. Findings of the Analysis of Case Studies

The design implications gathered from the case studies were numerous for future children's educational spaces design. The major themes among them are the importance of engaging the users through stimulus variation, and these can be accomplished in many different ways:

- Having a higher ratio of vegetation has been shown to make a designed space feel more inviting and comfortable.
- Optimize views onto nature by enlarging windows.
- The natural material used for the ground plane, benches, walls and other elements can all incorporate different colors and textures for visual and tactile variation.
- When designing for children, it can mean the difference between a child user feeling comfortable and understanding that a space has been created specifically for them, or giving that user a sense of unease and not knowing if they belong there.
- Natural day lighting creates an energizing environment, helping to increase student's concentration, learning speed and performance levels.
- Freedom is an important aspect for children. When you put children in a quiet small box, some of them get really nervous.

5.2. Findings of the one to one interview

Transcripts from questionnaires and children's drawings were read and coded for the common themes that appeared. For this initial step in the analysis, this part contains: details about the connection to nature levels of the participants; and an examination of variables that affect such connection. In analysing the results, children's responses demonstrated the following:

- <u>The different understanding and perception of nature among boys and girls</u>: Girls understood the natural environment in a more illustrative way and also they were more interested to learn about growing plants and watering flowers than boys.
- <u>Animals were of a big interest for the majority of children</u>: Children spoke often about their pets and the significant role of these living creatures play in their lives.

- Children are not allowed to play outside. Nearly one third of the children are either worried to be out alone (scared of trees or insects) or told by parents that it's danger to play outside and it's better to watch television or play some computer games.
- There are differences among children having rural or urban origins: participants in rural surroundings love vegetation, interaction with animals better than their urban associates.
- The favourite outdoor place according to children of urban or rural origins: Surprisingly a total of 5 participants of 30 (~16.6%) answered that they do not play: *"I don't play in open spaces".* Children of rural origins seem to love being in natural environments such as: parks, zoo or the club play ground. On the other hand, going to the beach was a typical answer, especially among city children*: "I can run freely and swim all day"*. The need for vegetation and animal's interaction were not of a big importance for the city children, due to the lack of it in their normal life as shown in figure (7).
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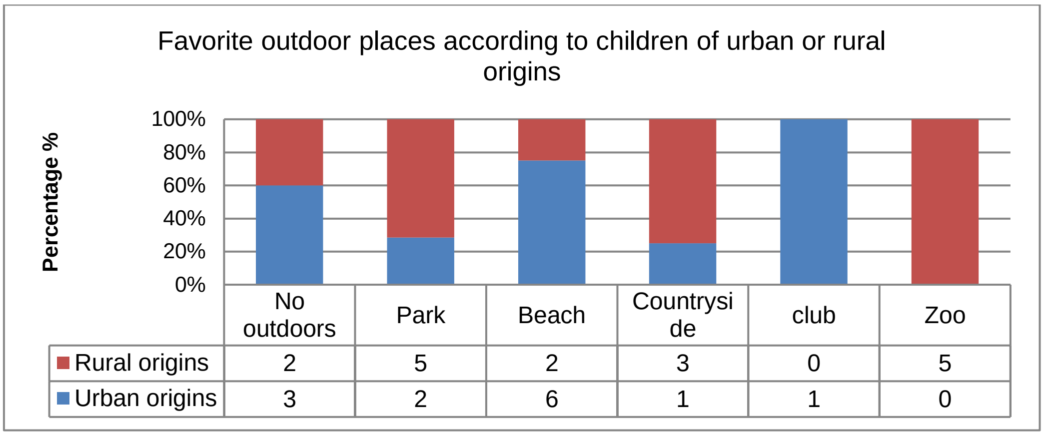

	No outdoors	Park	Beach	Countryside	club	Zoo
Rural origins	2	5	2	3	0	5
Urban origins	3	2	6	1	1	0

Figure 7: The percentage of the favorite outdoor places (by the authors, 2016)

- Family as a mean for experiencing nature for many children: Children of all ages expressed their appreciation for being in their favorite places is highly influenced by the presence of their siblings and parents. This trend was more prominent in the younger children; as children felt that nature brings families together.
- The Perception of children towards "Nature" When the participants were asked to write what they understood of the word "nature", the majority expressed their **love** to nature through many keywords. The responses demonstrated different conceptions that fit into the two categories as showed in figure (8). Younger students tended to have a more relational focus, while older students had a more object focus towards the environment.

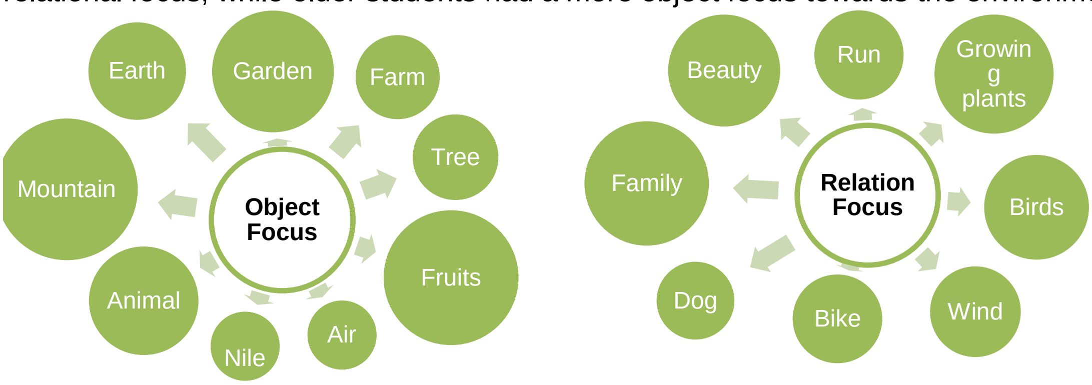

Figure 8: Model of how children describe "Nature" and their relationship with it in the Two different categories: (a) object focus and (b) relation focus (by authors, 2016)

- The children satisfaction in their existing educational spaces A total of 16 participants of 30 (~53.3%) said that they don't like their classroom, and never enjoyed being there, they don't like to stay on chairs and desks for long time and the space is not wide enough to play.

- <u>The interpretation of children of their dream classroom</u> When children were asked to design their dream classroom, many examples showed that early childhood normally have an emotional appreciation for all elements of natural environment. Their imagination for their dream classrooms in figure (9) expressed that they enjoyed being surrounded by nature and natural elements rather than in indoor boring classrooms.

Figure 964: Examples for the children during their participation: *(from the left)* a seven years girl draw her dream classroom on sea shore with wide widows - A 10 girl draw her dream classroom in the form of a huge fruit in front of a wide lake view with a fish-shaped door- a six years boy draw his dream classroom in the Forest, where he can see trees and animals around (by authors, 2016)

6. CONCLUSIONS

This paper aimed to explore "Biophilia" as a growing body of research and emerging design parameters in architectural terms. Through the discussion and findings, it became obvious that environment plays an important role for a child to receive direct nature experiences. The relationship to nature seems normally stronger in childhood, in another words, children are born as "*biophilic beings*". The results of children interviews indicate the following:

- Children have a positive intellectual and emotional appreciation for nature based on *"having experiences"* in nature and *"playing"* with nature elements as objects. Children simply enjoy being in nature rather than indoor spaces. The predominant themes from the study clearly indicate that nature provides children with opportunities for play/work, home, beauty, freedom, learning, and relaxation as well as a critical life support system.
- Children with rural origins seem to have a stronger relationship to nature. To the contrary, urban children did not necessarily consider themselves to either be part of nature due to the lack of nature elements, vegetation and interaction with animals in the city.
- In educational spaces, the children prefer informal and naturalistic outdoor landscapes as a learning environment rather than indoor boring classrooms.
- When children were asked to describe "nature", the majority expressed their **love** to it through many terms such as: trees, flowers, beauty, garden…etc. This indicates that children have an intellectual and emotional appreciation for all elements of natural environment.

The emphasis in this paper was not about finding causality or generalizing results and therefore, predicting future outcomes. Rather, the main intention was to raise the awareness to promote the relationship between natural spaces and children, this could be accomplished through following a number of guidelines such as: a) nature should be studied within the context of children's lives; to have better understanding on how to enhance children's tendency for 'Biophilia'. b) children must spend sufficient time in naturally healthy environment for biophilia to be fully engaged with them as a lifelong attitude which, in turn, will create a sufficiently large majority of biophilic adults who admire and respect nature and could do everything to protect it.

In conclusion, this emerging field claims that even young children, by simply being themselves and reflecting on their experiences, have the potential to change society. Results of this paper showed that children enjoy being in nature rather than in indoor spaces, which provides a glimpse into the potentials of integrating nature within architectural context; including offering beauty, freedom, efficient learning, and relaxation as well as a critical life support system.

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School Design through Participation

With Reference to Children in Primary Education

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Abstract: The involvement of the students in their schools' design/upgrade through participatory based projects proves to be one of the most efficient development strategies which are based on bottom-up approach. Children form a great portion of the inhabitants' structure especially in developing world countries such as Egypt, and the school plays a critical role in shaping their future.
Can more efficient adaptive creative learning environment in primary schools be achieved through participatory school design projects which target the school's students as main participants?
Through this research a set of elements of effective children participatory strategies will be illustrated and developed from general recommendations for participatory projects to structured guidelines for participatory school design.
The research starts with a theoretical base for the concept of children participation in their environments and illustrates the meaning, the nature, and the process of children participation and it addresses the topic of children in low income communities, with focus on children participation and the school environment. It addresses the change in learning environments and how this affected the school design. Then introduces four schools as applied case studies and introduces a participatory guidelines and criteria for school design.
The proposed school guideline can also be used as a tool of participatory design strategy planning and also as an evaluation tool, as it shows which criteria was chosen in the participatory design strategy and how effective these criteria were activated in the selected example by comparing the original criteria matrix to the new one.

Keywords: Children; Education; Sustainability; Participation; Playgrounds

1. INTRODUCTION

Cities in developing countries face urgent challenges in order to cope with the phenomenon of rapid urbanization. Cities' ability to cope with these challenges is based on their limited resources and the institutional environment in which they operate. Social structure, local culture, planning strategies and political dynamics are all factors affecting these cities ability to cope with such rapid urbanization challenges (Arandel and El Batran, 1997).

Egypt is attempting to cope with the phenomenon of the rapid population growth -26 million in 1960 to almost 90 million in 2014 (Central Agency for Public Mobilization and Statics - Arab Republic of Egypt)- with approx. 200,000 primary and secondary schools with some 10 million students in Egypt . The educational situation in Egypt can be described as very complex, as public education is struggling to provide quality education which is very difficult considering the shortage in facilities, lack of well-trained educators and inflation in classes.

All of these factors affect the efficiency and the quality of the educational, social and built environment provided in these schools. The governmental specifications and regulations for schools and educational facilities state the regulations regarding: the site, the buildings, and the services. These regulations don't cover the quality and non-physical educational environment aspects, also it doesn't cover the concept of individuality and that each student has a unique personality. Participatory programming in which children come together to address their concerns can be seen as one important element of a wider strategy to address students in different education stages.

Children always tend to associate their childhood with happy memories and experiences, and now professionals can argue that school plays a less dominant role in shaping the children pleasant memories. The architectural design of the school buildings should/can provide a bridge and a link between children and adults' perception of school spaces design as adults already experienced the interaction with school spaces during their own childhood. On the other hand the common actual situation now is that school buildings designs are a representation of adults' vision only in a building in which children should explore and encounter a range of spatial settings that help them to shape their memories and develop their identity.

The interactive design process between the designer/architect and participating students in which the design/upgrade of the school is based on the inputs and feedback from the participating students (educators and parents are involved as well) is considered one of the most sustainable and efficient methodologies dealing with school design/upgrade to maximize student's performance within a specified learning environment. The technique of participatory design is one of the promising techniques in the school design strategies as it has many advantages: (1) it leads to a better school design/upgrade decisions; (2) it represents a stronger democracy; (3) designers are able to gather greater knowledge about students' preferences as well as their knowledge and expectations.

The main objective of this study is to propose a specific measurable participatory school design/upgrade strategy and determine the significance of implementing participatory design process in the primary school design and upgrade projects, its effect on the school building design and learning environment, and its applicability based on the following points:

- Child experience of decision making and elements of children's perception of the school building and the built learning environment.
- Understand the relationship between learning method and learning environment and the school design.
- Identify the spatial and functional conditions which contribute in a positive manner to the learning processes.
- Analyze the project strategies used in different school examples.
- Characterize the morpho-typological principles in the selected school buildings.
- Develop a suggested participatory design criteria and school design guidelines for school buildings and upgrading learning environment.

2. LITERATURE REVIEW

Children participation is a process in which children and youth engage with other people around issues that concern their individual and collective life conditions. Participants interact in ways that shows respect each other's personality, with the aim of achieving shared goals. In this process also; the child experiences and visions are playing an effective role in the community.

2.1. A New Paradigm

Until the early 1990s, the concept of participation was related to adult-focused interventions. The Convention on the Rights of the Child (CRC), which was adopted by the United Nations in 1989, has provided a core step forward towards activating and ensuring children participation by governmental and non-governmental organizations in the development projects and decision making strategies as active civil future citizens and actors in the development process.

What is striking and interesting about much of the new paradigm is the methodology of research with children is its engagement. Developers and researchers see their work as the extension of a commitment not just to opening up childhood to new possibilities but also to open up to the social world, and to children; not only making children more visible as members of society but making society more accessible to children, which leads to a more sustainable society where all its members are active actors within a well-structured social civil system.

Thomas Nigel and Jo Campling argue in their book *Children, Family and the state Decision Making and Child Participation* that researchers have challenged the perspective that information collected from children is somehow less reliable than that collected from adults. This perspective has now been evaluated in relation to the reliability of children as forensic witnesses, and found to be without much foundation. According to Dent, research has demonstrated that 'children as young as six years can be as reliable as adults when answering both objective and suggestive questions' (Dent and Flin 1992). Children including children with learning disabilities are 'as reliable as adults when giving free recall or answering general questions. But they are less reliable when answering specific questions' (Thomas N. 2000).

2.2. Nature and Forms of Children Participation

The children ranking of factors in participation should be processed with consideration of the nature of the participatory program/strategy itself, and what forms of participation exists within the participatory strategy (check figure 1).

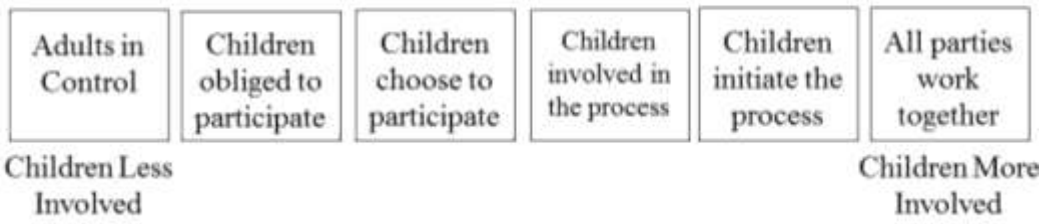


Figure 65: Forms of Participation (Author, 2014)

The forms of children participation were adapted from the work of (Hart 1992) Ladder of Participation and (Chawla 2001) into seven forms. These forms of participation are not necessarily the only ones and are not exclusive of each other as the participatory strategy can start with one form and then updated to include other forms of participation in different phases of the project (check table 1 and 2).

Table 10: Forms of Participation Matrix Based on Hart 1992 and Chawla 2001 work (Author, 2015)

Forms of Participation	Adults in control	Children obliged to participate	Children choose to participate	Children involved in the process	Children initiate the participation process	All parties work together
Prescribed	●	●				
Assigned	●	●				
Invited	●		●	●		
Negotiated	●		●	●		
Self-initiated			●	●	●	
Graduated			●	●	●	
Collaborative			●	●		●

Table 11: Roger Hart Ladder of Participation (Hart, 1992)

Levels	Roger Hart Ladder of Participation
1	Manipulation
2	Decoration
3	Tokenism
4	Assigned but informed
5	Consulted and informed
6	Adults initiate, shared decisions with youth
7	Youth-initiated and directed
8	Youth-initiated, shared decisions with adults

The ladder of participation developed by Roger Hart and the work done by Louise Chawla can be developed into a matrix of forms/levels of children participation, where the evaluation and the level of the children participatory process is measured and analysed within a matrix covering wider range of aspects and elements of participation rather than a ladder of participation (check table 3).

Table 12: Louise Chawla and Roger Hart Comparative Levels of Participation (Author, 2015)

Roger Hart 1990	Louise Chawla 2001
Levels 1-3	Prescribed
Level 4: Assigned but informed	Assigned
Level 5: Consulted and informed	Invited
Level 6: Adults initiate, shared decisions with youth	Negotiated
Level 7: Youth-initiated and directed	Self-initiated
Between level 7 & 8	Graduated
Level 8: Youth-initiated, shared decisions with adults	Collaborative

The previous comparison also can be combined with the work done by Thomas Nigel in 2000 which defines the different parameters/factors affecting the child decision making/participatory process including: The Context, The Setting, The Situated activity, The Selves, The Engagement, Relating to children, and Adult-Child Conflict: where the different scenarios were categorized as: direct action, compromise, discussion and explanation, sitting with the child, and having it (check table 4).

Table 13: Louise C., Thomas N., and Hart R. Comparative Levels of Participation (Author, 2015)

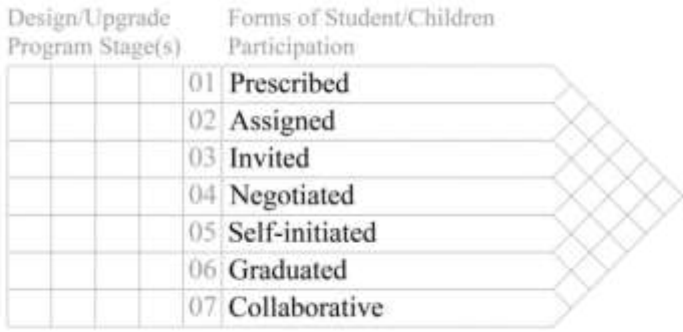
Roger Hart 1990	Thomas Nigel 2000	Louise Chawla 2001
Levels 1-3	Direct action	Prescribed
Level 4: Assigned but informed	Compromise	Assigned
Level 5: Consulted and informed	Discussion and explanation	Invited
Level 6: Adults initiate, shared decisions with youth	Sitting with the child	Negotiated
Level 7: Youth-initiated and directed	Having it	Self-initiated
Between level 7 & 8		Graduated
Level 8: Youth-initiated, shared decisions with adults		Collaborative

It's important to clarify that even if the collaborative participatory strategy has the highest level of children involvement, this doesn't mean that it's the best strategy in different situations. Each strategy and each level of participation can be the best option for a certain environment with certain criteria.

A participatory strategy/program can have different forms of participation in the different phases to utilize the children input and impact in each phase. The participatory strategy should also be introduced and implemented within an overall structured process which maintains a short and long term visions for the children participation strategy.

The forms of participation illustrated in tables 1 to 4 will be the starting point for the suggested school participatory design criteria/methodology, where the role and involvement of the student/child in the design process has different level/form of participation through the different design/upgrade stages according to the proposed seven levels in figure 4.

The levels/forms of participation developed by Louise Chawla (2001) will be the first part of the suggested participatory criteria illustrated at the end of the research. The seven suggested levels of participation can work within a matrix theme where one stage of the participatory design/upgrade process can contain one or more participatory level in order to maximize the efficiency of the overall participatory design/upgrade process.



3. CHILDREN PARTICIPATION IN SCHOOL BUILT ENVIRONMENT AND PARTICIPATORY DESIGN/UPGRADE STRATEGY

Schools are a result of adults or institutions visions which corresponds to the approach of mass education especially in the countries which face rapid inhabitants' growth such as third world countries (including Egypt). This approach is based on controlled learning facilities more like education factories, but now there is a change in learning environments which is changing into more a creative engagement learning environments in order to provide more healthy learning environments.

Students should be involved in the change of the physical environment of their schools, and in order to achieve that; architects should act like educators through participatory based school design projects. Participatory projects open up whole new ways of understanding the evolving nature of both education (pedagogy and practice) and of school buildings as an architectural form. With this approach, a closer new conception of how young people and children explore and define their space at school can be achieved.

For more understanding of the built environment a student encounters in the school some elements must be understood by the architect such as: users, objects, activities, routines, access, social and private spaces, individual landmarks, and place fear. These elements illustrate a fascinating range of aspects which could be included into the architect's thinking in term of detail design process.

A number of international case studies where student's engagement and perceptions of the school elements where the main engine behind the design were selected including: Montessori schools, Architect Hans Scharoun, and Baupiloten - Architect Susanne Hoffman. A general suggested criteria for school design was developed based on the researched three school design approaches in order to achieve a creative learning environment as shown in table 7.

Special school design guidelines should be linked to children's perception of the physical and non-physical environment in order to link it directly to child's behaviour, which also will enhance the complexity and overlap the guidelines in the suggested special criteria as shown in table 6.

Table 14: Special School Design Guidelines Phase 02 (Author, 2015)

Guideline/ Keyword	Guideline Criteria	Child's Perception							
		Users	Objects	Activities	Routines	Access	Space	Landmark	Place fear
Participatory Process	Prescribed								●
	Assigned	●	●	●	●		●		●
	Invited	●	●	●	●	●	●		
	Negotiated	●	●	●	●	●	●		
	Self-initiated	●	●	●	●	●	●	●	
	Graduated	●	●	●	●	●	●	●	
	Collaborative	●	●	●	●	●	●	●	
Explorative learning	Observation		●	●	●		●		
	Exercising		●	●					
	Space research					●	●		●
School curriculums	Applied curriculums		●	●	●		●		
	Children/space dialogue						●		●
Local environment	Outdoor comfort				●		●		
	Indoor comfort				●		●		
	Adaptive design				●		●		
Local culture	School role	●		●					
	Local community	●		●					
Place experience	Workgroup	●		●					
	Learning	●		●					
	Leisure	●		●					
	Space Geometry			●			●		
	Spatial perception			●			●		
Emotional significance	Own creation	●		●		●	●	●	
	School of dreams	●				●	●		●
	Space memory	●					●	●	●
User imagination	Children form environment	●		●			●		
	Manipulation			●			●		
Temporal aspects	Ownership		●	●		●	●		
	Uses/activities			●		●			

The demands of differentiated learning approaches in the selected school examples have a direct implication on the differentiated school environment. Thus, the typological spaces are varied, providing informal learning spaces inside the conventional classrooms as well as polyvalent working studios. The importance attributed to the processes of formal and informal learning is reflected in the treatment of socialization areas, which articulate community spaces with individual recesses which can be recognized in the school examples by Die Baupiloten where the design was based on a child participatory strategy in order to achieve and activate the previously mentioned space and design qualities. The special school design guideline_V01 targets the participatory process and design quality, more design guidelines targeting the different school spaces can be suggested as shown in table 7 with criteria(s) targeting directly architectural aspects highlighted in Green colour.

Table 15: Special School Spaces Design Guideline_V01 (Author, 2015)

Space Guideline	Space Criteria
Central Hall/Assembly/Main Atrium	Space for learning and leisure
	Social Meeting Centre
	Central position with different - large scale
	Open Entrance
	Use of different levels
	Connected to classrooms
Corridors and Circulation spaces	Interactive space
	Like urban streets
	Common meeting and group work spaces
	An extension of the classroom
	Gallery for student's work
Classrooms	Provide creative learning environment
	Encourage child's development
	Praise diversity
	Clustered like neighbourhoods for each level
	Connected to outdoor
	Good light and ventilation
	Main learning space
	Entrance lobby
	Service facilities
	Group study zone
School in General	School as a micro model of community
	Spatial sequence and hierarchy of private and public spaces
	Collaborative participation in space making
	Connected, free/accessible, house like environment

The design process consists of different overlapped/sequenced phases in which the participatory guidelines can be achieved within a structured overall project strategy based on implementing the participatory guidelines in the different phases. Each phase can provide a more elaborated understanding for the effect of activating or using a certain guideline and the overall chain reaction of the activated guidelines, which allows achieving more accurate strategy decisions in the following phases depending of the nature of the project (check table 8).

The phases are (check figure 6):

- 1st phase: professionals and children workshop

This phase might include: interviews, collage making, acting and role play, drawing ...etc. The goal of this phase is to break the ice between the project team and the children/students, also to encourage the students to take part into the participatory process and to freely express their needs.

- 2nd phase: Adults/staff workshop

This phase might include: interviews, activity diagrams, functional & educational aspects survey...etc. The goal of this phase is to activate and engage the school teachers within the project, to get their perception about the school design and how to include their students within the project itself, and to use their experience of dealing with the students and their observations on their behaviour.

- 3rd phase: Professionals/project team design proposals/alternatives

This phase will be done based on the input and gathered data from the previous two phases.

- 4th phase: children/students & teachers proposals presentation/feedback

The goal of this phase is to get all involved parties to evaluate and discuss the progress and the results of the participatory strategy/project, and to give their input in order to achieve decisions about progressing in the project or going back to a certain previous phase in order to reach more approved results.

- 5th phase: Finalizing design & building

Based on the input and the results from the last phase the project team can start finalizing and building.

- 6th phase: Project monitoring, maintenance, and after project strategy

One of the main goals of any participatory project is to have a long term and sustainable criteria that ensures the success of the project and its adaptability/durability for long term time span.

Table 16: Special School Design Guideline Participatory Strategy (Author, 2015)

Guideline	Children workshop			T	Transfer into design			Final stage			Guideline Criteria
	Dream Playground	Collage Presentation	Collage Analysis	Activity Diagram	Physical Dreams	School Setting	feedback	Finalizing Proposals	Building	Final Results	
Participatory Process			●			●		●		●	Prescribed
										●	Assigned
	●	●			●					●	Invited
							●		●	●	Negotiated
											Self-initiated
											Graduated
											Collaborative
Explorative learning				●	●	●			●	●	Observation
					●			●	●	●	Exercising
				●	●			●		●	Space research
School curriculums											Applied curriculums
				●		●				●	Children/space dialogue
Local environment				●	●	●		●		●	Outdoor comfort
											Indoor comfort
					●	●		●	●	●	Adaptive design
Local culture											School role
				●					●	●	Local community
	●	●	●	●	●	●	●	●		●	Gender
Place experience	●	●	●	●	●	●		●	●	●	Workgroup
			●	●		●	●	●	●	●	Learning
	●	●	●	●	●	●	●	●	●	●	Leisure
			●		●	●		●		●	Space Geometry
	●	●	●		●	●		●	●	●	Spatial perception
Emotional significance	●	●	●		●		●	●		●	Own creation
	●	●	●		●	●	●	●		●	School of dreams
	●	●	●		●				●	●	Space memory
User imagination	●	●	●		●			●		●	Children form environment
					●	●		●		●	Manipulation
Temporal aspects	●	●	●		●	●		●		●	Ownership
	●	●	●	●	●	●	●	●	●	●	Uses/activities

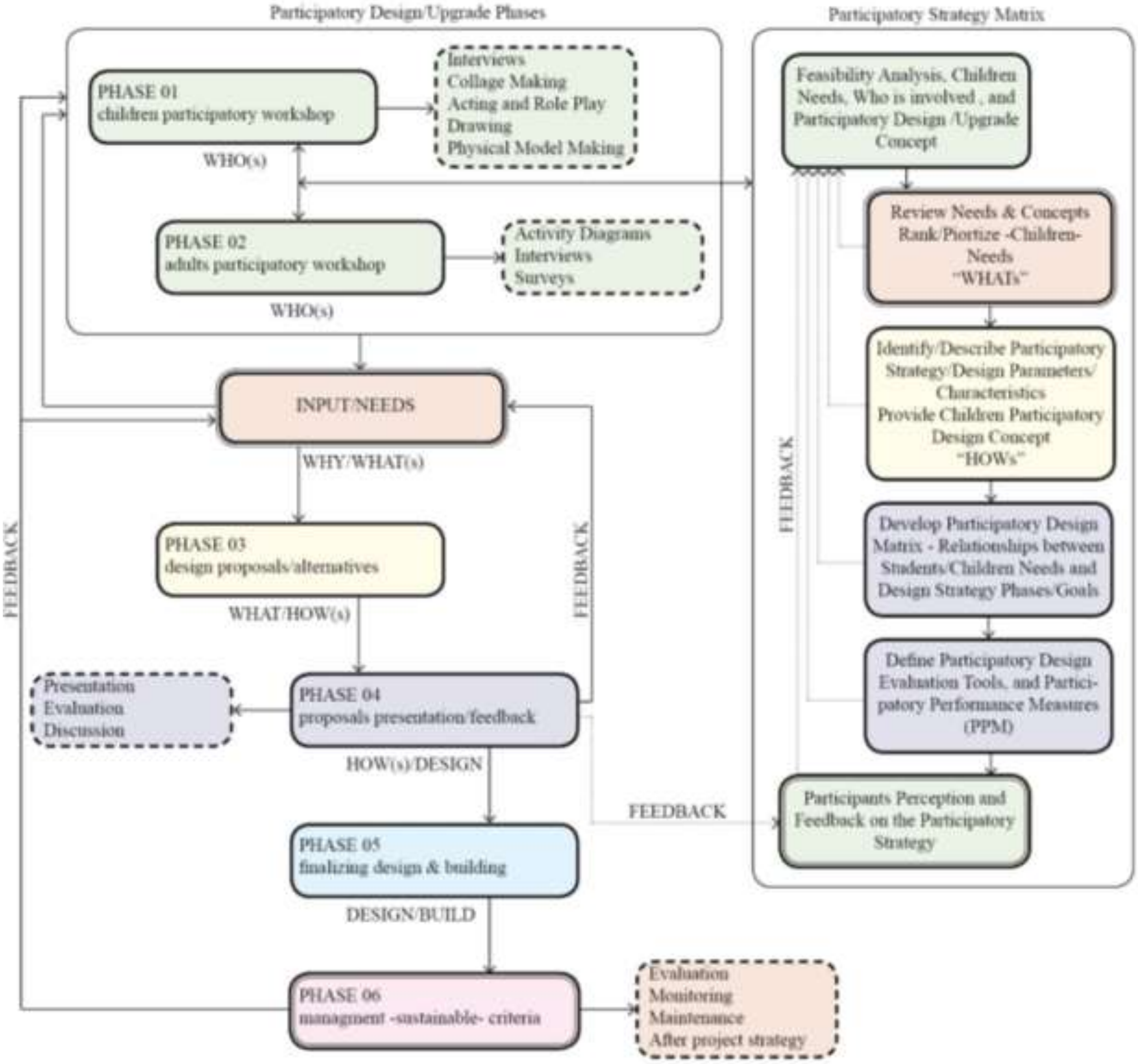


Figure 67: Combined Participatory Design/Upgrade Strategy and Phases (Author, 2015)

4. RESEARCH METHODOLOGY

This research was based on three methodologies (1) theoretical and analytical study, (2) analysing selected school projects (international and local examples), and (3) surveys to evaluate and criticize the suggested participatory school design criteria.

4.1. Theoretical and Analytical Study

The theoretical and analytical study includes understanding the concept of children participation and children rights on international and local levels, the current situation of school buildings' design approaches, and the idea of children participation in school design/upgrade projects.

Levels/phases of effective children participation will be proposed based on the theoretical findings.

4.2. Analysing Selected School Projects

Analysing existing projects international and local examples where the techniques of children participation in school design/upgrade were implemented in order to determine the applicability of the theoretical and hypothetical methodologies, also the case studies will address the civil society and non-governmental organizations on going initiatives to improve the school and learning environment conditions, student's needs, and the school design quality. From each example a set of school design guidelines will be adopted and merged with proposed the levels/phases of participation.

4.3. Participatory Design Strategy/Criteria

The primary school participatory design strategy/criteria and school design guideline will illustrate how participatory school design/upgrade approach can be a prototype for multifunctional interventions in the similar projects.

5. DISCUSSION AND CONCLUSION

Through the research a set of elements of effective children participatory strategies were illustrated and developed from general recommendations for participatory projects to structured guidelines for participatory school design (check table 8).

For any given school design strategies; the previous mentioned criteria can be applied within different school design or upgrade projects. The criteria's guideline(s) load changes depending on the goal of the design strategy, the aim, and the setting of the project, which proves the suggested criteria to be a flexible one that focus on enhancing and upgrading the participatory design approach and the education environment quality in general. Also this criteria can be used as an evaluation tool for the success of any given school design/upgrade project. The children participatory strategy can be combined with the different design/upgrade phases in order to reach and overall combined participatory design strategy (check figure 6)

Figure 6 illustrates an overall timeline for the different selected topics/researchers/case studies that were the base for the final suggested guidelines and phases for participatory school design/upgrade projects. The school participator upgrade/design project must ensure an effective participation process. These are the main key concepts for effective children participation:

Community aspects

- Building on existing initiatives: the project target existing community organizations and local parties to work with.
- Locality: the project should target the children related issues and understand their interests and needs.

Entry conditions

- Fair selection of participants.
- Targeting all categories with considering the children with special conditions.
- Children and their families are informed of the project aspects.
- Children have the freedom to choose to participate or not.
- Accessibility of the project data and lactation as well.

Children's role

- Children have real role and influence.
- Children have a part in defining the goals of the project.
- Children are helped to construct and express their views.
- Fair sharing of opportunities to participate.
- The project supports and encourages self-initiated attempts by children.
- The project has tangible results.

All of the mentioned participatory strategies and suggested design criteria and guidelines are for primary education level. The findings and recommendations can be developed and adapted for design projects with other school levels. Also for special educational environments like; special needs schools, Montessori schools …etc. All the data and findings from this study are recommended to be applied within the Egyptian Ministry of Educations rules/regulations for primary school design.

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A review of various factors for improving planning and scheduling of construction projects in the United Arab Emirates (UAE)

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Abstract: *The agenda of effectiveness, efficiency and economics has dominated business organisations operating in an agile environment where teamwork, accountability, transparency and responsiveness to client are paramount ingredients for business survival. Although construction organisations are not immune to these practices but they have to operate more smartly given very tight constraints associated with time, cost and quality constraints but also operate in an industry which is constrained by proliferation of austere requirements through legislation, building standards and safety. As a consequence construction organisation to have shifted the focus on pre-planning stages to eliminate or reduce the risks in the construction phases of the project. This paper proposes an integrated conceptual model to enhance planning and scheduling stages. The model consists of Six main parameters with associated elements include: the project (size, scope and complexity), the organisation (structure, lines of responsibilities, span of control and culture), the human aspects (education, experience and support), the construction methodologies (methods, preferred techniques, resources, out-sourcing, supply chain, health and safety) and the technology (software, tools and support); the contractual framework (obligations, risks legal); and the environment (internal and external). This paper discusses the Human factor in detail along with the rest of the factors in defining the conceptual model within the context of the United Arab Emirates (UAE).*

Keywords: Conceptual Model, Human factor, Planning, Scheduling, UAE

1. INTRODUCTION

One of the biggest challenges facing the construction project team is planning (Zwikael & Sadeh, 2007; Zhang *et al.* 2005; Waly & Thabet, 2003;Arditi, 1985; Kenley, 2004; Koskela, 2000) and that decisions made during this phase impact enormously on the successful completion of a project (De Snoo *et al.* 2011; Berglund & Karltun, 2007; MacCarthy & Wilson, 2001; Jackson *et al*. 2004; Jackson *et al.* 2004; McKay & Wiers, 1999). Planning, in fact, is often regarded as transitioning and developing effective collaboration of supply chain through to the work phases (Sriprasert & Dawood, 2003). Planning and Scheduling can be developed at various stages of the design and construction process (Faniran *et al.* 1999). It is commonly accepted that the planning process has two aspects: macro-planning, for decisions made prior to, and micro-planning, for more detailed decisions which are made during the construction process (Waly & Thabet, 2003). However, the ultimate aim of the planning process is to ensure *buildability* of the proposed schematic design as well as ensuring the planning and controlling of the actual construction phases. In fact, the planning and scheduling process is developed to satisfy the time, cost and quality constraints of a project together with developing a construction methodology which eliminates or reduces health and safety risks. In reality however, the planning and scheduling is a very complex process and heavily relies on reasoning process (Jackson *et al*. 2004; MacCarthy & Wilson, 2001). This process relies on the construction planners to translate tender documentations (drawings, specifications, bill of quantities, schedules etc) and produce a coherent set of work tasks based on method statement(s) with their logical sequential relationships and postulate a prediction of the work flow, visualising and capturing every aspect of the project stages including providing preventative measures reducing any safety risk (De Snoo *et al.* 2011; Berglund & Karltun, 2007; Jackson *et al.* 2004; MacCarthy *et al.* 2001; McKay & Wiers, 1999; Cherneff *et al.* 1991). Inevitably this stage will involve gathering of information and interpretation, communication and negotiation with different stakeholders to make decision and unpack or solve problems. In formulating planning and scheduling, the planners integrate their knowledge of construction practices, costing and productivity together with data specific to the project design. de Vries & Harink (2007) suggests that planners not only needs to possess knowledge and experience of the construction process but must be able to estimate labour and material requirements from the design documentation.

To date researchers concentrated primarily on operational level of project planning and control and have develop numerous models and framework associated in the following areas:

- analysing causes of low productivity (through inappropriate working methods, rework, mistakes, time delays and cost overrun (Banwo *et al.* 2015; Montaleb & Kishk, 2010; Al-Kharashi & Skitmore, 2009; Faridi & El-Sayegh, 2006; Assaf & Al-Hejji, 2006; Horman & Kenley, 2005; Zhang *et al.* 2005; Al-Tabtabai & Thomas, 2004; Alwi & Hampson, 2003; Koskela & Vrijheof, 2001; Lam *et al.* 2001: Morris, 1990; Winch, 1998).
- examination of the effectiveness of project management tools and the relative merits and demerits (Yaowu & Qingpeng, 2011; Kenley & Seppanen 2010; Galloway, 2006; Harris & McCaffer, 2006; Henrich & Koskela, 2005; Kenley, 2004; Arditi *et al.* 2002;

Atkinson, 1999, 2000; McKinney & Fischer, 1998; Hamilton, 1997; Jaafari, 1984; Moder & Phillips, 1970).

- Project management quality tools (Chileshe &Haupt, 2005; Ford & Bhargav, 2006)
- Stakeholder management interactions, collaborations (Becerik, 2004; Ahiaga-Dagbui, & Smith, 2014; Ahuja *et al.* 2009; Nguyen *et al.* 2009; Liu & Fang, 2006; Slattery & Sumner 2011; Wong *et al.* 2000).

However, there still remains a knowledge gap for developing a holistic model capable of capturing a range of key factors influencing the reasoning behind the strategic decision making in developing planning and scheduling for construction projects. Although these concerns have been raised by numerous researcher (King, 1976; MacCarthy & Liu, 1993; Buxey, 1989; McKay *et al.* 1988; LaForge & Craighead, 2000; MacKay *et al.* 2002) but there nothing has been presently conceptualized, implemented and tested. From an academic viewpoint, this paper formalises the conceptual model and contributes to useful directions to future research in this area with the detailed discussion on Human factor affecting the planning process.

Apart from the level of detail information contained in tender documentations which is dictated by the type of contract and procurement route selected by the clients professional advisory team e.g., design and build projects (tender documents may include but not limited to schedule of requirements, schedule of rates); traditional contracts (working drawings, specifications, schedules, bill of quantities) and in processing this tender information, the planner not only relies on his/her knowledge, experience and ability to visualise etc but there are often constrained and influenced by the external environment (contract form, communication structure within the team); internal environment in which there are working in terms of the organisation (its structure, culture, role, responsibility and level of control assigned); the technologies (working practices, preference on resources, supply chain, hard/softwares, planning tools); the human (Berglund & Karltun, 2007).

2. WHY UAE?

The landscape of UAE has been dramatically changing over the past 5 decades and UAE is widely known as one of the pioneer's of innovation amongst developing countries in the Middle East. UAE is associated with modern approaches to usage of land and unique built environment together unique infrastructure in terms of design and quality where cost and quality are not comprise and this has result be one-off mega construction projects building on reclaimed sea beds and desserts. Construction industry contributes 11% to the GDP (ADCCI, 2015). Every year the government invests billions in major capital projects. However, construction in UAE are not immune to delays and disruptions regardless of the cost injected to maintain building quality, according to Fairidi & El-Sayegh (2006), nearly half of the construction projects in UAE suffer from delays these are generally associated with construction companies and economic stability of the country. However, the construction industry of UAE employs diverse range of consultants (architects, project managers, cost engineers/ quantity surveyors etc); multiples international construction companies employing diverse range of workforce (from developing countries); and harsh environment setting. All these complex array of challenges and huge responsibilities placed upon the construction planners engaged in the planning process. Hence the remit of this research investigation is limited to the planning and construction phase of project's life cycle as opposed to the complete project's life-cycle.

3. RESEARCH DESIGN

The novel of the proposed conceptual model lies in the different perspective on the constructs and elements that characterizes cognitive decision making approach in develop the construction planning and scheduling process. The rationale of the present research is based on the fact that the construction industry suffers from lack of efficiency comparing to other industries (Koskela and Vrijheof, 2001; Winch, 1998; Zhang et al, 2005, Horman and Kenley, 2005). The model will aid a better understanding of the complex decision making process in the planning stages which in turn affects the project being delivered within the time, cost and quality constraints as well as increasing buildability on construction sites and related benefits. The research team intends to address several gaps in existent construction literature and to best of our knowledge all research undertaken in this subject domain have focused primarily on micro aspects of the planning process. The next phase of research methodology is not included within this paper and it will be conducted through a multiple case study analysis. It will be used with the two-fold purpose of exploring and theory-building research propositions and hypothesis related to the proposed model. The case study analysis was considered suitable to obtain in-depth results in a research area that is characterized by limited empirical research as planning process.

3.1. Conceptual Model

The proposed conceptual framework is displayed in Figure 1 and capture an environment in which the construction planners are constrained by. Figure 1 illustrates the relationships between the key elements which comprise both internal and external factors influencing the planning process. This paper talks in detail about the Human Factor.

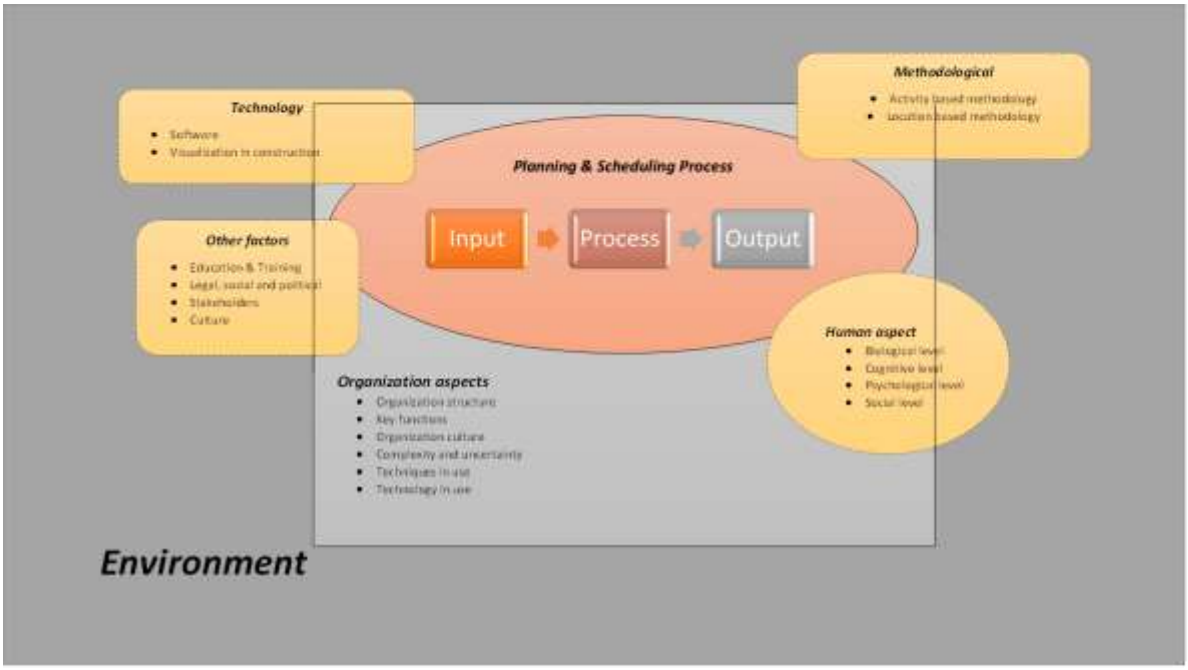

Figure 1: Proposed conceptual model of the Planning & Scheduling Process

3.2. The Human Factor

The success of execution of the planning and scheduling process hinges on the ability of construction planners to interpret, extrapolate, evaluate and synthesis the tender information to form decisions on time, allocate appropriate resources and develop a logical sequence. Hence this task ultimately challenges the construction planners cognitive reasoning and mental ability to visualize every aspects of the project sequences and their relative inter-relationship; communicate these to coordinate various members of the project team; and level of competency is displayed through the construction planners professionalism in terms of depth and breadth of professional experience and knowledge, educational background, and personal characteristics (De Snoo et al. 2011; Buchmann-Slorup & Anderson, 2010; Berglund, 2000; Berglund & Karltun, 2007; Jackson et al. 2004; Russell & Taylor, 2003; Meredith & Mantel, 1995). In this regard several researchers (Koo & Fischer, 2000; Illingworth, 2000; Kelsey et al. 2000) suggest the importance of a competent construction planner which is on the decline with increasing in project complexity (Allen & Smallwood, 2008).

At present there are no standards or guidelines or planning control framework available to assist the construction planner in making decisions, hence construction planners are totally reliant on using their intuition based on their personal experience. Daniellou (2001) describes the human contribution to the process at one of the following four levels:

- Biological level, where the human is regarded as a physiological system (this dimension is beyond the scope of this study and has not be taken forward),

- Cognitive level, where the human is considered as an information-processing system, including thought processes, representations, and decision-making,
- Psychological level, where the human has a unique history, leading to a specific subjective processing of the situations he/she experiences, and
- Social level, where it is emphasized that every single individual is a member of several social groups with different cultures, which will partly determine his/her values and habits.

3.3. Organizational Factor

Since the planning and scheduling process relies on team working ethics and information sharing within the organisation. The organizational structure - its culture, core values, protcols, ethics, experience, reputation, services delivery, agility and customer satisfaction affects how successful the organization is and this will directly influence the planning and scheduling process (De Snoo et al. 2011; Buchmann-Slorup & Anderson, 2010; Ajmal & Koskinen, 2008; Berglund & Karltun, 2007; Jackson, *et al.* 2004; Covin and Slevin, 1988). According to Robbins & Barnwell (2006), there are three key components are needed to be addressed within any organization: firstly, organization's hierarchy and its operating management structure; secondly job descriptions and role responsibilities through standardized; and thirdly, decision making structure and control. Hence the planning function will often vary from one organization to another; some organizations tend to assign a planner solely dedicated on this role, whereas, in other organization the planner has to perform other duties (Berglund & Karltun, 2007; Jackson *et al.* 2004; MacCarthy & Wilson, 2001).

3.4. Methodology Factor

Presentation techniques used for schedule communication are important vehicles for enabling the collaborative and coordinated work practices that are so important for the success of a building project. According to Kenley & Seppanen (2010) two main planning techniques that are designed to determine the sequence of the construction activities upon which a construction plan is developed and these are as follows:

- Activity based management: CPM (deterministic), PERT (probabilistic), Gantt Chart.
- Location Based Management: LOB (unit production), Flow line (location production)

3.5. Technology Factor

Due to increasing project complexity, there has been increased reliance in use of project management software as a tool for project tracking, time analysis, cost analysis, resource analysis and managing organizing construction projects (Liberatore *et al.* 2001; Choo *et al.* 1999; Hegazy 1999; Bounds, 1998). The most popular project management software packages Microsoft Project (MS project) and Primavera Project Planner, and these software packages are widely used with activity based management methodology (Galloway, 2006). VICO software is also available, though less popular and commonly used with location based management methodology (Kenley & Seppanen, 2010). The main technology aspects are:

- The scheduling software system availability and its ability to provide sufficient data, control and decision support.
- Automation in the construction industry: Building Information Modelling (BIM).

3.6. Environment Factor

The environment of any system lies outside the boundary limits of that system and it has negligible ability to control other systems beyond its boundary. System's boundary is used as a tool for understanding and defining the scope of an organization's interest (Cavaleri & Obloj 1993). There are some key factors within the environment of planning that influence the scheduling process are; Education and training provision; Legal and political; Culture; and Stakeholders.

Generally it is widely accepted that the background knowledge, experience and grooming of the individual project members has a significant impact on the project's success (Hinze and Plautz 1988; Marzano, 2004). There are other factors that will help in improving the professional knowledge of a person such as professional training, company training and project training (Hinze and Plautz 1988); higher education can foster the knowledge required to improve projects' performance, Tatum (2011). The contractors' experience affects the project quality, job efficiency, project cost and time and owner's satisfaction (Ling, 2004). Therefore, continuous education or training is important in order to raise the knowledge that is required to improve construction project performance.

4. SUMMARY

Generally, the measure of any project success (not limited to construction industry) corresponds to the extent to which customer needs are satisfied and the project objectives through time, cost and quality have been met. Cooke-Davis (2002) suggests that the realization of benefits is essential to establish project success. There are a number of tangible benefits from this research. Firstly, this research culminates into a deeper understanding of the planning process and the factors influencing the project success stem from undertaking a thorough scrutiny is paramount in avoiding project risks in terms of delays, disputes, disruptions and claims during the construction phases. Secondly a deeper understanding of factors will ensure seamless transition of effectiveness, efficiency and economic project targets are being attained and the planning model should be potentially value-enhance for all the key stakeholders within the design and construction team. Thirdly, this is especially valid for the construction sector, where there is a constant drive to implement time cost quality through innovation, efficiency and effectiveness not only from the individual company perspective but also from a multitude of participants.

Therefore, the cognitive, psychological; and social levels of human reasoning reflect on how people process acquired information. The processing activity involves use of various strategies that a person finds effective in solving current and future situations based on past experiences which offer learning opportunities (Young, 2011). Therefore, memory and knowledge are complementary aspects as they enable people to associate various scenarios in their lives and make both simple and complex decisions based on how they view a situation presented to them. In addition, people take information and expound on it however; this depends on the personal experience since some individuals can simply recall and relate a situation in order to make a decision.

People behave differently depending on their social setting and influencing factors that determine how they communicate and participate in different activities. Therefore, different psychological development determines the differences in reasoning capacity of each person. The process of communication plays an important role in all the levels analysed above since it involves an exchange of information through the use of language or behaviour. Therefore, it is important to note that through different levels of social interaction, some people acquire power over others. Power gives them an opportunity to influence and manipulate information relayed to others. Personal relationships determine the level of interactions among individuals hence influencing the decision-making process among individuals.

5. CONCLUSION

This paper has to be framed in a wider research project, which aims to unpack the key factors influencing the planning process and their interactions but also presents a holistic planning model to ensure that planning process is more effective. Organisations can provide additional support on a contingency-basis to meet the project objectives of time cost and quality. The objective of this paper was to present the results of literature review on the planning process, discuss the human factor in detail and to propose a conceptual model with the related research agenda. The model was developed directly from the literature on this topic. It represents an initial attempt at identifying the various elements to be managed within the organisations internal and external environment and how each element interacts within the planning process. The elements that compose the model have been described and a set of further research questions and hypothesis have been proposed.

In conclusion, every construction activity depends on effective planning and scheduling processes. These activities are strongly inclined to the decision-making process by individuals in the building process. The decision-making involves acquiring and processing of information to reach a conclusive outcome. Therefore, this involves analysis of human behaviour and is influenced by available information within their environment and their capability to process the information depending on their brain capacity and ability as individuals. This analysis will involve the determination of the human contribution to the planning process under cognitive, psychological and social levels. The scheduler/planner plays a vital role in developing project plan/schedule. The planning and scheduling process is influence by the scheduler adding human capabilities that cannot be automated such as problem solving, negotiation, linking different department for problem resolution and personal experience and knowledge.

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An Effective Client-Supplier Relationship for A Successful Project

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Abstract The main purpose of this research is to identify the main factors that lead to an effective client-supplier relationship. In addition, examining their influence on the success of the relationship, thus the project performance. Among the many factors that have been found which contribute to the success of the relationship, this research will examine only three critical components; trust, commitment and adaptation, that have been identified by many researchers to greatly affect the relationship.

Methodology – Interviews are the main methods used to collect empirical data. For analyses and to examine the influence of key factors on the supplier-client relationship, a qualitative research method has been used.

Findings – The analysis of the case study indicates that existence of the trust, commitment and adaptation has a positive influence on the client-supplier relationship, thus project success. Furthermore, the longer the relationship lasts between client and supplier over time, the higher the level of trust and commitment will be.

Limitations – Limitations include lack of inputs from suppliers with regard to their relationship with the client because of their busiest schedule. In addition, the lack of access to certain documents due to their confidentiality.

Recommendation – For the success of future projects, it is recommended to monitor and evaluate supplier's performance over the project lifecycle and their selection should be based on multi-criteria. For future research, it is recommended to involve suppliers in, to examine the client-supplier relationship from their perception as well.

Keywords: Adaptation, Client-Supplier Relationship, Commitment, Supplier Evaluation, Supplier Performance, Trust.

1. Introduction

Nowadays, procurement plays an important role in event profitability; therefore, decisions related to procurement have become more significant and organisations become more relying on their suppliers. Thus, poor decision-making can be costly and risky for them. Furthermore, delays in events are one of the biggest problems organizations face and result in payment delays, increase costs, loss of revenue or worse, cutting business relationship with suppliers or sponsors. Managing the client-supplier relationship (CSR) become at the top priorities in many organizations as they depend on their supply chain members to perform their business activities. The main purpose of this research is to identify the key factors for effective CSR and examine their influence on the success of the relationship, thus project performance

2. Literature Review

2.1 Evolutions and Definitions

Researchers like (Monczka et al., 2002) propose that the modern evolution of procurement is due to the current requirement of the businesses and government. They suggest that procurement evolution can be traced through different stages; development around mid of 19th century, through the stage of recognition before WW II, rapid development during that war, followed by quiet development. However, over the past three decades, the functions and roles of procurement have been changed into a period of major improvement in material management due to globalization, advanced technology and emergence of supply chain management (SCM).

In SCM, the relationship and collaboration between client and supplier are crucial in order to achieve the project objectives with maximum benefits and minimal risks through developing and implementing a proper relationship management strategy. Due to collaboration, a synergy between client and supplier is developed, which encourages joint planning, decision-making and real-time knowledge sharing, thus, developing and sustaining a strong relationship. (Sridharan and Togar, 2002) define client-supplier relationship (CSR) as two or more parties agree to work together to achieve desired goals. Similarly, (Corsten and Felde, 2005) define it as a kind of relational exchange where necessary information is shared, goals and incentives of all parties are aligned and decision-making is made jointly. (Morgan and Hunt, 1994) claim that a good relationship develops trust and enhances commitment between the different parties, thus resulting in a long relationship.

2.2 The Concept of CSR Management

(Turner, 1995, p.145 and 256) emphasises on the significance of managing the relationship between the owner and contractor as a healthy relationship leads to achieve the project goals stated in the contract. He also highlights the importance of the contractual agreements in establishing a successful relationship as it motivates and balances risks for both parties. The relationship between client and supplier can be complex as each party seeks to maximize their own benefits, which may result in a conflict of interest, consequently ruins the relationship. (Smith, 2007) states that both client and supplier are responsible for the development of their business relationship through their behaviour and reaction to each other requirement. (Walker and Rowlinson, 2008) report that building and maintaining a win-win business relationship requires all parties to show good attitudes.

2.3 Key Factors for Successful Relationship

Based on the intensive literature review, it has been found that there are many factors that have an influence on the success of the relationship. For example, (Walker and Rowlinson, 2008) state that both the client and supplier should keep in mind many factors such as trust, commitment, collaboration, adaptation, integrity and teamwork while developing a long-term, sustainable and win-win relationship. Additionally, (Smith, 2007) points out that trust, commitment towards contract and alignment of goals and processes are key factors for effective CSR management. Furthermore, (Dulaimi, 2013) highlights the importance of the client's openness and transparency while developing a relationship with contractors, and stresses on the significance of early informing suppliers about the project priorities. Moreover, (Morgan and Hunt, 1994) consider trust and commitment as crucial mediating factors in effective relational exchange; particularly trust, as they believe it is a cause of commitment.

On the contrary, (Storey et al., 2005) claim that factors such as differences in strategies and priorities, lack of commitment, divergences in trust and commitment level will impact the relationship between client and suppliers. Similarly, (Barratt, 2004) agrees that lack of trust between client and supplier impedes the development of the relationship. Whereas, (Morgan and Hunt, 1994) believe that both trust and commitment lead to a cooperative and log-term relationship between client and supplier. According to (Anvuur and Kumaraswamy, 2007), a good relationship will bring about an increase in cooperation and a reduction in risks, thus an ultimately a good project performance. Among the many factors that have been found, this research will only examine three critical components; trust, commitment and adaptation, that have been identified by many researchers to significantly affect the CSR.

2.3.1 Trust

The literature research results show that trust is important; however, only a little focus has been given to it when it comes to CSR (Smeltzer, 1997). (Moorman et al., 1993) define trust as "a willingness to rely on an exchange partner in whom one has confidence". Researchers like (Göran, 2005) examines trust in terms of mutual and interactive. He argues that interactive trust is a sort of continuous trust in the relationship, which reflects a continuous process, whereas, mutual trust is sort of instant and conditioned trust and reflects a discontinuous process. (Beth et al., 2003) highlight the importance of trust between parties and argue that it should be led by smart contracting. The same is emphasised by (Walker and Rowlinson, 2008) who said that trust is significant when parties have decided to entre into any sort of contract since sensitive information such as competitive and financial situations will be shared. This is to be followed by commitment, coordination and joint-decisions to overcome any challenges and prevent any disputes. (Maini and Sahay, 2002) state that successful CSR is characterized by a high level of trust and when it exists, all parties value the relationship and as stated by (Mentzer et al., 2000) and (Frankel et al., 2002) a strong relationship that is based on a high degree of trust increases the possibility of sharing sensitive and critical information required for the project success. Whereas, (Muhwezi, 2009) claims that trust reassures that the other party is capable enough to do the work and can be relied upon.

2.3.2 Commitment

Owing to commitment, client and supplier can provide the required resources to support and promote the goals of cooperation that best benefit the project and all parties. According to (Dion et al., 1992) commitment is the belief that the different parties are ready to dedicate efforts to build a sustained relationship. (Morgan and Hunt, 1994) consider it as a “central aspect” of a successful relationship and define it as a continuing desire of both parties to maintain and develop an on-going relationship. They report that with commitment, both efficiency and effectiveness are promoted as well as parties become more tied to their established goals. Whereas, (Ellram, 1990) indicates that both client and supplier are required to entre into a mutual commitment and work closely to gain mutual benefits. Furthermore, (Anderson and Weitz, 1992) note that commitment of a party is based on his commitment perception of the party, which means that client’s commitment, impacts positively supplier’s commitment.

2.3.2 Adaptation

(Mukherji and Francis, 2008) define adaptation as a certain modification taken by one party to match the requirement of the other party, which mostly serves the project. According to (Hallén et al., 1991), it happens when a supplier adapts to the client’s requirement and that client adapts to the capabilities of the supplier. Whereas, (Zineldin and Jonsson, 2000) say that client and supplier formally write down many of the adaptations made to their normal operation in the contract, while they agree upon other informal adaptations to overcome the problems that occur or at the request of the other. In addition, (Hallén et al., 1991) state that adaptation is an important feature in the dynamics of the relationship as one or both parties do certain changes as required to best matching between their needs and capabilities. They believe that adaptation is also important in an on-going relationship. Furthermore, (Fabriek et al., 2008) state that the more cultural alike and familiar both client and supplier are, the more likely that their relationship will create successful outcomes for both. In addition, team members on both sides should be introduced to know each other and the way of working to minimize the gaps related to organizational fundamentals. They also say if cultural differences exist, then parties should have the knowledge about them to be capable enough to deal with them.

2.3.3 Effective Management for Successful Project

(Willis et al., 1993) say that effective purchasing strategy and selecting the right suppliers will lead to important savings for organizations, thus, support them in improving their competitiveness. In contrast, selecting the wrong suppliers may not only result in financial problems, but also operational problems as Degraeve and Roodhoft stated in (1999). Therefore, to develop a strong CSR that leads to a successful project, an efficient and systematic approach is required for supplier selection to ensure a sound decision is made. Organization’s purchasing includes all activities concern buying process and one of these activities is selecting the best suppliers who are able to procure the client’s needs and requirements (Van Weele, 2005). As for (Monczka et al., 2005) supplier selection is a vital task of purchasing and counting on a single criterion for selecting a supplier is risky; therefore, multi-criteria method is recommended. Similarly, (Mwikali and Kavale, 2012) stress on the significance role of supplier selection in procurement success and say that selection criteria differ from one organization to another; however, a few criteria are frequently considered as important ones such as quality, delivery speed and cost. For supplier selection, they suggest five steps which are: 1) identifying the needs, 2) setting selection criteria, 3) pre-qualification, 4) deciding on the supplier and 5) monitoring. For the on-going search for new suppliers, they recommend building a databank for suppliers, which will assist in supplier selection process.

According to (Smith, 2007), there are two popular models being used for managing suppliers, which are arms-length and partnering. The first one assists organizations in minimizing their relying on suppliers and maximizing their bargaining power. It is characterised by short-term contract; whereas, a partnership is characterised by long-term contract and supports in establishing and developing a long and open relationship with suppliers. (Dyer et al., 1998) believe that organizations should use a combination of the two models in their purchasing practices. They also suggest dividing suppliers into categories such as suppliers that offer non-strategic products or services and strategic for those who provide strategic inputs and each group to be managed differently.

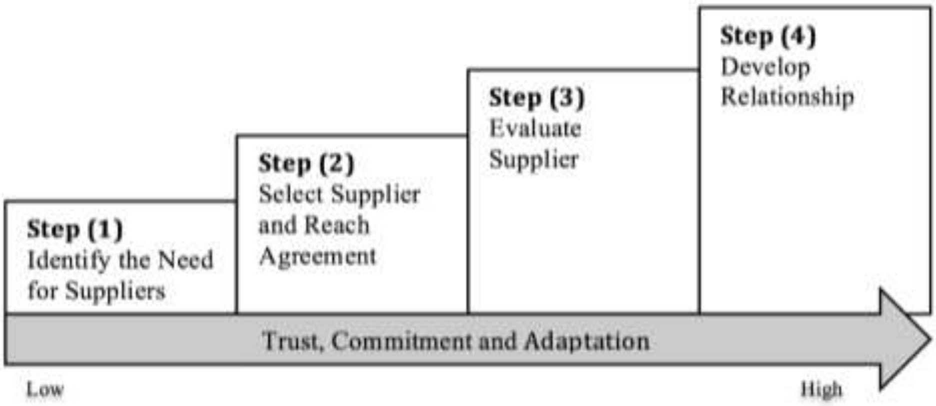
As soon the work on the contract begins, (Turner, 1995, p. 350-351) suggests three key elements for controlling during the project lifetime for effective management of CSR. Firstly, the review meetings that should be scheduled when the work on the contract is executed and these meetings vary from strategy meetings that gather clients with contractor’s directors, to technical meetings between engineers and progress review meetings between clients and other party’s project manager. Secondly, documents control, which is vital to protect the position of parties and includes controlling and managing all documents that pass between both to avoid any conflicting instructions bing issued at different phases. Finally, building a relationship at all management levels, which leads to mutual understanding and successful project. Furthermore, there is no ideal way to assess the performance of suppliers, and modes of evaluation rely on industrial problems appropriate to each client-supplier relationship. Therefore, the performance evaluation criteria for contractors, goods suppliers and services suppliers vary and must be adapted to each situation.

(Narayanan and Raman, 2004) report that monitoring and evaluating supplier’s performance over the project lifecycle will help in detecting any variation in the progress. Whereas, (Liker and Choi, 2004) emphasise on the importance of the method used by clients to communicate the supplier performance evaluation. They report that the evaluation report should contain true and accurate information about supplier’s performance to ensure continuous improvement and motivation. (Morgan and Hunt, 1994) believe that both trust and commitment lead to a cooperative and long-term relationship between client and supplier and according to (Anvuur and Kumaraswamy, 2007), a good relationship will bring about an increase in cooperation and a reduction in risk, thus an ultimately good project performance.

In summary, trust, commitment and adaptation not only have a positive influence on the CSR, but also promote the development of a strong relationship. In addition, as the relationship between the client and supplier becomes stronger, the level of trust, commitment and adaptation becomes higher.

3. Conceptual Model

According to the literature search, the following conceptual model is developed. It presents the steps to develop a strong relationship for successful projects based on an effective supplier management. It also shows the relation of the three factors (trust, commitment and adaption) on the CSR as it continues overtime. The model indicates that the more developed



the relationship becomes, the higher the level of trust, commitment and adaptation will be.

Figure 1: The Client-Supplier Relationship (Self-generated, 2014)

Step 1: Identify the Need for Suppliers

At this stage, the client has finalized the project concept that supports in identifying the need for suppliers. The appropriate model of purchasing management will be selected based on the project requirement. According to (Dyer et al., 1998), (Smith, 2007) and (Dulaimi, 2013) findings, for project's non-strategic requirement the arms-length model will be appropriate, so the client will have a strong bargaining power and the first three steps are suggested for this since it is characterised by a short-term contract. Whereas, for strategic requirements where both parties will entre into a long-term relationship, the model suggests the four steps to build a solid relationship that will influence the project performance. It is also recommended to early inform suppliers about the project priorities and the most important is to have a certain level of credibility and openness in their relationship at this phase to be a cornerstone to successful supplier selection.

Step 2: Select Supplier and Reach Agreement

At this phase, the client selects the best suppliers that best match the project's requirements and meet the organization's sourcing strategy. The findings of (Willis et al., 1993), (Turner, 1995), (Monczka et al., 2005), (Smith, 2007) and (Walker and Rowlinson, 2008) suggest that supplier selection should be based on multi-criteria rather than one criterion to avoid the risk of selecting wrong suppliers, thus prevent financial and operational issues at later stage. At this phase, both parties are responsible for developing their relationship through sharing an interactive trust and commitment toward signed contract. In addition, make joint-decisions and necessary adaptation in their processes for the benefit of the project and all these should be reflected in their contract to ensure the confidentiality of sensitive information and both risks and benefits are equally shared between parties.

Step 3: Evaluate Supplier

Once the contract is signed and both parties start working toward achieving the project's goals, the need for monitoring the progress becomes more significant. As per the results of (Narayanan and Raman, 2004), (Turner, 1995) and (Liker and Choi, 2004), the client at this stage monitors the performance of suppliers to ensure that the project is progressing well. During this phase, the client schedules regular review meetings and controls all documents being issued to prevent conflicting instructions and keep records of all work. To sustain a good relationship, it is important to be honest when evaluating suppliers and to choose the appropriate method to communicate feedbacks to them.

Step 4: Develop Relationship

According to the research conclusion of (Morgan and Hunt, 1994), (Anvuur and Kumaraswamy, 2007), (Maini and Sahay, 2002), (Fabriek et al., 2008) and (Muhwezi, 2009), effective supplier selection and evaluation is vital to support in developing and maintaining a strong relationship. At this stage, the relationship between the two parties can go beyond the project and continue for a long time. However, it should be characterized by a high level of trust where critical information required are shared and each believes that the other party is capable of performing the required tasks. Moreover, mutual commitment should be present to promote efficiency and effectiveness; thus, parties become more tied to the project goals. Furthermore, parties should be more cultural alike and familiar about other party's way of working.

4. Methodology

For this study, a qualitative method is selected, since it allows gaining detailed information as participants give thorough answers to the research's questions as stated by (Stake, 1995). Furthermore, as most of the questions begin with what or how rather than how many, thus, this method will result in an in-depth understanding of the subject. According to (Flick et al., 2004) interview is one of the common qualitative research methods used; therefore, it has been chosen using a semi-structured approach where open-ended questions will be asked. A total of three separate face-to-face interviews with key employees at ZZAH (events manager, procurement manager and quality control executive) have been conducted for data collection. The main reason for choosing this approach is to benefit from the in-person interaction for gaining a detailed insight into the subject, which will be less accessible by utilising other methods. All interviews were recorded after obtaining participants' approval and transcribed subsequently. The collected data were then analysed and relevant pieces of information were coded in order to group them into themes; trust, commitment, adaptation and suppliers.

5. Case study

ZZAH is a semi-government organization established to promote the Emirate of Sharjah as a leading dining, entertainment and cultural destination. Therefore, the yearly calendar is full of events that vary in terms of size, duration and complexity. Food Festival is an outdoor mega event that lasts for 17 days and is full of activities for families and celebrities. This event like other mega yearly events organized by ZZAH is subjected to changes compared with the approved plan especially during implementation stage for many reasons such as not achieving the sponsorship target, changes in events activities and timing, withdrawal of chefs from the participation, adverse weather condition and many other reasons.

For big events, ZZAH used to deal with an event management agency that sub-contracts most of the requirements to other suppliers resulting in a high cost and communication issues surrounding sub-contractors. For instance, ineffective delivery of information, long-duration response to their needs and request for changes in layout and kiosks design due to sub-suppliers chain length, consequently, dependent tasks got affected. Last year, the management has decided to deal with different suppliers each specialises in a certain area to prevent the issues that occurred in the previous events. At the beginning, ZZAH has faced lots of challenges in managing different suppliers, but as the time passes and the number of events increases, they have become more knowledgeable and proficient.

This year Food Festival was a success in terms of activities diversification and number of sponsors; however, the overall quality of stages and kiosks was not up to ZZAH and tenants expectation. In addition, one of the stages (stage F) was not ready until the second day of the event resulting in a cancellation of all planned activities on the stage for the first day. According to interview results, ZZAH encountered issues during the implementation phase, such as divergence in proprieties and low performance of some suppliers. To elaborate, supplier (A) cared about the quality of the end results, whereas ZZAH management main priority was to finish the project on time as deals were signed with celebrity chefs each on a certain day. Furthermore, suppliers were informed about the weather condition during the event based on past experience and requested that the stage should be strong enough, so it would not be damaged by the adverse weather. However, issues were noticed from the first day of using the stage such as a water leakage from one of the kitchens and the electronic oven did not work. All these caused payment delay to supplier (A) till all issues were fixed. Consequently, these disputes affected the relationship between ZZAH and supplier (A) although he had been working with ZZAH for more than five years.

Client Name: ZZAH
Suppliers Name:

- Supplier (A): responsible for delivering the main stages with lighting and stage equipment (refer to Appendix B for contract sample pages)
- Supplier (B) is responsible for delivering the event branding production

6. Data Collection and Analysis

In this section, the selected case study will be analysed against the findings of the literature review. The interview results reveal that ZZAH has built a list of suppliers that they always deal with. Suppliers are listed based on certain criteria such as quality, the speed of service and performance history. However, there is no such a technique adopted to evaluate supplier's performance and only rely on their performance while dealing with them and the completion report, which is developed to evaluate suppliers for the purpose of releasing payment only. The event manager states that their highest priority is to ensure that all set-ups will be ready on time and equipment will be tested at least a day before the event. Thus, when selecting suppliers, they consider their capabilities to deliver the requirement on time to avoid the risk of delay to the event start time; otherwise, the whole event will be affected dramatically. According to quality control executive (QCE), there was a great improvement in managing events and suppliers' performance in terms of communication and the speed of delivery over the past two years. However, supplier performance is not effectively monitored during the implementation causing delays of certain deliverables that affect the progress of other dependent tasks.

The outcomes support the findings of (Monczka et al., 2005) and (Degraeve and Roodhoft, 1999) of having multi-criteria for supplier selection to avoid the risk of ending-up with financial and operational problems. In addition, the discoveries prove (Mwikali and Kavale, 2012) results about the most important and common criteria used by many organizations, which are quality and speed of service/delivery. The analysis results also support (Narayanan and Raman, 2004) statement of the significance of monitoring and evaluating suppliers throughout the project lifecycle to identify any issues or variation in the project progress. It is therefore not surprising the delay in finishing stage (F) and cancellation of the first day activities as a consequence.

As said by QCE, an openness relationship has occurred between ZZAH and suppliers, and information such as event concept, budget and new ideas are exchanged. However, the level of trust is low prior to signing the contract, although some suppliers have been working with ZZAH for more than five years. To elaborate, event details are clearly communicated to suppliers including previous event problems; however, information about the budget only shared at a later stage when proposals and quotations are received. During meetings with suppliers, a number of them mentioned that if budget details were shared earlier, this would save them time and efforts, as they would only submit proposals that fit the client budget instead of re-doing the work or modifying the proposals. The procurement manager justifies the reason for this procedure to receive the best offers from suppliers and then negotiate the price that best suit both parties, otherwise amendment will be required to fit the budget. Consequently, this undermines the level of trust and some suppliers insist on sharing information about the budget before submitting the revised proposal. Whereas, others refuse any request unless information about the budget is shared.

The findings are supported by the results of (Mentzer et al., 2000) and (Frankel et al., 2002) which reveal as the relationship gets stronger, the level of trust becomes higher, thus, the likelihood of sharing sensitive information with suppliers. The analysis results of re-doing or modifying the proposals can be linked to some researchers findings such as (Morgan and Hunt, 1994) and (Barratt, 2004) who state that trust enhances the cooperation between the two parties, as a result, improves the project progress. Therefore, the low progress prior to signing the contract and re-doing some tasks is a consequence of a lack of trust. The result of sharing critical information related to budget at later stage proves the findings of (Anvuur and Kumaraswamy, 2007) and (Muhwezi, 2009) that sharing information means the client trusts that suppliers can be relied upon and ready to cooperate with them to reduce the risk and deliver a successful project.

As stated by the QCE, in one of the meetings with supplier (A), he mentioned that ZZAH has a strict policy that prohibits suppliers to commence the work onsite five days prior to the event's start date, which gives them only 2-3 days to finish the set-up onsite, so other suppliers can start their job. He pointed out that the venue set-up is a surprisingly lengthy activity and there should be a sufficient time to allow the crew to complete all tasks comfortably. The event manager justifies that ZZAH is a public destination and gets crowded particularly during weekends; therefore, it is difficult to close the area especially for big events. In terms of adaptation, the procurement manager mentioned that ZZAH has the flexibility to adapt its payment terms to suit suppliers if this will benefit the project; however, the majority of suppliers agree to ZZAH's standard payment terms. Furthermore, the results indicate that there is an organizational cultural difference in the way of conducting business that causes communication problems. According to the event manager, many suppliers particularly new suppliers approach their finance department for payment, whereas all internal requests to other departments are done through an online system including payment requests for suppliers and the event team should initiate all requests that will be routed for approval or actions.

The findings can be linked to the conclusion of (Fabriek et al., 2008) of the role influence of having a similar cultural organization to a build successful relationship, thus, delivering the project successfully. If the client and supplier have not matched their business cultures or processes at the beginning, then some difficulties and issues may occur during implantation phase and can not be resolved without matching or integrating the two parties cultures, processes or policies.

To summarize, ZZAH has gained a good knowledge about event management; however, their knowledge when it comes to supplier management still needs to be enhanced. In addition, if the management has not considered sharing a high level of trust, commitment and adapting its policies to suit suppliers' requirement, then challenges will be faced while attempting to build a strong and long-lasting relationship with them.

7. Conclusion and Recommendation

In conclusion, trust, commitment and adaptation play a key role in developing the relationship between the client and suppliers, thus having a good SCM and successful project. The findings also show that trust improves the relationship between the client and suppliers and leads to commitment, which is crucial for adapting and integrating parties processes and goals for the advantage of the project. Limitations to this research paper include, but are not limited to the lack of suppliers inputs with regard to their relationship with the client due to their busiest scheduled in addition to the lack of access to the completion report due to its confidentiality. Moreover, the research paper only focuses on a single industry, which makes it difficult to compare the findings with other industries such as construction and IT. Based on the literature review and case study findings, the following are some recommendations that may improve the relationship between the client and suppliers and establish a strong and long-lasting relationship.

- Critical to effective CSR is information sharing. Therefore, the client must have a total trust that shared information with suppliers will remain confidential and it is important to established knowledge sharing through multiple interfaces. For instance, client and suppliers must share information about their various processes when it comes to event management and critical financial information to better assist and serve the client.
- Integrating both client and suppliers processes, priorities and goals as well as share a high degree of trust, commitment and adaptation to ensure that all parties work closely toward achieving common goals and eliminate the obstacles that hinder the progress of the project.
- Monitoring suppliers performance over the project lifecycle to detect any issues in order to take corrective or preventive actions. This can be done through review meetings, document control with the assistance of event/project management tools and selecting the proper method for communicating performance to suppliers.

For future research, it is recommended to involve suppliers in the study to gain insight into the relationship from suppliers' perception and cover different industries, so a comparison can be made among the different industries and against the findings of previous researches.

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