SUSTAINABLE- ECO- BUILDINGS

ASSESSMENT METHOD FOR THE EVALUATION OF RESIDENTIAL BUILDINGS IN HOT DRY CLIMATE

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Abstract:

This research aims to investing the present situation of residential buildings in Greater Khartoum to evaluate them by sustainable environmental parameters. The problems of residential in the indoor and outdoor environment and services. The research also aims to find a sustainable assessment method to enable us to evaluate residential areas and their services in the Greater Khartoum.

The methodology of the research starting by literature review. Identify the passive and sustainable solutions suitable to hot dry climate. This method contains eight main categories which are, sustainable site, indoor environmental quality, outdoor thermal control, building form, materials and resources, water supply, power supply system and environmental plan process. The total points achieved should be 125 points, the method has a scale of points for evaluations, main categories and sub issues calculate the total of points to get the result of evaluation for the building. The scale, of evaluation and range of evaluation from pass, good, very good and excellent according to the study method of assessment.

The survey starts by identifying the standards of selecting the case study, tools of investigation, and the documentations methods, interviews with professionals and owners; then survey studied forty-eight cases in the residential areas in Greater Khartoum, analyzing the data by the evaluation method of the research, summarizing in tables and figures.

The finding by the method of assessment and got the result as; zero of the case studies were Excellent, 18.75% of the cases studies were Good, 25% of the cases studies were PASS and 56% were Weak .The analysis of buildings showed Good results in sustainable site and outdoor thermal control and indoor environmental control. Weak result in building form, materials and resources and services, such as drainage system, water supply system, power supply system and environmental process in the first class areas and shows Weak results in all categories in the areas third class areas General conclusions for areas of study in the main categories are set in the conclusion. Conclusion and Recommendations in urban, housing, services, building construction and community level are set up to be applied in sustainable ecological building in Greater Khartoum

Keywords:

Passive solutions, Sustainable Eco Building Principles, Sustainable Assessment Methods, Greater Khartoum Environmental parameters, Introduce Assessment method for evaluation of residential buildings.

1. Introduction

This research aims at investigating the present situation of residential buildings in Greater Khartoum to evaluate those buildings using sustainable environmental parameters. The problems of residential buildings to that will be investigated are environmental problems in the indoor and outdoor environment and services. The research also aims to find a sustainable assessment method to enable us to evaluate residential areas and their services in the Greater Khartoum. The location of the case study is in The Greater Khartoum, which is classified into the three towns, the capital Khartoum, Khartoum North and Omdurman. The climate described as hot dry climate, it between latitude 15° 36' north and longitude 32° 3 east, with an altitude of 380 meters above sea level, The temperature in summer ranges between 40°C to 45°C, in winter it drops to 14°C to 25°C. The rains range between 100mm to 150 mm. The range of relative humidity is 40% to 60%. Greater Khartoum is facing floods, desertification and rare earthquakes and it has wide variety of natural vegetation's in the lands around River Nile.

2. The Literature Review

2.1 The Passive solutions and Environmental Principles Suitable to hot dry climate

The aim of this paper is to define the sustainable-eco-building principles in relation to the environment, and at the end, we will study all suitable solutions to hot dry climate to be applied in sustainable-eco-building and environmental comfort. Sustainable development started in 1992, Sustainable development define as: that meet the needs of the present without compromising the ability of future generations to meet their own needs this concept has been explained by Conway, 1987.

The building design should be economical in: reducing costs of materials, building construction, maintenance, building equipment's, energy and water

consumption and there is a need to focus on the fact that the building should be socially connected to the surrounding environment, by providing social services, recognizing human health and safety and to improve the quality of life; beside that the building should be controlled in, British Architects' (Architect, 2010) considered minimum issues key indicators for sustainability design and grouped them according to the structure issues to be recommended for consideration which are: Land and ecology, Community, Health, Materials, Energy and water. (Kubba, 2010) Today new concepts of architectural design allow us to greatly improve the energy performance and to reduce the environmental impact of materials use in buildings. The Leader in Energy and Environment (LEED) announced six main categories of sustainable design, which are Sustainable Site, Indoor environmental quality, the energy, the water, the material and innovation.; As well as there are many books discussing the issues of sustainable design and eco design principles one of these books is: (Kubba, 2010) and (Fower, 2006) discussed these issues in his book 'LEED Practices, Certification, and Accreditation Handbook as well as (Bromberek, 2009) discussed the principles of designing eco resorts which are site selection and landscape, construction, energy management, water management, waste management, climatic performance in addition to that (Barrows, 2009) .(Sassi, 2006) And (Van, 2009) published a book in 1996; they discussed the principles of ecological design which are: Solutions Grow from Place, Ecological Accounting Informs Design, Design with Nature; everyone is a Designer, Make Nature Visible. The book's second part, title is "The Ecological Design Process Sustainable site, Energy, water, materials; economic dimension which will appear in such solutions as energy efficiency, water efficiency and ecological building material, recycling of grey water, recycling of construction materials. The social dimension, this appears in community participation, and managing the outdoor environment. Then; provides an introduction to each principle, and provides sustainable and technical solutions for each principle from global position that has been applied. (Roaf, 2005). reviews the literature on thermal comfort principles and design with reference to the hot-dry climate. discuss the basic thermal comfort principles; thermal comfort definition, the heat balance between human and the building, the heat flow, the time lag, human thermal comfort and balance, building thermal behavior, the building material and the important of ceiling and wall insulation in such climate as hot- dry climate and the six basic factors of thermal comfort. the passive solution in architectural design suitable to hot dry climate such as urban planning control and spatial control, architectural element and components control, physical aspect control and controlling the design in indoor environment and outdoor environment and detailing the three building components and discusses the solutions the hindrances the risks of solar radiation and high air temperature. The landscaping, and implantation of the traditional solutions such as passive cooling tower, courtyard system and controlling building form, ventilation and orientation. (Hassan, 1995) .

Why we need to introduce new assessment method for assessment the eco building in Greater Khartoum?

The global assessment method were designed for specific environment, culture, social and economic problems on those community, that's why the research highlight the need of studying the environmental, social, culture and economical needs for Greater Khartoum.

What are the suitable principles could be added to the hot-dry-climate?

(Abdelmoneim, H., 2016) discussed the global sustainable assessment methods and concluded five categories between them: sustainable site, indoor environmental quality, water efficiency, energy efficiency and material. In addition the paper arrived to adding more categories suitable to Greater Khartoum like outdoor environment category; people in Greater Khartoum use the outdoor for sitting, collaborating, and sometime sleeping because of hot climate. Also, Building form category: studying building form is become crucial, it should be studied with solar angle to have more building shades, and better ventilation, the building should oriented towards north-south direction. In addition to that environmental design process to control the whole process in building design, construction and maintenance.

The suitability of research method of assessment and proved summary to research method of assessment that will be discussed in details.

3. METHODOLOGY

The methodology of this research the intensive study of the available assessment methods leads to the rationalization new evaluation method for testing the case study according to their nature, residential buildings in Greater Khartoum. This method has been applied to the all levels of urban classes. The Methodology consists of many steps these include:

1. Review of previous literature in Environmental Sustainable Development (ESD) and the principles of ecological design, a review of the passive solutions suitable to the hot dry climate, the nature of the case study in the environment. architectural, spatial and infra structure is reviewed as well as review the historical background of residential areas in Greater Khartoum and the problems faced by them. General review of the environmental assessment methods; the physical assessment methods and the quantitative and qualitative assessment methods and the sustainable assessment methods which had been adopted in 1992; rationalization of the new assessment method of the research to evaluate the residential buildings in Greater Khartoum. Presenting the study method of assessment and reflect the passive solutions suitable to hot dry climate into the principles of sustainable eco buildings.
2. Comparison between four sustainable buildings assessment methods was done during the research and the result was published (Abdelmoneim, H., 2016).
3. From the comparison, the researcher highlight the main principles of sustainability which are: sustainable site,

indoor environmental quality, material and resources, energy and water efficiency.

a. Why we need to add a new sustainable assessment method that is suitable to Greater Khartoum?

The global sustainable building assessment methods were introduced in specific countries to solve the local environmental, cultural, economic and social problems.For instance, Australia

introduced management, transportation and land ecology, ESTIDAMA liveable community and integrated design process, and GSAS social and culture. It was evident that all these countries had their own sustainable evaluation methods and had similar as well as different categories for solving their local social, economic, and environmental problems.

e. The need to add more categories to solve the local environmental, social, and economic problems

The researcher further added three more categories, which are as follows:

i) Outdoor Environmental Quality: This was integrated for social and environmental impact because people use the outdoor environment for sitting, welcoming their guests, celebrating, and sometimes sleeping in hot summers. In addition, the researcher added solutions,such as the use of canopies, terraces, areas with shade, plants and trees, fountains, and the like to cool the air surrounding the buildings.

ii) The Building Form: This was included for economic and environmental impact. Studding the building form with solar angle provides more shade to the building and cools the air around the building;and for energy efficiency, studding the windows, vertical and horizontal sunscreens, wind towers, and courtyard system was seen to be more effective.

iii) Environmental design process, it was added for two reasons, to control the whole design process including the eight categories, and for educational reason, to educate the architects and engineers and the community about sustainability.

4. Present the study method of assessment in main categories, the sub issues, and the scale of evaluation, and then, criteria for selecting the case studies, the fieldwork tools, documentation, analyses, interviews with owners and specialists are also included.
5. The fieldwork including a survey to evaluate 48 case studies in different areas in Greater Khartoum will be done, data collecting documenting, presenting and demonstrating them in tables and figures and analysis by computer programmes.
6. The discussion and analyses by the study method of assessment for all areas of the study, and then the average results for the main categories of the case studies will be done, analyzed and discussed for all areas of study in Khartoum, Khartoum North and Omdurman, then conclusion for the discussion.
7. General conclusion and recommendations will be applied in residential buildings in greater Khartoum, and recommendations for the areas of study and recommendation for the future researches will be given.

3.1 THE STUDY METHOD OF ASSESSMENT

The study has reviewed environmental assessment methods including the sustainable assessment methods identifying five main principles of the study method of assessment. The literature reviewed previously; discussed passive solutions suitable to hot dry climate, also identified building form and outdoor environment and environmental design process, as well as detailed the main principles of sustainable-eco-buildings. To conclude the main categories of the study method of assessment are: sustainable site, indoor environmental quality, outdoor environment, water efficiency, energy efficiency, building materials and building form and environmental design process. The study method of assessment shall be explained and detailed.

3.2 Development of the study method of assessment

The research method of assessment has been developed using different methods:

1. By carrying out intensive literature review in the area of the study, including the principles of sustainable development, principles of environmental design in urban components, architectural components, spatial aspects, physical aspects, outdoor and indoor environments, as well as studying previous assessment methods and critically analysing them.
2. Five global assessment methods of sustainable buildings are analysed; identifying the main categories for the sustainable assessment method; such as: sustainable site, indoor environmental quality, materials, energy efficiency and water efficiency.
3. After studying the environmental conditions in Greater Khartoum, the research identified three categories that are suitable for the hot-dry climate. These are: building forms, outdoor environmental quality and environmental design process.
4. Some sub issues were developed to support the research method of assessment in the field of sustainable buildings (see Appendix-6) to support the method. These issue i.e the importance of materials in roof, walls, floors, and décor shown in the evaluation method; and the use of air conditioning as a negative (-1 point) because it has negative impact on environment.

5. Some solutions were included when reviewing literature on traditional solutions such as the use of courtyard systems, wind towers, domes and vaults effects on absorbing solar radiation.
6. Other solutions were also included based on practical experiences; such as the use of vertical and horizontal sunscreens, orientating the building at 45˚, and the use of wells and septic tanks in drainage systems.
7. Technological solutions, globally and regionally, are introduced, this is by using energy simulations programme to achieve energy efficiency, and using IBM software to develop eco building designs in computers.
8. Local natural resources in wind energy, solar energy, eco building materials were studied and imposed in the research method of assessment.

3.3 Scale of evaluation

This Scale shall be used to evaluate each issue of evaluation of residential buildings in Greater Khartoum.
Table (5.1): The Scale of evaluation

The Mandatory	Meaning	Points given for evaluation
Positive	Means it's applicable	From 1 to 2
	Positive impact on the environment	1
	More Positive impact on the environment	2
negative	Means it's not applicable	0
	Negative impact to the environment	-1
	Too negative impact to the environment	-2

These points are incorporated according to The Predicted Mean Vote (PMV) and scales index.

3.4 Method of evaluation

The Suggested sustainable-eco-building evaluation method for hot dry climates, such as Greater Khartoum, which is applied in this research on the level of Eco Buildings on 48 case studies on Greater Khartoum are shown in Appendix 1.
The research has designed this sustainable-eco-building evaluation method, which is suitable to the local environment in Greater Khartoum. This contains eight main categories: Building form, materials and resources, drainage system and resources, water supply and drainage system, power supply system, environmental plan process, the total points that should be scored is 125points. What makes the difference between this method and the other three systems? The answer is: This method included other three main categories, which are outdoor thermal control, building form, and environmental process as a separate category. Also, this method gives five main evaluation ranges of points which are:

< 40	Weak
(40 - 44 pts)	Pass
(45 – 59),	Good
(60 - 75 pts)	Very good
(76-126pts and more)	Excellent

These levels of evaluation were included in reference to British standards of green buildings BREEAM. (BREEAM, 2014) That uses the same method of evolution: weak, pass, good, very good, excellent.
The method of assessment that has been applied to the 48 samples in different areas in Greater Khartoum., the sustainable-eco-buildings assessment method was designed after wide review of the environmental assessment methods and the suitable passive solutions for hot dry climate. The method combines sustainable main categories, and the passive solutions. Taking into account the environmental, spatial, architectural, residential and technological conditions of the case studies.

3.5 THE MAIN CATEGORIES OF THE METHOD OF ASSESSMENT

Table 5.2: main categories of the assessment method

item	category	symbol	No. of points
1	Sustainable Site	SS	13 points
2	indoor environmental control	IEQ	34 points
3	outdoor thermal control	OTHC	9 points
4	Building form	BF	8 points
5	materials and Resources	MR	34 points
6	water supply and drainage system	(DS&WS)	16 points
7	natural power supply	NPS	15points
8	environmental design process	(EDP)	1 points

See appendix-1

3.5. 1 SUSTAINABLE SITE (SS)

Sustainable site deals with issues outside the building, i.e., the land that is being developed and the surrounding community. Appendix-5 shows the requirements the total points for the sustainable site is, 12 points equal to 10% from 125 points. This 12 points comes from the main content of the sustainable site category contains sub-issues. These are: site selection (1/12) equivalent weight (0.083); construction system (3/12) equivalent weight (0.25); controlling systems (3/12), i.e., parking control, construction activity control and natural water features. Alternative transportation (3/12), i.e., public transportation access, bicycle storage, and low emitting fuel. Improve thermal environment (2/12) equivalent weight (0.16), i.e., maximized open space and enhanced landscaping on site; and the study of the heat island effect (1/12)

equivalent weight (0.083). All these sub issues are detailed in Appendix-1 and Appendix-2. For the applied assessment method, each sub issue scores one or two points according to its importance and positive impact on the environment.

3.5.2 INDOOR ENVIRONMENTAL QUALITY (IEQ)

The indoor environmental quality (IEQ) portion deals with materials and systems inside the building that affect the health and comfort of the occupants and construction workers. The indoor environmental quality category of the method of assessment consists of 7 sub issues. See Appendix-1 and Appendix-2 for details on the assessment method, Appendix-5 for the requirements and benchmarks for the main categories of the assessment method of the research. The total points should be achieved are 30/125 which equivalent to 24%; This 30 points comes from the detailed content indoor environmental quality main issues and sub issues. The first issue is the building orientation (4/30) equivalent (0.13) which includes applying the building orientation to the North-South direction (1/30) equivalent (0.03), to East - West direction (2/30) equivalent (0.06). The second issue is to control building dimensions by applying surface volume ratios, which should be between 0.12 to 0.16 to avoid exceeding solar radiation on the building (1/30). The third issue is roof thermal control (5/30) equivalent 16.6%, which includes roof thermal insulation (1/30), white colours (1/30), double roof (2/30), and green roof (1/30). The fourth issue is the study of wall thermal control (12/30) equivalent to (0.40) which includes building materials (1), windows (5) equivalent (0.16), shaded devices (4/30) equivalent (0.13), wall paints and colour (1), and green walls (1). The fifth issue is the study of floor thermal control (1/30); choosing the floor finishing material from an eco-floor material manufactured from recycled construction building materials such as concrete, stones, bricks, ceramics, and has long term of durability, easy to clean, easy to maintain, durable to pressure, non-slippery, heat and moisture resistant. The recycling content is suitable to the most of the residential buildings. The sixth issue is the design of thermal comfort (4/30) is equivalent to 0.13 which includes individual thermal comfort (1/30), controlling the natural ventilation e.g. maximize the windows (1/30), the use of traditional solutions such as wind tower (1/30) and the courtyard system (1/30) that improves the air movement and air temperature in buildings. The seventh issue is supporting these solutions by mechanical means (3/30) equivalent to 0.10 such as using of fans, desert coolers or HVAC systems, which help in controlling the air temperature, air humidity and filtering the air from dust. These solutions vary in different residential areas. However, the use of air conditioning system is evaluated as -1 points because it has negative impact on the environment. Each sub issue scores one or two points according to its importance and positive impact on the environment.

3.5.3. OUTDOOR THERMAL CONTROL (OTHC).

The researcher added the outdoor thermal control category. Table 1 in Appendix-1 includes the details of the sub issues of outdoor thermal control category. The total points achieved is 9/125 points equivalent to 7% , this number comes from detailed issues and sub issues of outdoor thermal control category. Each sub issue scores 1/7 equivalent to 0.14 or 2/7 points equivalent to 0.28 according to their importance and positive impact on the environment. People in Greater Khartoum are aware of the outdoor environment because the climate is hot and dry. They spend part of their time, especially at nights, in the gardens, which are also utilized during holidays and celebrations. The first issue is to provide shades to the building in the North-South direction (2/9). The second issue is to provide shades to the East-West direction (1/9). The third issue is to provide shades using balconies (1/9). The fourth issue is to enhance landscaping on site using plants and trees that provide shades (1/9). The fifth issue is to build fences to protect the site from dust (1/9). The sixth issue is to build swimming pools (1/9). The seventh issue is apply fountains to change the dry climate into a humid climate (1/9). Terraces (1/9). See Appendix-1 for the assessment method of the research and equivalent percentage, Appendix-2 for details, and Appendix-5 for the requirements and benchmarks for the main categories of the assessment method.

3.6.4. BUILDING FORM (BF)

The building forms category was added to the main five categories by the researcher, because it is important to study the relation between solar angle and building form, and choose the best solution that gives more shades to the building. This helps in cooling the surrounding air of the building. See Appendix-1 for details on the sub issues of building forms. Total points should be achieved are 8. Each sub issue scores 1 point according to its importance and positive impact on the environment.

Although LEED V4 did not add building form as a separate category, Council, U. S. G. B. (2014) stated, “Provide shade from structures covered by solar panels that produce energy used to offset some non-renewable resource use. Provide shade from architectural devices or structures that have a solar reflectance index SRI of at least 29. Implement a maintenance program that ensures these surfaces are cleaned at least every 2 years to maintain good reflectance”. This was added under sustainable site category in LEED V4 and LEED V3. Further, Council, U. S. G. B. (2014) mentioned, “Naturally ventilated buildings must comply with a local standard that is equivalent to ASHRAE Standard 62.1-2007”.

In my opinion, there is no specific category or sub issue dealing with building forms. It is essential to deal with building forms to control building shades and natural ventilation through building orientation. The total points of building form is 8/125 points equivalent to 6.4 %.This 8 points comes from the detailed sub issue. The research draws details such as linear forms (1/8) equivalent to 0.125, U-shaped forms (1/8), L-shaped forms (1/8), cubic forms (1/8), circular forms (1/8),

courtyard systems (1/8), use of vaults (1/8), and use of domes (1/8).

3.6.5 MATERIALS AND RESOURCES (M & R)

The materials and resources category has 13 credits with a total of 34 points. See Appendix-1 for details on the sub issues of materials and resources category. Each sub issue scores one or two points according to their importance and positive impact on the environment. Materials and resources consist of 13 sub issues. Total points should be achieved are 34/125 points equivalent to 27%. The number 34 points comes from the detailed issues and sub issue of building material category. The first issue is the material used in the base like bricks, cement, gravel and stone (6/34) equivalent to 0.176. The second issue is the material used in walls like bricks, stone (9/34) equivalent to 0.264. The third issue is the material used in the roof like cement, bricks and wood (3/34) equivalent to 0.088. The fourth issue is the materials used in finishing's such as wood and carpet (5/34) equivalent to 0.147 The fifth issue is the recycling of building materials such as recycled ceramic (2/34) equivalent to 0.058 The sixth issue is wall claddings (1/34) equivalent to 0.029. The seventh issue is indoor décor (3/34) equivalent to 0.088. The eighth issue is construction waste management (1/34) equivalent to 0.029, the ninth issue is calculating the embodied energy (1/34) equivalent 0.029, the tenth issue is life cycle analysis (LCA) (1/34) equivalent 0.029, the eleventh issue is adopting technologies (1/34) equivalent 0.029, the twelfth issue is applying regional materials like wood and stones (1/34) equivalent 0.029, and the thirteenth issue is low emitting building materials (1/34) equivalent 0.029.

See Appendix-1 for the assessment method of the research, Appendix-2 for details, and Appendix-5 for the requirements and benchmarks for the main categories of the assessment method of the research.

3.6.7 WATER SUPPLY AND DRAINAGE SYSTEM (WS&DS)

The water supply and drainage system category has 7 credits. The total points should be achieved are 16/125 points equivalent to 12.8%. 16 points comes from the detailed issues and sub issues of water supply and drainage system. See Appendix-1 for details on the sub issues of water supply and drainage system. Each sub issue scores one or two points according to their importance and positive impact to the environment.

The first issue is choosing the appropriate technology for the drainage system (5/16) equivalent to 0.312. The second issue is studying the water source (3/16) equivalent to 0.187. The third issue is water efficiency (4/16) equivalent to 0.25. The fourth issue is rain water container (1/16) equivalent to 0.062. The fifth issue is grey water recycled in the site location (1/16) equivalent to 0.062. The sixth issue is to reduce water usage (1/16) equivalent to 0.062. The seventh issue is to use water sense labelled products (1/16) equivalent 0.062. A total of 16 points. Most areas of Khartoum in the first and second urban areas use septic tank and well system because there is no net drainage system available in most of these new urban areas. This system (well and septic tank) is connected to an artesian well which is usually about 50 meters in depth underground or until reaching the underground water bed. This system needs regular cleaning to secure continuous water flow and to avoid clogging. Taking into consideration the continuous risks of floods during the raining season, regular maintenance is essential in order to guarantee an efficient system. See Appendix-1 for the assessment method of the research and Appendix-2 for details.

3.6.8 POWER SUPPLY SYSTEM (PS).

The power supply system category 4 credits with a total of 15/125 points equivalent to 12%. The total points 15 comes from the detailed issue and sub issues of power system. See Appendix-1 for details on the sub issues of the power supply system category. Each sub issue earns one or two points according to their importance and positive impact on the environment.

The first issue is studying the source of energy; an eco-building should provide natural resources such as solar energy and wind energy (6/15) equivalent to 0.4. The second issue is energy efficiency (1/15) equivalent to 0.06. The third issue is studying the applications (5/15) equivalent to 0.33; in Khartoum the sun shining is adequately around the seasons, and can be utilized as a source of power in all buildings for various activities, lighting, cooking, heating, and cooling; storing this energy in batteries. The fourth issue is adaptive technologies, like photovoltaic technologies, using simulations and energy smart panels (3/15) equivalent to 0.20. A total points of 15 points.

See h ppendix-1 for the assessment method of the research, Appendix-2 for details and Appendix-5 for the requirements and benchmarks for the main categories of the assessment method of the research.

3.5.8 ENVIRONMENTAL DESIGN PROCESS (EDP)

The main scope of design is to apply the sustainable categories in the whole design process. The term holism has been used to describe the view that a whole system must be considered rather than simply its individual components, as shown in Fig. 5.2. The Vales have addressed this point in their book "Green Architecture", suggesting that a building should attempt to address all of the principles of green design in a holistic manner (Hide, 2008). Architects should consider the eight categories of the method of assessment of this research to be applied in the design process at all design levels. The total points in this category is one (1/125) equivalent to 0.008.

See Appendix-1 for the assessment method of the research points and equivalent. Appendix-5 for the requirements and benchmarks for the main categories of the assessment method of this research.

(i) Pre building phase:

Pre building phase is the design phase for the primary, developed and final designs; adopting sustainable eco-building categories as its main goals.

(ii) Building phase:

Building phase is for the construction and system operations. In this level one should deal with contractors and suppliers, applying appropriate technologies in mechanical systems, construction of waste disposals, and noise control from site.

(iii) Post building phase:

This level deals with users, after the construction of the building. The building should be maintained regularly in order to guarantee long life and durability. The building should be evaluated using appropriate method of assessment. These levels are identified after a review of the previous methods in chapter five such as (BREEAM, 2014) .

< 40 is weak
(40 - 44 pts) pass
(45 – 59) good
(60 - 75 pts) Very good,
(76-132pts or more) Excellent.

The more points you get the higher building level will be

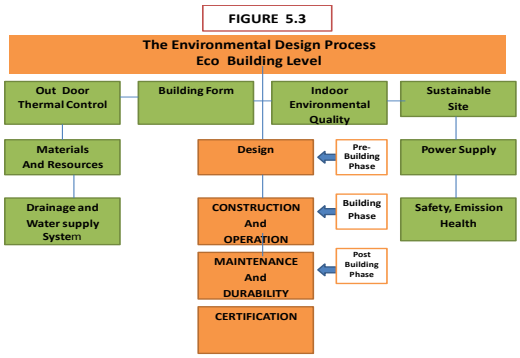

Figure (2): shows the environmental design process on the level of eco building.
Source Abdelmoneim, H., (2017)

4. FIELD WORK:

Here explaining the procedures of fieldwork in selected areas of the case studies representing different areas in Greater Khartoum. The duration time of the study from 2015 to 2017. The presenting the fieldwork results. The presentation of the case studies and selected samples and then application of the sustainable-eco-building assessment method sheet of this research (see Apendix-2) made in 48 case studies, and then will give a general summary of information for each case study. The results are presented in figures, tables, pie diagrams and photos.

The survey was made in residential areas in Greater Khartoum, in Khartoum includes Eltaief (10 case studies), Al Sahara middle (8 case studies) and Khartoum Two (5 case studies then in the illegal areas in west Sarya (3 case studies).In Cafori, Khartoum North, (5 case studies), Al Shabia (7 case studies). In Omdurman in Al Rouda (5 case studies) and Al Mourada (7 case studies), the total number of case studies is 48. The method of presentation of these samples in photos, and short notes and documents about each house were written including information about the name of the owner, the plot size, the built up area, construction starting date, construction ending date. Then document is concern about the main categories of sustainable design that identified in chapter two and discussed in chapter six about the energy used, water, material, indoor environment and outdoor environment and the infrastructure. That has been followed by summarizing this information about these specific main categories in tables and figures for each house of the case studies.

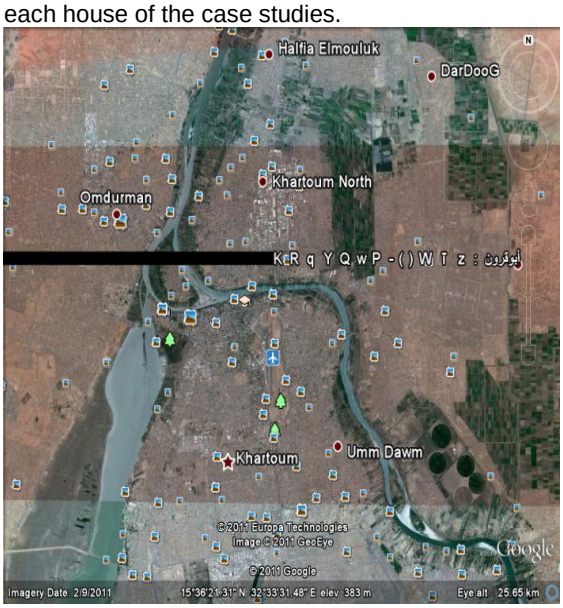

Figure 3 :Shows the area of study at Greater Khartoum

5. Conclusion and Findings

51 At urban design level: Sustainable site

(i) Accessibility

The research found good accessibility of the first group (El Taief, Kafoori and Al Rouda); the study received a score of 35% for this group, because the plot is near to a public transportation axis. However, the third group (Al Sahafa, Al Shabia and Al Mourada) has poor accessibility; revealed a score of 20%, because the plot is far from the main road, because site selection is according to land distribution from the Ministry of Housing and Urban Planning.

(ii) Site control

Good control in parking covered by shed, noise prevention, and waste management for (El Taief, Kafoori and Al Rouda) has been achieved because, received a score of 65%, because owners and professionals have experienced in such solutions. However, the research found weak control in parking, noise and waste prevention for the third group, revealed a score of 40% because of owners' lack of knowledge and experience.

(iii) Maximize the outdoor

Large open spaces were found for the first group (El Taief, Kafoori and Al Rouda) due to the moderate plot sizes ranging between 400 and 600 sq m. received a score of 60%. On the other hand, the research found limited plot area in the third group, size (250-300 sq. m)

With a score of 40%, according to distribution land standards for urban classes from Ministry of Urban planning.

(iv) Heat island

Heat island effect is not treated in all samples disclosed a score of 20%، because owners have a lack of knowledge and practice in applying such solutions like white paint, green wall and green roof.

5.2 At house unit level

(i) Indoor Environmental quality

Good solutions were found such as roof insulation, building dimensions, windows design, vertical and horizontal sunscreens, and natural ventilation, use of fans and desert coolers, and good orientations, recived a score of 33%, because owners and professionals have good knowledge and experience in applying such solutions. Weak solutions are seen in using techniques such as wind towers, courtyard systems and double roofs. It is found that no green walls, green roofs, thermal comfort control, lighting control HVAC systems and occupancy based blinds or curtains are used. This is because people have no experience and knowledge in using such solutions, and HVAC system is expensive. Outdoor environment

For group one (El Taief, Kafoori and Al Rouda), there were good applicable solutions for the outdoors such as shades, terraces, canopies, balconies and vegetation and landscape, received a score of 67%, because of large plot sizes ranging between 400 and 600 sq m. On the other hand, there were weak solutions for group three (Al Sahafa, Al Shabia and Al Mourada) revealed a score of 14.5%, because of the small plot sizes ranging between 250 and 300 sq m. There were non-applicable solutions for third and illegal areas such as swimming pools and fountains because of their limited appreciation of the importance of such solutions to minimize heat. Moreover, these solutions could be costly.

Environmental design process and building form

Weak points for environmental design process for all areas of the study have been found, the study received a score of 33% as average result.

Most of the buildings in the areas of study used linear forms with a received a score of (60%), then cubic forms (19%) and courtyard systems. There were no alternative solutions to SEBAM like vaults, domes (Only case study No. 9), L-shaped forms revealed a score of (11%) (Only case studies No. 8 and No. 47) and U-shaped forms. The reasons could be the high price of plots and the need to maximize built-up area.

5.3 At building construction level

(i) Construction method

Applicable solutions were observed, such as concrete skeleton for the first group (El Taief, Kafoori and Al Rouda) received a score of 57%. Load-bearing systems for the third group (Al Sahafa, Al Shabia and Al Mourada) revealed a score of 44%, and mud bricks in illegal areas by a score of 100% because these solutions meet the residents' needs and are economical. The research found problems in ceiling and poor insulations in the third group.

(ii) Materials used

Concrete ceilings by 57%, bricks or hollow blocks in walls, and ceramic by 67% or marbles by 16.4 % on floors have been used for the first group. Wood and zinc on ceilings 32%, bricks on walls, and recycled ceramic on floors by 12% have been used for the third group. Sand, gravel and clay blocks for the illegal areas are found, because owners and professionals use materials available in the local environment

(iii) Solutions that are not found

Applicable solutions such as waste management, roof clay tiles, wall cladding, glass, aluminium and wood were not found. The reason for not using wood, roof clay tiles and cladding is that they are expensive and not available in the local market. Limited solutions are found in recycling materials because of lack of knowledge in using such recycled materials, especially in the first group.

5.4 At the building services level

(i) Water

All case studies: the water comes from the National Grid. The research shows unsuitable solutions in using biological treatment, rainwater containers, water metering system, water recycling, and water efficient products because residents cannot afford to use such solutions.

(ii) Drainage system

All the case study samples in El Taif, Kafoori and Al Rouda neighbourhoods used septic tanks and wells the research received a score of 75% in a drainage systems. These drainage provisions could contaminate the underground water. Khartoum 2 neighbourhood uses a drainage network by 100% in sewage system. However, in Omdurman, some buildings still use the Pit latrine received a score of 12.5%; and in illegal housing areas, sand and gravel filters are used by 100%.

(iii) Energy

The research obtained a result of, all case study samples use energy from the National Grid. By 100%. There are few alternative solutions for SEBAM in using solar energy, energy heating system, outdoor lighting and solar heating. Only case study No. 5 used solar heating and case study No. 9 used solar PV cells . The research shows that there are unsuitable solutions in wind energy and solar boiling because people do not have experience in using such solutions and they are expensive.

Recommendations regarding the samples studied by the proposed method of evaluation:

6. Recommendations

6.1 At urban design level: sustainable site

(i) The research recommends creating accessibility to all plot areas which should be near to a public transportation axis.

(ii) The site should have parking control, covered by sheds, construction activity control, noise prevention and waste management.

(iii) The site should have good landscape management and outdoor lighting control.

(iv) Heat island effect should be studied by plant trees and use light colours.

6.2 At house unit level

(i) Indoor environmental quality

The research strongly recommends effective solutions for natural ventilation, the use of horizontal and vertical sunscreens, and the use of mechanical means such as desert coolers and fans to improve the thermal comfort inside the building. In this study, orienting the building towards the East-West direction, the use of wind towers, the use of courtyard

systems, and the implementation of light colour paints on ceilings and walls is recommended. Moreover, in this research, adopting solutions such as double roofs, green roofs, green walls, floor thermal control, design thermal comfort and lighting control are suggested.

(ii) Outdoor environmental quality

Maintaining open spaces at the house unit level, controlling shades by the building construction like cantilever and canopies and fences in the outdoor environment are recommended in this study. Adopting swimming pools, fountains, terraces, trees and vegetation cover to improve the air from dry to humid in all areas of the study is proposed.

(iii) Environmental design process and building form, applying of environmental design process in the three phases as an educational value is strongly recommended in this study. Using the linear and cubic forms, vaults, and domes is proposed in this study. Applying L-shaped and U-shaped forms in sustainable-eco-buildings is also suggested because they provide more shades to the building and this cools the air through the building and improves ventilation.

6.3 At building construction level

(i) The use of eco concrete, eco structure, and thermal hollow blocks to all case studies and managing the ceiling structure and insulation for the third group is recommended in this research.

(ii) Building Materials should be used from the local environment like bricks, ceramic and stones because it will be economic. Also, the using of wall cladding with special specifications, and adopting steel, hollow blocks, recycled materials, eco carpets, and suspended ceilings is proposed in this study.

(iii) Using of recycled building materials, especially for the outdoor area, is recommended in this study.

6.4 At services level

(i) Water system

The research recommends adopting water metering system, biological treatment and applying water efficiency.

(ii) Drainage system

The research recommends adopting distribution network for sewerage systems or otherwise maintaining and minimizing the use of septic tanks and wells, as they are contamination threats to the underground water. In addition, solutions such as recycling of grey water, and rainwater containers are recommended in this study. For illegal housing areas in West Sarya, using wells and septic tanks as “best practice” and network as future solution for drainage system is suggested in this study.

(iii) Energy efficiency

In this research, applying natural resources for energy such as solar energy system in different applications, solar heating, solar cooking, solar photovoltaic technology is proposed. The use of stimulations, the use of smart panels, and wind energy especially for suburb areas is recommended. For illegal housing areas in West Sarya, power supply to be supplied by the National Grid is proposed.

(e) At community level

The research strongly recommends adding educational value to increase the knowledge of the community and teach the students, architects, designers and people about sustainable- eco- building through lectures, workshops, conferences and courses corresponding to its main categories.

Acknowledgements

I would like to thank Dar Al Uloom University staff and members. University of Khartoum staff for continuous help for my PhD research. This humble effort would not have been possible without the help of others. I would like to thank Prof .Saud Sadigq Hassan the supervisor of the Ph.D. research , Dr. Abubker Hesien Dean of faculty of Architecture, Khartoum University., Dr.Gamal Mahmud Hamid the previous Dean of faculty of Architecture , Khartoum university, Dr.Awad Saad, Dean of Architecture, university of Sudan. ALL Professors and Doctors helped me in this research for their continuous help and guidance.

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