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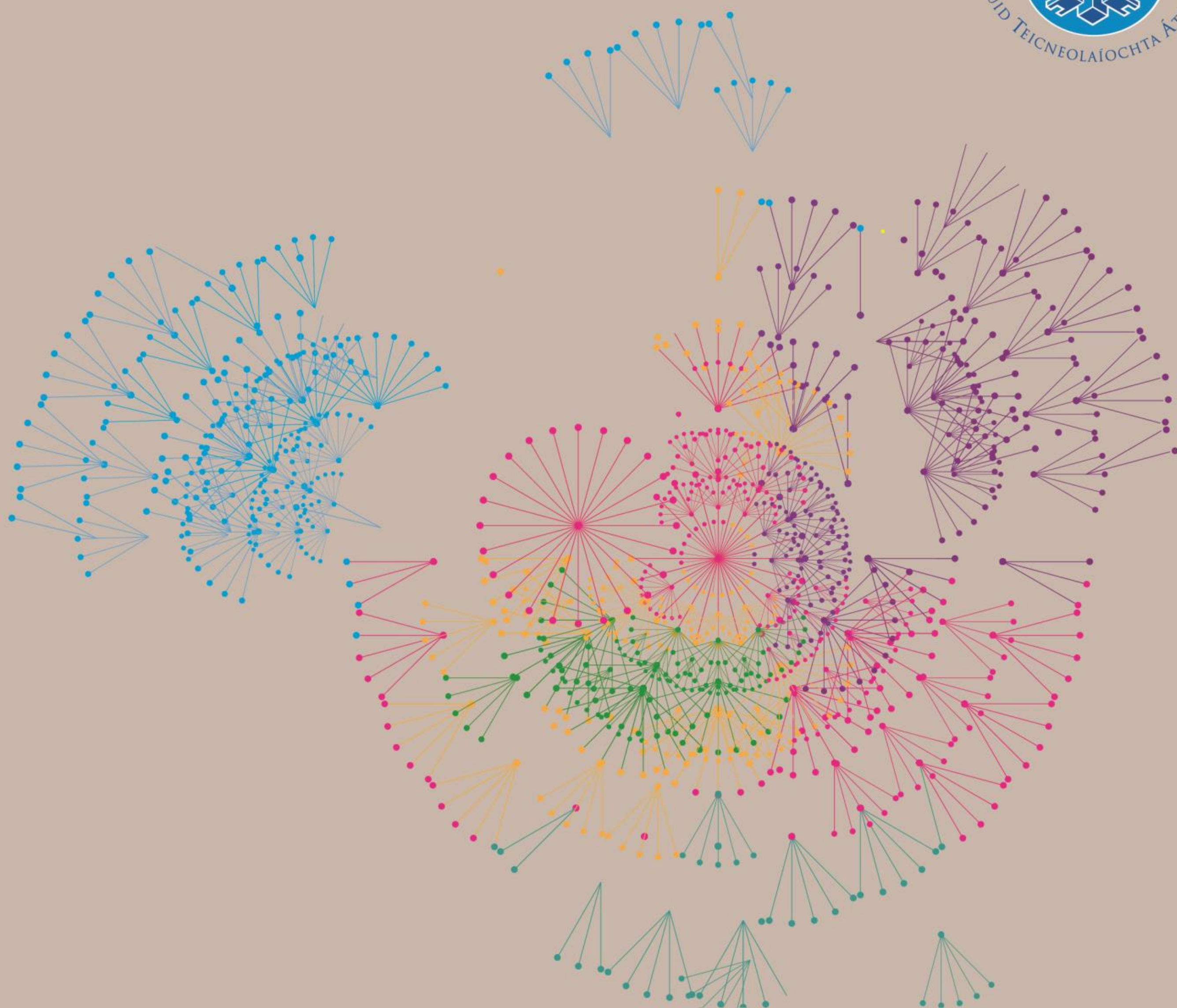

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Fostering Sustainable Development through Integrating Geographic Information System in the Application of Strategic Environmental Assessment Process

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Keywords: Strategic Environmental Assessment, Geographic Information System, Regional Planning, Sustainable Development.

Abstract

In Egypt, decisions are not rich enough with environmental considerations, therefore, environmental deterioration consequently happens. Many areas in Egypt, especially Sinai, has a considerable number of sensitive areas that need to be environmentally planned. This raises the question of how planners and decision makers can preserve these sensitive areas against the negative impacts of their plans and decisions. Strategic Environmental Assessment (SEA) is a powerful instrument which takes into consideration the environmental impacts during the very early stages of the decision-making process. However, there are some limitations regarding SEA which require the support of an advanced tool, like the Geographic Information System (GIS) which is able to perform a variety of complex spatial analysis. This research aims to examine the integration of GIS into the entire SEA process and their implementation in regional planning. To accomplish this, a comprehensive background about the research topic will be studied through assessing the SEA as a tool for sustainable development during regional planning and the GIS as a supporting tool for the whole process.

The research outcome will be revealed through implementing a preliminary methodology to develop an environmental integration model that will be further used in determining the conflict zones in Sinai. This study is considered as a pilot one that can be globally applied.

1. Introduction

For the past four decades, Egypt as a developing country has been facing a demographic explosion. Its population has risen from approximately 24 million in 1952 to 76.5 million in 2006 (El-Batran, Nazmy, & Sweedan, 2011). As a result, new developments were occurring in order to accommodate this rise in population. However, environmental considerations were neglected during the planning of such developments which has led to various environmental deteriorations and pollution including the damage of the aesthetic of the Egyptian heritage sites (El-Batran, Nazmy, & Sweedan, 2011).

The Strategic Environmental Assessment (SEA) was firstly introduced in 1989, as the kind of assessment which has a strategic nature and more applicable to policies, plans and programs rather than individual projects (Partidario, 2012). It is defined to be an instrument of a strategic nature, composed of several key elements that form a flexible framework and acts strategically in the decision-making process, thus, facilitates and adds value to it (Partidario, 2012).

However, there are temporal and spatial aspects of the SEA process which require expertise analysis tools. These expertise analysis tools are inherent in the Geographic Information System (GIS) due to its ability to: Integrate, compare and store data from various sources; link between database information and spatial features; graphically present data in a quick, easy and understandable manner; perform Spatial relationships and trends analysis over time; and assess the potential and existing developments' spatial impacts (Blair & Schwartz, 2008). For this reason, GIS is an essential tool throughout the different stages of the whole SEA process as it provides adequate information to decision makers.

This research targets investigating how effective is the GIS as a tool to be integrated into the SEA process will facilitate the decision making and promotes sustainable development. For achieving this, the following aims have to be fulfilled through the research methodology; Firstly, Building an in-depth understanding about the research topic through an intensive literature review. Secondly, developing an integration model from the literature review to help in integrating the GIS into the SEA process. Thirdly, applying this integration model on a national case study. This model will primarily aim in identifying the conflict zones on which development must not occur, as they are defined from the researcher perspective as the zones in which the "highest negative impact" and the "highest sensitive environmental aspects" will overlap.

2. SEA as A Tool for Sustainable Development

The most quoted definition offered by Sadler and Verheem (1996) is *"SEA is a systematic process for evaluating the environmental consequences of proposed policy, plan or programme initiatives in order to ensure they are fully included and appropriately addressed at the earliest appropriate stage of decision-making on par with economic and social considerations".* In addition, SEA was defined by Fischer (2003), as an instrument for supporting decision-making by formulating spatial and sector policies, plans and programs that are sustainable, in order to ensure that the environment has been considered appropriately. In addition, it is considered the "big brother" of the project-level Environmental Impact Assessment (EIA) and it has been applied worldwide to a large extent in several countries. In addition, Partidario (2007) defines SEA as a tool for impact assessment that has a strategic nature and aims at facilitating the integration of the environment and evaluating the opportunities and risks of strategic actions under a sustainable development framework. Strategic actions are substantially linked to policies formulation, and they are developed through planning and programming procedures.

Environmental considerations should be integrated into decision making, just as social and economic considerations are in order to achieve sustainability goals, as the three pillars of sustainable development are: economic, social and environmental. SEA is considered as the most promising tool for allowing this to happen (figure 5). It assists decision-makers to have a better understanding about how the three sustainable development pillars can fit together. Without such understanding, today's development will be altered to tomorrow's environmental challenges. In short, decision-makers are guided to consider the consequences of their plan through the implementation of the SEA process (OECD, 2006).

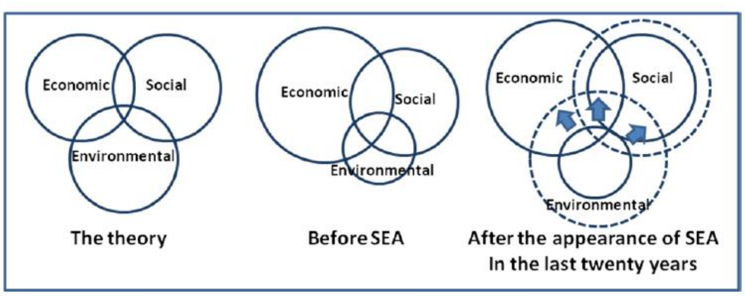

Figure 1: The three pillars of sustainable development before and after SEA appearance.

(Source: (Salheen & EL-Khateeb, 2010)).

There are three approaches for applying environmental assessments worldwide. The first approach is the "Top Bottom Approach" in which the SEA is firstly applied then the Environmental Impact Assessment EIA and lastly, the Life-Cycle Assessment LCA. The second approach is the "Middle Approach" in which the EIA is firstly applied and then the SEA and LCA. The third approach is the "Bottom Approach" in which the LCA is firstly applied then the EIA and lastly, the SEA.

According to Vukicevic, J., & Nedovic-Budic, Z. (2012) Strategic Environmental Assessment can be observed as a method to integrate the perception of sustainable development into planning. They consider the integration of SEA into planning should be based on GIS multicriteria process, accordingly they proposed how to apply the environmental protection based on the standards of dynamic modelling keeping into consideration the planning activities potential impacts. Moreover SEA integration model has been proposed with identifying the conflict zone to finally reach assimilation of the two processes to assist the planners in decision making to be able to reach sustainable concrete decision.

3. Principles of an effective SEA

A successful SEA procedure enhances the decision-makers perception of sustainability of strategic decisions and assists in the suggestion of the best alternatives (Fischer, 2007). For this reason it is essential to identify the following principles (Fischer, 2002; Therivel, 2004; Fischer and Gazzola, 2006): **Sustainability driven:** The SEA aim should be the achieving of sustainable development., **Early involvement**: SEA should be involved early in the planning process of a strategic action that will have an impact on the environment., **Integration**: full integration of SEA should be done in the planning process and it’s contributions must be considered when adopting a new proposed action. Also it must have a strong influence on the program's final decision-making., **Flexibility:** The teams and procedures of SEA must be flexible in dealing with uncertainties and responding to different inputs from the public., **Focus:** SEA must be modified according to the strategic proposal's characteristics and context and merely focus on key environmental issues suitable for the decision-making at a specified level., **Decision-centered:** The provision of quality information in an adequate form by the SEA teams is essential for facilitating and streamlining the decision-making process., **Wide participation and transparency:** The public and other stakeholders participation in the planning and decision making process should be a considerable part of the SEA process. Also, it is important that the process and the outcomes be transparent to the public and the different parties, **Accountability:** SEA should minimize the negative effects and optimize the positive ones, in order to the proposed strategic action's environmental performance.

4. Benefits and Limitations on SEA

The righteous application of the SEA process may result in a range of benefits, as it does not only support sustainable design that integrates environment in decision-making, but also strengthens the strategic processes, builds good governance and enhances confidence and public trust in strategic decision-making (Marsden and Mulder 2005).

The following benefits are the outcome of introducing SEA process (Therivel et al., 1992; Sadler and Verheem, 1996; Partidario, 1996; Sadler and Baxter, 1997; Fischer, 1999; Partidario, 2000): Environmental aspects and sustainable development integration in the decision-making process, design of polices and plans that are environmentally sustainable, provision of various alternatives to the proposed plan than possibly available in the project-level EIA, consideration of cumulative effects and global change, enhance institutional efficiency through avoiding the need for project-level EIAs, Strengthen of project-level EIA through: shaping individual projects through environmental goals and principles incorporation in policies plans and programs, early identification of impacts and information required, and reduction in the time and effort needed for reviews conduction. Finally, it allow public consultation in sustainability related discussions of plans at a strategic level.

However, there are obstacles that are considered as limitations on SEA application. According to Glasson and Gosling (2001) there are numbers of interrelated and mutually reinforcing obstacles, such as**: Inadequate political will**: less priority is given to public participation and environmental concerns integration in decision-making, **Lack of definite objectives**: environmental goals are not incorporated in the policy, plan and program levels, **Narrow issues' definition**: more emphasis on the economic growth rather than consideration of strategic environmental implications, **Absence of accountability**: environmental implications are being neglected in the economic agencies' actions, **Lack of incentive**: advisers and policy makers are rarely rewarded for expecting environmental problems, **Low experience in SEA**: limited experience in dealing with SEA compared to experience in project-level EIA, also experience in using SEA at the programs and plans level is higher than using SEA in the policy level, **Political pressures**: less effective SEA can result due to political pressures.

5. SEA Procedure

The SEA procedure comprises the core structural elements that are concerned with "how could the SEA process be applied?" (Hegazy, 2010). According to Fischer (2007), these core structural elements are: "screening, scoping, impact assessment, mitigation, report preparation, review, public participation and consultation and monitoring. The **Screening** stage is required to determine whether or not, it’s mandatory to carry out the SEA process (Partidario, 1996), the **Scoping** stage identifies the assessment's extent and level of details and the information needed to be included in the SEA and the environmental report. Therefore, data and baseline information have to be established in this stage (Sommer 2005). While, the **Impact Assessment** stage is a meaningful SEA process is characterized with clear assessment of the effects of strategic actions (Jones et al, 2005). This stage provides a chance for decision-makers to decide the best development alternative that achieves the aims with the lowest cost and greatest benefit to the environment (Therivel, 2004) and the **Mitigation** stage aims to provide ways for enhancing or remediating the positive and the negative effects of a proposed action on the environment, which were identified during the SEA process (Hegazy, 2010). The **Report Preparation** stage includes the assessment process's findings of the proposed plan and the expected effects on the environment. This report is considered a base for the consultation and public participation and should be considered adequately in the process of decision-making (Fischer, 2007). The **Review** stage provides means of evaluating the presented information quality, which will assist the decision-makers to identify the suitability, sustainability and practical feasibility of the strategic action (Andre et al., 2004). In addition, the **Public Participation and Consultation** stage is not considered as a separate stage of the SEA process, as ideally the public and relevant authorities should participate at different points during the SEA process. It generates a sense of ownership of the development between the stakeholders as a result of public involvement in the decision-making improved (Jones et al., 2005; Heiland, 2005). Finally, the **Monitoring** stage aims at monitoring the strategic actions after they are adopted by SEA, so as to ensure that the SEA is achieving the purpose it is intended for and to find out any problems that would act as barriers for achieving the expected results (Therivel, 2004). The following figure presents a summary for the overall SEA process:

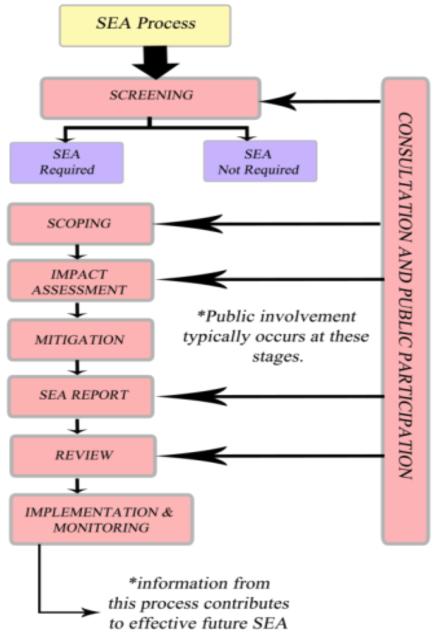

Figure 2: SEA overall process.

(Source: (Researcher)).

6. SEA process and GIS Integration Model

This section describes the components of the integration model through stating all the SEA stages present in the model, the main purpose of each stage, the steps done in each stage and the main GIS tools and techniques used. The first SEA stage in the model is **Screening** and the main requirements of this stage are determining the area of study and deciding either SEA is required or not. The second stage is **Scoping** and the main requirements of this stage are determining the environmental issues of the area of study and current Environment Description through: collecting raster format maps and information about the environmental issue, describe of each environmental issue, verify that all relevant datasets has been provided, check the quality of each dataset and converting raster maps into GIS format.

Concerning the third SEA stage in the model which is **Baseline Environment**, overlay analysis should be done for all the gathered maps of all environmental issue, this will be done through: buffer analysis for each point/multipoint dataset, overlay analysis for each separate dataset and overlay analysis for all the datasets together. After overlay analysis is done, environmental problems can be identified. The fourth stage in the model is **Definition of Alternatives** and this stage will include a development alternative for the study area. The main steps in this stage are: Correlation Matrix, query on the GIS, activities best allocation.

The fifth stage in the model is Assessment **of Alternative**. The main aim of this stage is to identify the conflict zones, this could be done through: identifying the various impacts and their indicators for the environmental issues and identifying the level of negative impact of each activity. The level of impact for each activity will be identified through: firstly, Categorizing the level of impacts according to their levels of affecting the environment, then, secondly, assigning these levels of impact to the development activities on GIS, thirdly, assign a corresponding number for each level of impact, lastly, Use the "feature to raster tool to convert the map into raster. After that, the sensitivity of the site potentials to the new development should be determined through: firstly, classifying the levels of sensitivity into three categories according to how sensitive they are to development, secondly, assigning a corresponding number for each level of sensitivity, thirdly, converting each dataset into raster through "feature to raster tool, lastly, using Weighted sum GIS tool to overlay all the dataset converted raster maps and generate a sensitivity overlay map. After completing all the previous mentioned requirements the conflict zones will be determined through using weighted sum technique to overlay the impact raster map and the sensitivity overlay map.

After assessment of alternative stage comes the **Mitigation Measure** stage whose main aims are minimizing negative impacts while maximizing the positive one and choosing less risky option. Finally, the seventh stage in the model is the **Monitoring** stage, in which the development plan is being investigated whether it is achieving its objectives or not and negative impacts which require remediation are identified.

The following section is an application of this integration model on a selected case study in order to investigate its applicability.

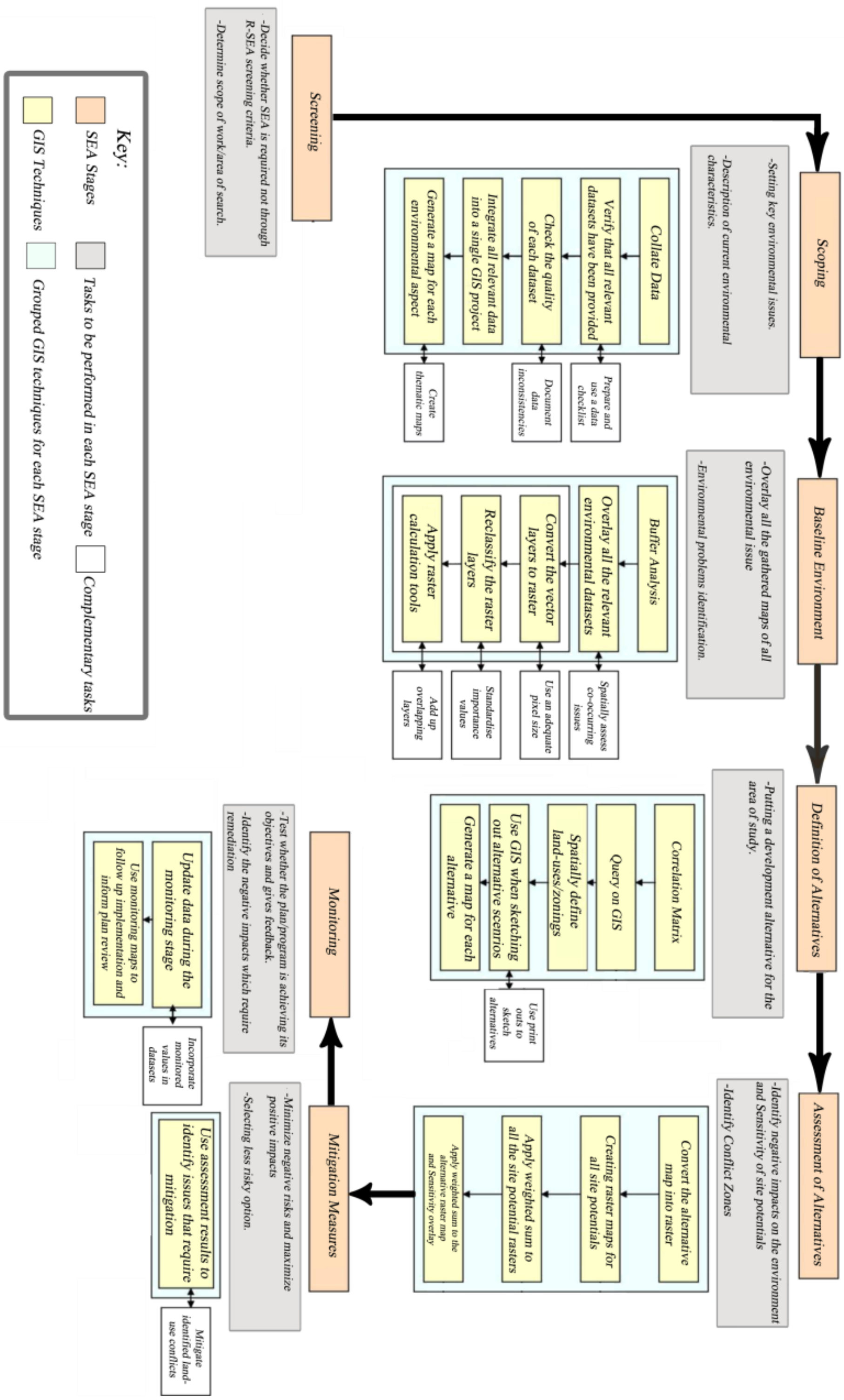

Figure 3: GIS and SEA Integration Model

(Source: Researcher)).

7. SEA in Egypt

In Egypt, EIA (Environmental Impact assessment) started to be applied on projects since 1982 with the emergence of environmental law No.4 (EL-Khateeb, 2010). Despite the fact that EIA is applied to all the projects before they receive the establishing licenses, still SEA is being neglected up till now in Egypt. The Egyptian environmental law states that merely projects and buildings must be subjected to EIA, but EA of "Policy, Program and Plans" (PPP) is not clearly referred to in the Egyptian environmental law (El-Khateeb, 2010). Another significant aspect which has been neglected is the "Cumulative Impact" (CI). As a result, the natural environment carrying capacity is not calculated during uses allocation in Egypt (Sadler, 1996). For instance, industrial uses cumulative impacts should be significantly considered during the evaluation of a new industrial facility impacts. However, this does not always and mostly the decision is being left to the evaluator's subjective judgments (El-Khateeb, 2010).

However, several discussions and preparations about the regulation of providing the legal and institutional framework for SEA have started in The Egyptian Ministry of Environment, but the fields in which the SEA should be practiced and how are still undefined as the scientific approach of the SEA process is recently introduced in Egypt (CEIAC, 2008).

8. Applied Case Study

Sinai is a 60,000 km2 triangular Peninsula with an approximate population of 1,400,000 people that is located in Egypt. It is bounded by the Mediterranean Sea on the north, and the Red Sea on the south. It is the only part of Egyptian territory that is located in Asia and it serves as a land bridge between Asia and Africa (New world Encyclopedia, 2015). Administratively. The peninsula is divided into two governorates out of Egypt's 27 governorates. Besides to its formal name, It is also referred to by the Egyptians as the "Land of Fayrouz", due to the Ancient Egyptian "Dumafkat", which has the same meaning (New world Encyclopedia, 2015).

The focus in this case study will be merely on the development of "Zone A" of Sinai Peninsula, which is 5374684.454 FD and starts from Port Said to Sharm El Sheikh. It lies in three Government (Ismailia, Suez, Ganoub Sinai, PorSaid and Shamal Sinai).

The case study will be composed of the generation of an alternative for developing "Section A" of Camp David Accords which is located in Sinai for its potentiality to adopt all kinds of development, then, this alternative will be checked for its impact on the environment through applying the integration model of GIS in SEA process, with the main aim of allocating the conflict zones in the study area. These conflict zones are defined from the researcher perspective as the zones in which the "highest negative impact of the proposed alternative on the environment" and the "highest sensitive environmental aspects" will overlap.

8.1 Applying the GIS and SEA process integration model

As illustrated in the previous section, the integration model of GIS and SEA process is composed of each SEA stage discussed in terms of its main purposes and the GIS tools and techniques needed to fulfill these purposes. This section will demonstrate how this integration model will be implemented on the case study.

8.1.1 Screening

This is the first required stage of the SEA process and the main purposes of this SEA stage is to: determine the Area of study which is "Zone A" of Sinai whose area is 5374684.454 FD and decide either SEA is required or not. SEA must be applied in this area for the following reasons: This zone has a unique location which is between the Mediterranean and Red sea and along the Suez Canal. For this reason, it's location is considered as a strongest one among the other developed areas in the world, there is no existing planned strategy for this zone that regulates and organizes the development of different activities in it, such as: agriculture, trade, tourism, industry and residential and the presence of huge investment in this zone that requires planning and organization in order to reach the optimum methodology to manage the sources of this area.

8.1.2 Scoping

It is the following stage after screening and the main aims of this SEA stage is: firstly, setting of key environmental issues. The available environmental issues for this area are: climate, water, conservation areas (flora and fauna), soil, building material, metallic and non-metallic materials, sunshine duration, fault lines, oil wells, risk areas, infrastructure, solar radiation destruction, topography and land use. Secondly, description of current environment**.** This purpose is related to determining the characteristics of the current environmental issues. This was done through data gathering on each environmental issue. The gathered data was in the form of information and raster maps format which were further transformed into GIS format. Data was gathered on the following environmental issues: climate, water, conservation areas (flora and fauna), soil, building material, metallic and non-metallic materials, sunshine duration, fault lines, oil wells, risk areas, infrastructure, solar radiation destruction, topography and land use.

After gathering all data needed for the environmental issues, these data has been classified under different dataset. To do this, database has been created on version 10.3.1 ArcMap, and was named "Sinai_A". This database was divided into 9 datasets including: Climate, Conservation, Sunshine duration, geology, hydrology, infrastructure, land use, solar radiation destruction and topography. These 9 datasets are created to include all the previous mentioned environmental issues raster formats but in GIS format.

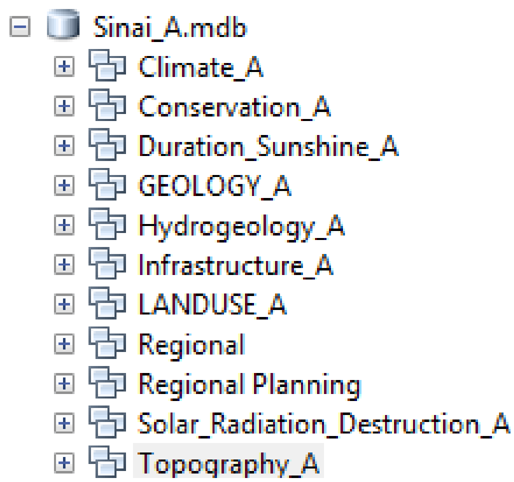

Figure 4: Zone A database

(Source: (Researcher)).

8.1.3 Baseline Environment

In this stage it is required to overlay all the maps of the gathered data of each environmental issue, in order to identify the whole existing environmental characteristics of each part in the study area. Thus, facilitating the allocation of the development activities and identifying any environmental problems. In order to do this buffer analysis was firstly done then overlay analysis was done to combine the several datasets characteristics into one.

8.1.4 Definition of Alternatives

In this stage the researcher has adopted the correlation matrix done by Professor Samy El-Zeiny in his published work. Prof/ Samy El-Zeiny has put the development activities against the site potentials and constraints, thus, determining the activities that could be done. The following are the activities stated by Professor Samy El-Zeiny, which are to be included in the development alternative of "Zone A" of Sinai, as they are possible to be carried out with the existence of design constraints. AGR. A: Agriculture depends on El-Salam Lake, AGR. B: Agriculture depends on Groundwater, AGR. C: Agriculture depends on rainwater, IND. A: Industry depends on transformation, IND. B: Industry depends on extraction, IND. C: Industry depends on agriculture, TRA. A: Trade depends on main roads, RES. B: Residential places, TOUR C: Tourism depends on the presence of touristic resources.

This Correlation Matrix is used with the database in generating an alternative for Zone A development and allocating its activities to their appropriate locations, this was done through:

- Using attribute queries in GIS, the database was related to the correlation matrix.
- Each activity has varying priorities, according which the allocation alternatives for the activity are concluded.
- The allocation alternatives are evaluated according to economical, technical and social parameters but not environmental parameters.
- Final determination for the adequate allocation for each activity.

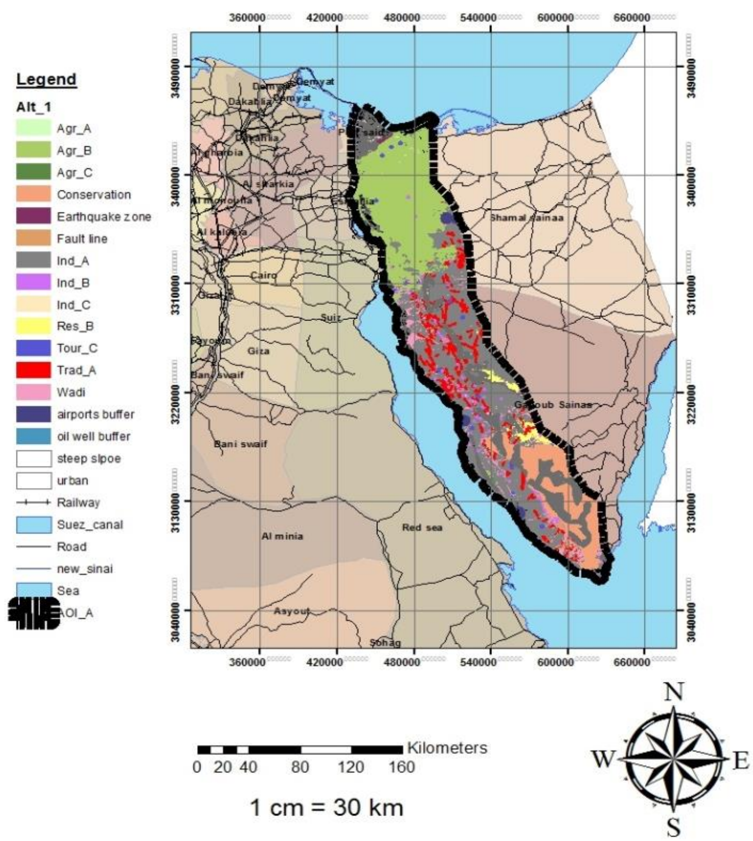

Figure 5: Zone A Development Alternative

(Source: (Researcher)).

8.1.5 Assessment of Alternative

In this stage, the researcher will identify the conflict zones according to the primary focus of the SEA which is choosing the most compatible allocation with sustainability, for instance: reducing air pollution, water pollution and the expected cumulative impacts from the proposed activities. In order to do that, the following steps were done:

1. Identifying the various impacts and their indicators for the environmental issues (El-Khateeb, 2010).

Table 1: Possible impacts on the environment

Environmental Issue	Impact	Indicator
Soil	Soil contamination/degradation	buildings and industrial areas
Climate	− Air quality deterioration − Emissions	No2/Co2
Fauna	− Loss of habitats and species. − Immigration birds loss − Endangered species' habitats deterioration	Nature Urbanization
Water	− Ground water/Water quality deterioration − Negative impacts on Surface water	− Dissolved Oxygen − Salinity
Flora	− Mangroves loss. − Land cover deterioration	High Urbanization
Land use	Cultural/Natural landscape deterioration	High Urbanization
Marine Life	− Coral reefs degradation − Loss in marine life	− Pollution of water − Oil spills
Touristic Places	Negative impacts on monuments	Un organized tourism tours

2. Identifying the level of negative impact of each activity. This was done on the GIS through creating a new field under the name "Impact_On_Environment" is in the attribute table of the final Overlay (Final_Overlay_Union_A) in order to identify the level of impact of each activity/use on the Environment.

The negative impacts on the Environment are classified into four categories according to their level of affecting the environment: **High Impact:** High Impact on the environment with no possible mitigation measures, **Moderate Impact:** moderate impact on the environment with but with possible mitigation measures that could decrease it, **Low Impact:** Slight impact on the environment and need slight mitigation measures to decrease it and **No Impact:** No Impact on the Environment.

After assigning the level of impact for each activity, a new field under the name "Impact_Intergers" was created to assign a corresponding number for each level of impact. **Number "3"** was assigned to **"high impact"**, **Number "2"** was assigned to **"moderate impact"**, **Number "1"** was assigned to **"low impact"** and Number **"0"** was assigned to **"no impact"**.

After determining the level of impact for each activity and assigning numbers to them. This alternative was converted to raster according to the "Impact_Integers" field, through using the "Feature to raster conversion" tool in the GIS, and the output raster was named: "Raster_Impact".

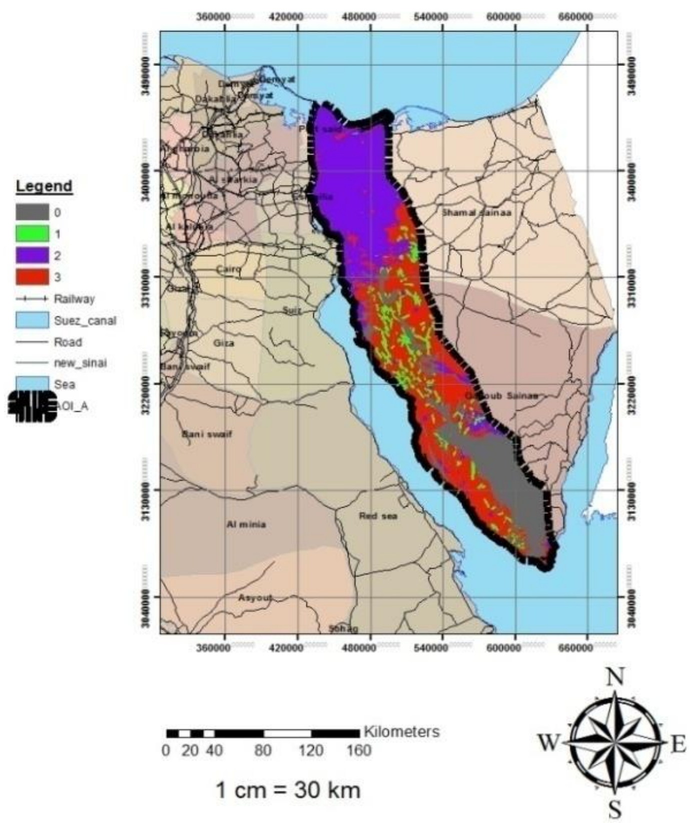

Figure 6: Raster_Impact Map

(Source: (Researcher)).

After that, the sensitivity of the site potentials to the new development was identified through classifying the levels of sensitivity into three categories which are: **High Sensitive:** Highly affected negatively due to change, **Moderate Sensitive:** Moderately affected negatively due to change and **Low Sensitive:** Slightly affected negatively due to change. Then, a new field which includes a corresponding number for each sensitivity level, was added to the attribute table of the overlay of each potential to determine its level of sensitivity. For instance, for the hydrology, a new field under the name "Sensitivity_ Hydrology" was added to the attribute table of the Hydrology overlay named "Hydrology_Union_A", and this was done for the overlay of each site potential. **Number "3"** was assigned to **"High Sensitive", Number "2"** was assigned to **"Moderate Sensitive"** and **Number "1"** was assigned to **"Low sensitive"**

After assigning the level of sensitivity for each site potential. The overlay map of each potential was converted to raster according to the sensitivity field, through using the "Feature to raster conversion" tool in the GIS. For instance, the "Hydrology_Union_A" was converted to raster according to the "Sensitivity_Hydrology" field and the output raster was named: "Raster_Hydrology". The same method was used for each site potential.

After converting all the site potentials overlay maps into raster, The researcher has assumed weights for each site potential according to their priorities in conservation and the "Weighted Sum" tool in the GIS was used to overlay all the raster of the site potentials together, multiply each one of them by its assumed weight and sum them all together. The output raster was named "Sensitivity_Overlay".

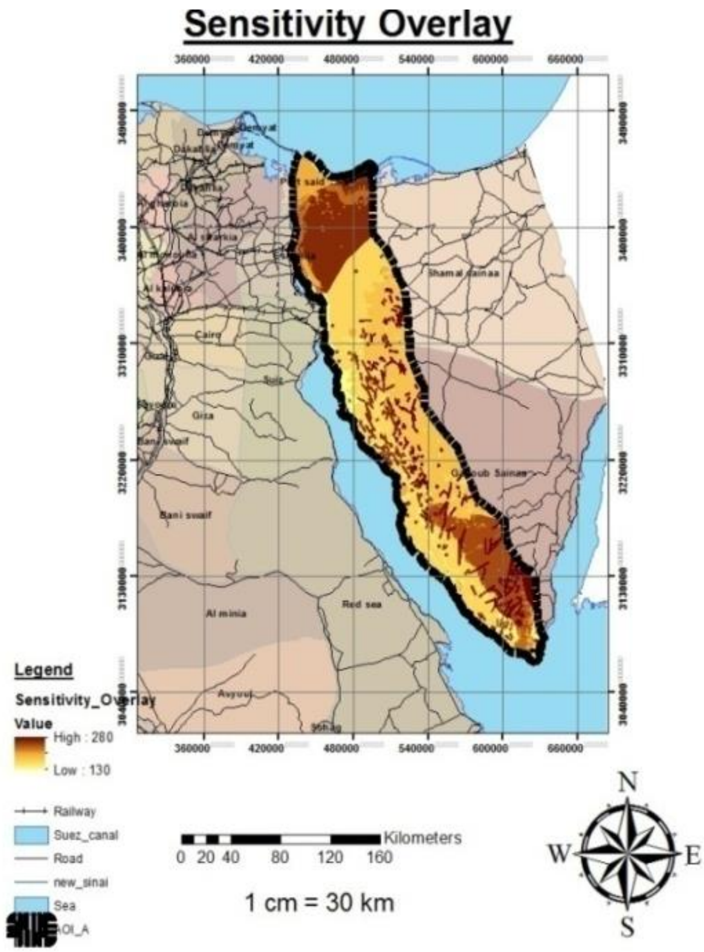

Figure 7: Sensitivity Overlay Map

(Source: (Researcher).

Finally, the conflict zones were identified through using the "Weighted Sum" tool in the GIS, by overlaying the "Raster_Impact" raster and the "Sensitivity_Overlay" raster, both with the same weight. The output raster was named "Conflict_Zones".

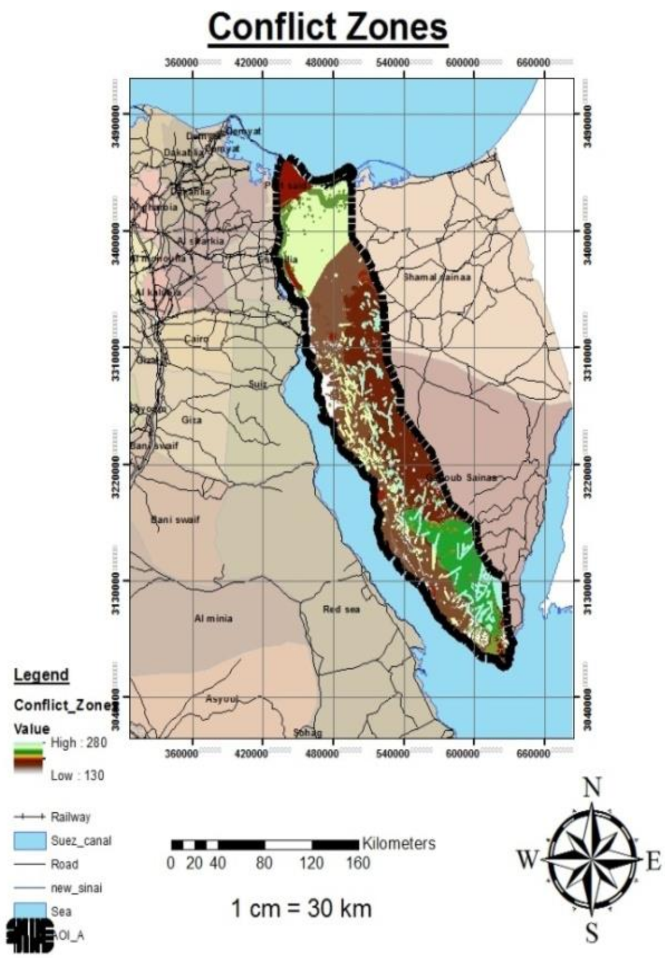

Figure 8: Conflict Zones Map

(Source: (Researcher)).

Assessment Result

From the assessment of the proposed development alternative, It can be concluded that the areas on which high negative impacts and high sensitive site potentials overlap, are considered as conflict areas on which development should not occur, such as fault lines, earthquakes areas and rain ways areas.

8.1.6 Mitigation Measures

Some of the activities/uses of the proposed alternative are likely to have negative impacts on the environmental issues. Therefore, mitigation measures are to be applied in order to reduce these negative impacts. There are various types of possible mitigation measures, which are in fact depends on the cause and type of impact. However, in general negative impacts could be reduced through the enforcement of regional planning legal frameworks and nature conservation policies. Additional measures are to be developed within the objective context.

8.1.7 Monitoring

The aim of this stage is to examine the effects of the implementation of the proposed development on the environment. It enables immediate actions to be taken when any unexpected negative environmental impacts occur. In other words, the tasks to be done during this stage are: To reveal any negative unexpected impacts on the environment, to investigate the validity of the above mentioned environmental assessment and to investigate the mitigation measure effectiveness.

9. Conclusion:

- The research, has developed a model for the aim of sustainable development being considered during decision making, through GIS integration into SEA process. This highlights the essential aspects that were brought to light and offers a new conventional perspective to SEA study.
- This research offers a great contribution to the original body of knowledge through studying the SEA process and underlining the GIS techniques and tools that assist in enhancing the SEA performance, through a developed integration model.
- SEA is considered a developed response to the types and levels of decision making that were not considered by the EIA. However, Current practices of EA in Egypt have to be explored and there should be an emphasis on applying the SEA process during the early stages of the decision making process in order to ensure the availability of clean environments, achieve sustainability goals and consider environmental aspects as well as social and economic aspects. Finally, there are some barriers that could obstacle the effectiveness of the SEA application, such as unclear identification of goals and objectives of integrating environmental issues at the levels of policies, plans and programs.

- GIS provides ways of integration and environmental and planning considerations assessing in a single interface. Therefore, it supports the prediction and evaluation of spatially cumulative impacts, so it is considered as an effective tool to integrate in the SEA process. Cumulative impacts can be a result of a several individual actions of a plan/programme (e.g. pollution, loss of habitats. Hence, it is essential to address these cumulative impacts. Co-occurring environmental resources evaluation and their sensitivity by GIS can assist addressing cumulative impacts. SEA allows for better decision making, through alternative design and location analysis. GIS helps in conducting the study of site suitability for the best location of the project, besides, alternatives' impact analysis by various spatial analysis tools. GIS supports the technical stages of SEA, such as: data organization, storage and visualization. In addition, GIS provides accurate expected impacts and better usage of management and mitigation measures.

- The developed GIS and SEA integration model through this research is a tool used for combining the GIS tools and techniques and the stages of SEA process to support decision making in achieving sustainable development. The developed integration model is a unique proactive one which is not intended to solve problems but rather avoiding their occurrence. There is no evidence on the existence of a similar model that integrates GIS in SEA process. The integration of GIS tools in the SEA stages allows integrating the three pillars of sustainable development, which are (social. economic and environmental).

- The integration model is based on integrating the GIS in each stage of SEA, which provides a base for conducting the SEA study. This aids project stakeholders and authorities to achieve sustainable decision-making. After the development of the integration model, it was found that the contribution of the GIS tools and techniques is not equal in all the SEA stages, this is due to the scope of each stage and its purposes.

- The integration model is a direct contribution to the original body of knowledge as a tool that can be utilized by the stakeholders to enhance sustainable development. The integration model is generic and can be applied on any SEA system worldwide as it only addresses the process of SEA. However, further research in needed to reveal the full potential of the GIS and SEA integration model.

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Green Heritage Assessment and Benchmarking;

Case Study: Sabil Mohamed Ali

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Keywords: Cultural heritage development projects; Green heritage; Green rating systems; Sabil Mohamed Ali; Sustainable rehabilitation

Abstract

Sustainable practices for cultural heritage projects require their own contextually designed indicators. This study investigates available assessment and benchmarking tools for green heritage practices; with a particular focus on the role played by Green building rating systems (GBRSs) owing to their increasing market potentials. This investigation shows the lack of specific, adequate and simplified tools for the sustainability assessment of rehabilitation actions. It is also difficult for the existing scoring mechanism of GBRSs to consider the socio-cultural, economic and environmental roles played by cultural heritage projects. Hence, the study develops a Multicriteria Assessment Framework (MAF) with a set of indicators tailored for cultural heritage projects to be applied in Egypt. The study would verify its outcomes by evaluating the restoration that took place for Sabil Mohamed Ali in Al Moez Street in Old Cairo according to the proposed assessment framework. This includes compliance with the new functional requirements, maintaining the historical and cultural values, recognition of its societal role and the integration with the external environment and social fabric. This is followed by validation and corrective action to the proposed framework so that it would be able to contribute to the existing body of knowledge concerning green heritage assessment and benchmarking.

1. Introduction

There is a lot of debate concerning means of integrating cultural preservation and sustainability as two faces for one coin. This requires further investigation on how to provide proper guidelines, assessment of qualitative and quantitative aspects of heritage preservation, as well as a method of benchmarking these strategies against a reference point. Hence, the paper reviews the existing frameworks, tools and methods provided for cultural heritage projects and the discussion focuses on the use of Green building rating systems (GBRSs). The investigation indicates the insufficiency of guideline criteria for cultural heritage projects. Hence, the study develops a proposed Multicriteria Assessment Framework (MAF) with a set of indicators that present guidelines and assessment criteria for sustainable heritage development projects. The study adopts a qualitative research method applied in a case study project - Sabil Mohamed Ali in Al Moez Street in Old Cairo. It had witnessed a huge deterioration in its physical condition due to structural problems, the rise of underground water as well as environmental problems causing the erosion of its facades. Following that, rehabilitation actions took place in 2007 converting the Sabil to an outstanding museum for the Egyptian textile fabrics. Accordingly, the case study presents a good opportunity to investigate the sustainability of its rehabilitation actions and test the proposed MAF framework. Eventually, this shall support a robust decision-making process and adds to the existing body of knowledge about heritage policy and practices.

1.1. Sustainability and preservation

Many initiatives aim at integrating sustainability and preservation. This can be traced through a series of international studies shown in Fig. (1); starting from Sustaining the Historic Environment (1997) to the European research project “Sustainable development of Urban historical areas through an active Integration within Towns” (S.U.I.T.). These initiatives aimed at stressing the fact that historic preservation is an important pillar to achieve sustainable development. Hence, this requires discussing common goals to achieve sustainability and preservation. It also calls for integrating heritage policy within larger sustainable goals and promoting processes of greening, reinvestment and reuse of green heritage (Dupagne, 2004; Ross and Powter, 2005; U.S. Gbc, 2010).

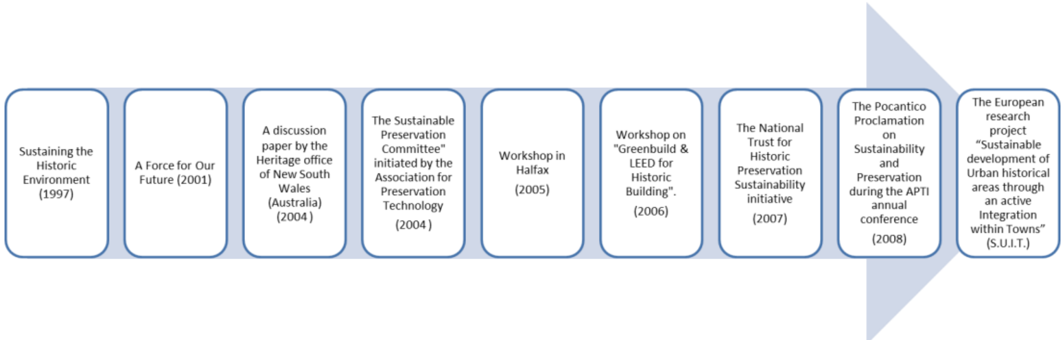

Fig. 3. Review of international studies for integrating sustainability and preservation

Source: Authors' elaboration based on Powter and Ross (2005)

1.2. Principles of green heritage

Knowing that heritage needs its own tailor-made indicators, then drawing up rating criteria for green heritage projects requires adopting the three bottom-line aspects of sustainability to support a long-term decision-making process (Ross and Powter, 2005). Accordingly, the 'Green heritage' is used in this article as a recently developed term that considers the triple bottom line objectives of cultural heritage projects. This includes the socio-cultural benefit in order to protect the diversity of cultures through education, training workshops, encouraging research and documentation of historic values and symbols (Ross and Powter, 2005). This aims at creating vibrant places that reflect social and cultural values for regional differences and unique local character and respond to their community's needs. The economic benefit is reflected in more job creation, revitalising old historic areas and eventually stabilising the national economy. The environmental stewardship considers the effect of preservation practices on the environment. This includes pollution and depletion of natural resources, including; site, water, energy, emission production and waste management. This is particularly evident by applying Life Cycle assessment methods to assess the environmental effects of materials, products, systems and services for the proper selection of sustainable preservation practices (Rypkema, 2006).

1.3. Green Heritage Assessment and benchmarking

Indicators, measurement, and third-party certification are important tools to manage sustainable heritage processes and practices and explore the divergent methods of understanding and evaluating green heritage (Liusman et al., 2013). This can be performed using quantitative and qualitative assessment with functions that represent time, condition and use for the proposed sustainable intervention practices (Mcdonagh and Nahkies, 2010). It also requires methods of monitoring, evaluating and managing change of a heritage development project. This requires a mechanism for assessment and benchmarking that would determine which indicators to assess, and the recommended tools for assessment.

Jönsson (2000) suggested four methods of presenting quantitative data: absolute values, relative values, relative to a threshold value, and belonging to an interval.

This requires identification and application of cultural heritage elements and values. It should also support progress measuring to identify areas of precedence and drawback in comparison to a reference case. It is noteworthy that it is considered challenging to select the integration of accumulated layers of history and culture over time and space (Aronson and Le Floc'h, 1996).

1.4. Green rating systems and Green Heritage

It is important to note that the process of assessment aims at increasing not judging the quality of the development project. It includes a process of audit, analysis, goal defining and measuring, evaluation of obtained results and comparing it in terms of quality and quantity to the planned goals and objectives. GBRSs offer quantitative and qualitative assessment through a stand-alone procedure offered publicly to national or international markets (Brandi McManus, 2010; Mateus and Bragança, 2011). They also provide a mechanism for defining measurement and benchmarking criteria to reach an overall rating for the whole heritage development project as shown in Fig. (2). The results present third-party verification and certification of the project's sustainable performance, which are now considered projects' requirements in many countries. This includes qualitative criteria such as cultural value, site and context potentials and other intrinsic values. It also includes quantitative criteria such as energy, water, materials and resources as well as waste and emissions.

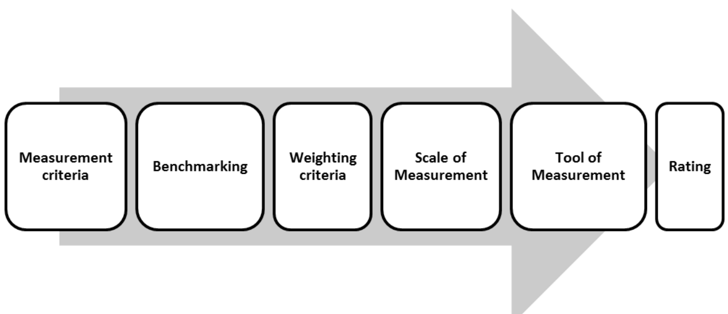

Fig. 4. The process of assessment using green rating systems
Source: the authors

It is important to note that there exist few GBRSs that address green heritage. The Global Survey of Urban Sustainability Rating Tools listed the current available worldwide assessment tools (Criterion Planners, 2014). Examples are BREEAM in the UK in 1990 and LEED in the US in 1998 which provide standard criteria which have later expanded in different contexts. Moreover, in 2005, the Green Building Challenge and GB Tools were developed to adapt to local contexts and reflect socio-cultural factors such as heritage.

These GBRSs provide some potential when applied to green heritage, yet there exist some challenges as well. Their governing structure may encourage greenwashing which contradicts with the principles of cultural heritage preservation of favouring minimum intervention scenarios and repair before replacement. It is also difficult to consider the tangible and intangible benefits of green heritage buildings within their communities and represent them by point scoring method. Another major concern about existing GBRSs is their adaptability to other regions or contexts (Ismaeel, 2016). Also, the majority of existing GBRSs do not consider the intrinsic cultural value of green heritage buildings and their unique features. Another challenge concerns the assessment and benchmarking method. Both energy and water efficiency require robust quantitative assessment compared to a reference building of similar building type, context, and scale. The challenge is to define such a base case for cultural heritage buildings. Moreover, comparing current practices or standards with old ones would not create a good base of comparison, hence, time and technology constraints should also be considered. Also, the sustainability of materials and assemblies should include information about the environmental impact of different preservation strategies, materials, and procedures. It should also account for their differential durability and service quality under the broader concept of Life Cycle Assessment. The former provides a sort of comparative analysis of functional aspects of materials which are estimated according to their rate of maintenance and repair, while the latter, is associated with other attributes such as the aesthetical value of the ageing subject (Frey, 2008; Ross and Powter, 2005).

2. Literature review

An updated literature review was conducted using an institutional link on Science Direct database from 2000-2017. The search used the following keywords; cultural heritage development projects, green heritage, green rating systems, Sabil Mohamed Ali and sustainable rehabilitation. This included a collection of reviewed E-books, peer-reviewed journal articles and conference papers published in English to be able to determine the extent and value of existing research and identify gaps and limitations of relevant studies. This highlighted a number of factors to be considered while drawing the proposed framework to assess the rehabilitation strategy of the selected case study.

According to previous studies, there are some main approaches to deal with cultural heritage projects, these are; preservation, conservation, restoration, renovation and rehabilitation (Moreira et al., 2006; Sutton and Fahmi, 2002). These approaches differ according to the guidelines they present, as well as the tools and methods used to evaluate the final product. Defining heritage goals, required information, the needed expertise and the acceptable ranges of variability are essential steps to be able to define relevant assessment and benchmarking criteria. It is also important to determine at what point repair and reconstruction might erode the integrity of the heritage attributes to be able to determine the cultural heritage value or interest held by the property. This is maximised by following an early integrated process and requires consideration for the whole built fabric as well as individual heritage buildings to ensure their integration and harmonisation within their surrounding contexts. Other review studies included the work of Plevoets and Cleempoel (2012) who compared, classified and pointed up gaps of different theories for adaptive reuse strategy towards conservation of cultural heritage: typological, technical and architectural. Also, Seyedashrafi et al. (2017) reviewed existing methodologies, approaches and tools regarding heritage impact assessment.

Clemente et al. (2015) argued that cultural heritage should extend beyond the gentrification of historic centres to play an active role for the urban regeneration; increasing its cultural activities and promoting the valorization of the urban area. Sutton and Fahmi (2002) stated that the rehabilitation of the built fabric should consider historic buildings, existing buildings as well as open spaces as part of a comprehensive rehabilitation plan.

The process should consider their socio-cultural role and function which should be maintained to meet the community. This should include public-private partnership along with inputs from professionals and local community (Lamei, 2011). Ronda (2007) added that the adaptive reuse of abandoned buildings should consider additive layers and dimensions of the evolution of the society needs and times and creates place identity. Tran (2011) added that exploring layers of inspiration embedded within an existing site shall eventually yield new insights and meanings to link historic buildings to their evolving surrounding contexts. Also, Malhis (2016) used spatial and perceptual analyses using various spatial descriptor tools of space syntax for Mamluk architecture.

Some studies discussed energy renovation of cultural heritage buildings. De Santoli (2015) developed Guidelines to evaluate and improve the energy performance of historic buildings and a framework for the design of possible energy efficiency upgrades in accordance with the conservation criteria. Also, Tomšič et al. (2017) investigated measures to improve the building thermal envelope, energy systems and installations as well as the use of renewable energy systems. Moreover, the role of daylight as an essential contextual element in preserving visual perception and identities in heritage context was pointed up by Al-Maiyah and Elkadi (2007). This indicated the necessity of minimizing changes in daylight levels and reflections in the rehabilitated space owing to the use of new finishing materials. Also, assessing the visual performance of buildings in relation to their urban context was pointed by Almaiyah and Elkadi (2012).

The aesthetic integration of the structure within its surrounding environment was discussed by Danaci (2015). Also, Pendlebury et al. (2009) pointed out the problem of authenticity related to the designation, assessment and management of conservation objects in the context of dynamic and heterogeneous urban systems. Similarly, Trifa (2015) raised the problem of maintaining authenticity while suggesting new functions and intervention strategies for the former industrial areas to become a key-tool and landmark in urban regeneration projects. Moreover, AlWaer and Kirk (2016) discussed performance-based metrics for community sustainability assessment to estimate the impacts of large-scale development projects on the local and global environment. Additionally, Rasoolimanesh et al. (2017) attempted to develop a model for community participation in a World Heritage Site through motivation, opportunity and ability factors.

Moreover, advanced technologies have been pointed out by a number of studies as part of a top-down solution and bottom-up engagement. Hausmann et al. (2015) review paper investigated the usage and benefits of applying web-based applications in cultural tourism heritage to improve accessibility, comprehension and allow entertainment-oriented learning. Applications such as online travel planners, mobile tour guide systems, or review portals to be used before, during or after users' visit. Mortara et al. (2014) pointed to the potentials of learning cultural heritage through advanced technologies such as serious games that include virtual environments and augmented reality. Khodeir et al. (2016) discussed means of integrating heritage building information modelling tools in the application of sustainable retrofitting of heritage buildings in Egypt to provide a comprehensive dataset of information to aid the decision-making process. Also, Rua and Gil (2014) discussed inaccessible monuments modelling automation in heritage buildings using parametric and associative design strategies. The paper discussed a methodology used in the three-dimensional virtual representation of monuments in relation to heritage management.

Some attempts have been carried out to set a defined framework and develop indicators for the assessment of historic sustainability. Stubbs (2004) developed a set of qualitative and quantitative indicators for measuring the sustainability of historic contexts. Then, it was further developed by Liusman et al. (2013) into a set of 18 indicators called Heritage Sustainability Index consisting of environmental, social and economic dimensions. Later, it was developed by Almeida et al. (2018) to consider five major areas: water, energy, materials, emissions and cultural, economic and social environments. For each of these criteria, measurement indicators and levels of assessment were settled. Also, Hashim et al. (2012) developed a conceptual conducive design guideline or framework to assess functional aspects through Post Occupancy evaluation of refurbished historical public buildings.

The structure of these frameworks demonstrates similarities and variation; Stubbs's work used more parameters to develop this list of indicators and it was based on midpoints and endpoints which provided better chance to do a further weighting analysis to the selected indicators in terms of their relative importance. Liusman grouped his work into three defined index categories which correspond to the three bottom lines of sustainability. The social dimension included; accessibility of use, civic pride and sense of place, links to education and learning in the community, ability to engender skills, promotion of leisure or arts-based program for heritage buildings as well as promoting virtual heritage websites. The economic dimension included; employment created by the need to manage and maintain the historic building, boosting the local economy, ability to generate resources for operating expenses and future restoration, in addition to the multiplier effect which guarantees wider benefits of visitors/tourists to the local and regional economy and accordingly on investment/regeneration. On the other hand, the environmental dimension included indicators associated with compliance with building standards, methods/techniques for sustainable building construction and energy efficiency. The former discussed the measurement of carbon emissions, harvesting onsite renewable energy as well as investigating visitor mode of travel in favour of public transport. The latter discussed waste management and consumption as well as building adaptation due to climate change. Moreover, Stubbs work pointed out two major indicators related to public awareness and appraisal in the heritage sector. Yet, in general, a comparison between the two frameworks indicates considerable similarity between both of them.

Reviewing previous literature indicates that parallel research effort is directed at researching green heritage assessment and benchmarking; be it on the elemental, building or urban scales. Nevertheless, it is noted that applying these frameworks was faced by a lack of scientific data, assessment, measurement and benchmarking criteria for cultural heritage sites/buildings and above all, they were not able to link the gap between research and application. This shows that more work is required to further take the proposed frameworks into action and relate it to fieldwork.

3. Method

The research adopts a qualitative approach to develop a green building rating system for cultural heritage projects in Egypt. This is based on insights from the previous literature review and practical approach. This can be divided into the following steps;

3.1. Data gathering

3.2.

The first step starts with creating a balance between heritage sustainability indicators and integrating the related goals of sustainability and preservation in such a manner that would eliminate any areas of conflicts. This also implies coordination with other jurisdictions and other assessment methods. Hence, data gathering should be categorised into qualitative and quantitative criteria. These include a set of five indicators; cultural, social, environmental, economic and management.

3.3. Data processing

This includes the collection and manipulation of data to produce meaningful information. Data should be processed to fulfil the aforementioned indicators. The cultural and historic indicators include the following criteria: determining site accessibility and transportation, determining the baseline case of the heritage building and site value as well as developing cultural values for regional differences and unique local character. The social indicators include enhancing social capital and build institutional capacity. This is in addition to promoting research and development as well as awareness of heritage problems and preservation/ conservation approaches. The environmental indicators include measuring energy consumption and water use as well as sustainable materials and waste management through Life Cycle assessment. The economic indicators can be measured by reducing the cost of energy consumption and water use and promoting local markets of sustainable materials and products. The management indicators can be divided into; strategic management which takes account of compliance with the national policy of Egypt 2030 to promote sustainable development and limit emissions as well as compliance with the international building codes and standards. Operational management ensures safety, serviceability, amenity and disabled facilities and Marketing management guarantee local and international branding.

The qualitative data for social and cultural indicators may be gathered using questionnaires, interviews and observations. The type of data may include binomial, nominal and ordinal data. On the other hand, quantitative criteria for environmental, economic and administrative indicators may be gathered using statistical continuous measurements in intervals or ratio, or discrete counts.

3.4. Analysis, evaluation and validation

The selection of measurement criteria, tools and methods should be based on the expected change resulting from the heritage development project. Accordingly, this should determine the unit of measurement and the baseline case. This should be followed by a process of validation. This process should provide a sensitivity analysis for many different factors that should be determined case by case, such as regional difference, climatic conditions, accuracy and suitability of the measurement tools.

Measuring cultural and historic indicators consider proximity to local transportation, ease of access and wayfinding as well as services and infrastructure. It also measures site cultural and natural values and visitors' satisfaction. Measuring social indicators takes account of public engagement and awareness as well as social impact assessment. Measuring crime rate can provide an inverse indicator for visitors' safety and public satisfaction. This is in addition to the number of international and national research and funds allotted the heritage project. Environmental indicators can be measured using software simulation programs for Energy use and Life Cycle assessment, while, calculations for water use should be divided into potable and non-potable water for both indoor and outdoor water use. This should also include calculations for waste management of recycled, reused and landfilled waste. It should provide a clear description of the type of waste; solid, liquid or gaseous, in addition to its contamination level. Measuring economic indicators account for cost-effective performance and social progress. Finally, measuring management indicators include strategic management to ensure transparency, integrity, accountability as well as institutional bureaucracy and red tape. It also includes operational management for safety, serviceability, amenity and disabled facilities and marketing management by tracing local and international branding.

3.5. Decision making, monitoring and feedback

Decision making includes a process of comparing alternatives against the predefined benchmarks for the proposed heritage development project. This determines the change process and its impact size, magnitude, dimension and time frame. It may be followed by a process of mitigation and control to reduce expected adverse impacts. The impacts are going to be measured according to the predefined set of indicators. The benchmarks for the cultural and historic indicators take accounts for accessibility, livability as well as indicators for regional differences and unique local character. The social indicators' benchmarks comprise social capital, institutional capacity, research and development as well as public awareness. The environmental indicators' benchmarks refer to both international treaties and national legislation. The economic indicators' benchmarks include the National Gross Domestic Product as well as cost savings through energy and water use reduction. Finally, the management indicators' benchmarks include the national policy of Egypt 2030 as well as the international building codes and standards.

Following the development of the proposed framework, testing and validation steps were conducted on a case study in Egypt- Sabil Mohamed Ali. The required data was collected through site visits, observations and in-person interviews with users and persons in charge of the management process of the Sabil building. A sequence of site visits identified the current state of the rehabilitated project. This step identified gaps and limitations in the proposed MAF framework so that it would provide a systematic framework for assessing and benchmarking green heritage. This supports decision makers, heritage conservators and experts toward developing a more integrated approach to heritage protection in the context of sustainable development.

4. Result

The study develops the MAF proposed framework for developing green heritage rating system as shown in Fig. (3). It shows the selection of sustainable indicators for green heritage projects, data types, measurement and benchmarking criteria. This framework addresses the peculiarities of heritage development projects and practices. It starts with the process of data gathering and data processing according to the type and scale of the heritage project at hand, as well as its site location and context peculiarities. This should be followed by a process of analysis, evaluation and validation to ensure recording accurate measurements. Accordingly, it enables comparison against predefined benchmarks to support the decision-making process for green heritage development projects.

This could present the basis for developing sustainable rating systems for green heritage projects. Project's assessment could be carried in advance of any development action (ex-ante assessment) or after carrying on the development project (ex-post assessment) in order to provide a quantifiable and a standardized method of assessing and benchmarking sustainable preservation practices.

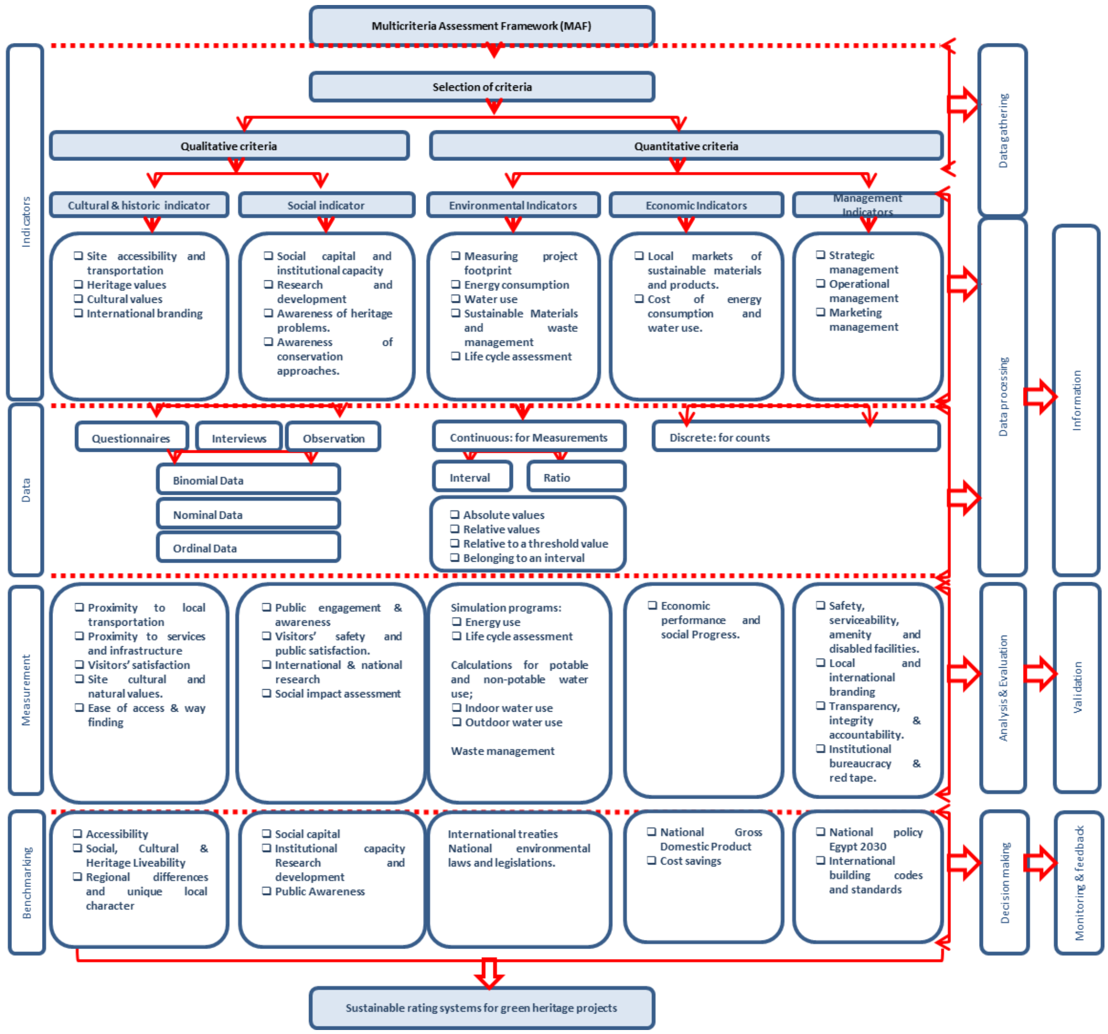

Fig. 5. The proposed Multicriteria Assessment Framework (MAF)
Source: the authors

5. Case study validation- Sabil Mohamed Ali

The proposed framework is verified through the rehabilitation project that took place in Sabil Mohamed Ali in 2015. It is noted that the case study was identified by the United States Agency for International Development (USAID/ Egypt, 1993) as a priority site for restoration and protection owing to its significant cultural value.

The authors verified their outcome through a series of site visits and interviews, extended for five months starting from August until December 2017. The first site visit aimed at investigating different restoration and rehabilitation practices along Al-Moez Street. It also resulted in the selection of *Sabil Mohamed Ali* due to its capacity to provide a comprehensive insight regarding most of the framework's indicators. This step also initiated the start of the data gathering process. The second and third site visits in December 2017 included the architectural documentation of the new rehabilitation project and establishing better comprehension of the relationship between the project and its surrounding context, while the latter included a number of structured interviews with administrative bodies in the museum and other restored monuments in Al-Moez Street, respectively.

The site observations focused on the relation between the historical monument and the new interventions as well as defining the contextual relations in terms of connectivity and transportation proximity. This provided indications of how far the cultural values of the monument were considered after the rehabilitation process.

5.1. The case study background

The *Sabil* as a term is a charitable water dispensary Kiosk used to store and distribute water from the river Nile in huge water tanks called *Saharig*. *Sabils* were a widespread Islamic tradition that took different forms according to their time and place. The case study was built in Cairo by Mohamed Ali Pasha- the Great-in 1828 in order to dispense free drinking water to the public, besides its educational mission as a Kutab. It's considered a prototype for the Ottoman architecture in Cairo. The half circled ottoman typology offered more dispensers and a new form regenerating the urban fabric. It's located in al Nahaseen street - Bein al Kasrein district, one of the oldest neighbourhoods in Cairo which embodied the main spine of commercial activities. The Sabil is located at the corner overlooking both Beit al-Qadi and Al-Moez Streets. The site is composed of three historical stratifications. The first is the eastern Fatimid palace that was located in the same area. The second is the *Zaheria* School that was built during the Mamluk command over the ruins of the palace. The third and last layer is that of the *Sabil* that was built during the Ottoman period. The area is very rich with its unique collection of Islamic architecture of different periods, including *Qalawoon* complex, *Barquk School*, *Bashtak Palace*, *Al-Kamelia School*, *Enal bath*, and *Sabil Katkhuda.*

5.1. Describing the baseline case

The *Sabil* is of Turkish influences; it is covered with marble cladding tiles and decorated with sophisticated ornaments and calligraphy. The first floor is composed of the main water dispensary room and other services, while the second floor inhabits a school for teaching young orphans.

The entrance is located in the western part of the main façade along al Moez Street. The water dispensary room is a rectangular room on the ground floor covered with an oval dome of marvellous rococo decorations and vegetal paintings. It has a circular façade along Al Moez Street supported with four marble water dispensers for the public. The school is composed of 4 classes along beit Al-Qadi Street and one class at the corner which is clearly distinguished from the main façade. All rooms are supported by rectangular openings in order to allow sufficient natural light. During the restoration process, the huge underground tanks were discovered with a depth of 11.30 m below the water dispensary room. It is supported by 10 stone columns, roofed with 18 domes. When discovered, the water tanks were full of clear water which reached a level of 9.60 m and currently, the water is being pumped out gradually. The facades were articulated vertically and horizontally. It is dominated by the classical style enhanced by rococo decorations and ornaments. The water dispensary room is elevated with five circular steps forming a distinguished relation with the urban structure of Al-Moez Street. It is supported by five dispensaries for water. The school's façade is distinguished in form with an extrusion including five openings.

Lately, the *Sabil* incurred lots of violations, which caused clear deterioration of its facades and architectural structure and resulted in a direct degradation of its cultural, historical and aesthetic values as shown in Fig. (4). Deterioration features were associated with improper restoration practices that caused the substitution of authentic stones with incoherent ones of different colours and textures. This was alleviated with poor maintenance practices which increased the moisture and salinity levels. Unfortunately, this led to the rapid erosion of the façades and resulted in cracks. Moreover, the improper functional use practised along the ground floor increased the degradation of the *Sabil.* Finally, the effect of time and lack of maintenance caused a general deterioration in the building's structure. It is noted that the only exemption was the water dispensary room which was well protected by the commission of monument's conservation.

Fig. 6. Photos describing the deteriorated state of the Sabil

5.2. Describing the rehabilitation case

As part of the Historic Cairo Rehabilitation Project in 2010, the Sabil was converted to the Egyptian textile museum, after a serious restoration process saving the *Sabil* from an expected collapse. The museum is almost the first of its kind in the Middle East; narrating the history of Egypt through textiles, tools and Artefacts that starts from the Pharaonic era, the Graeco-Roman, Coptic, Umayid, Mamluk and finally the Ottoman period as shown in Fig. (5) and (6).

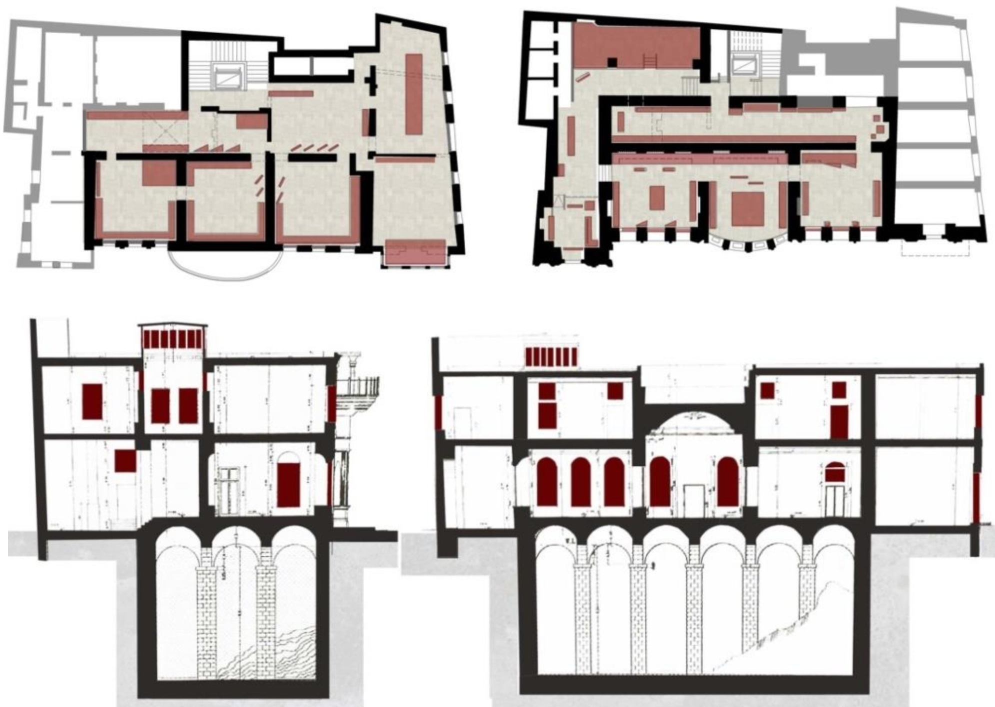

Fig. 7. Architectural drawings of the Sabil building after rehabilitation process, the red coloured elements represent the new additions, source: the authors

Fig. 8. Photos documenting the current rehabilitated indoor spaces of the Sabil
Source: authors

5.3. The framework validation

The framework's validation is represented through an assessment model fulfilling the indicators, data and measurements criteria as shown in Fig. (7):

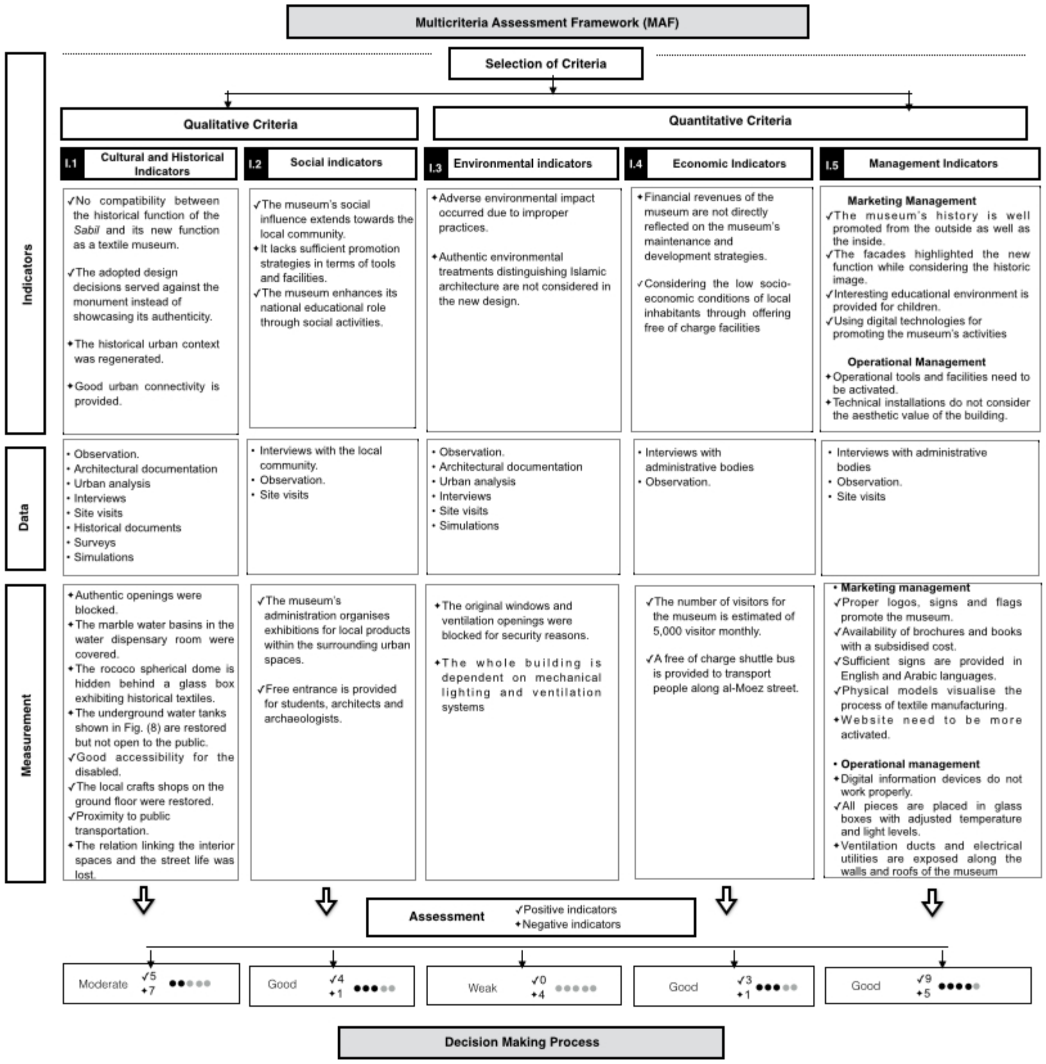

Fig. 9. Applying the MAF framework to the case study

Source: authors

Fig. 10. Photos documenting the Saharig of Sabil Toson Basha (left) and the introduced accessibility (right), source: authors

5.4. Framework Modifications

This section includes a set of modifications to the proposed MAF framework after performing the case study validations. As a preliminary step, the study suggests investigating the efficiency of the restoration process after documenting the baseline condition of the cultural heritage building. The cultural and historic indicators should be divided into factors associated with the building and urban settings. This should also be complemented by a thorough study of the proposed form and design and its reflection on the building's authenticity and image value. This is directly related to decisions concerning the building's original and new use and function. Additional decisions should take into consideration the new urban setting supporting the authentic function of the rehabilitated building. This may include decisions associated with changing or maintaining the surrounding land uses. Finally, as part of the marketing indicators, the study suggests tracing visitors' reflections on social media, tourist websites and search engines to create open channels for effective monitoring and feedback. This should also include developing touristic facilities with advanced tools and technologies.

6. Conclusion and future research

It is considered an enormously complex process to provide a comprehensive approach for sustainable preservation interventions for cultural heritage projects. This requires defining a set of guidelines, assessment and benchmarking methods to support a long-term decision-making process. Knowing that current GBRSs operate in quite a simplistic and abstract manner, hence this study develops a multicriteria assessment framework integrating sustainability and preservation goals through a user-friendly approach for practitioners and decision makers. The proposed MAF framework is divided into the following steps; 1) data gathering, 2) processing, 3) analysis, evaluation and validation and 4) decision making, monitoring and feedback. It identifies a set of indicators for evaluating the sustainability of the restoration process, this includes the cultural and historical, social, environmental, economic and management indicators, as well as a set of assessment and benchmarking criteria for each indicator. This indicates the tangible and intangible benefits of heritage buildings and sites.

The paper provides a literature review and validates its outcomes through a qualitative case study analysis- Sabil Mohamed Ali which has experienced recent restoration process to turn it into a textile museum. Hence, the baseline case and the rehabilitated cases were described and compared to determine aspects of development and drawbacks using the proposed MAF framework. Findings of this study present a preliminary step to develop a comprehensive framework for assessing and benchmarking sustainable retrofitting initiatives for heritage buildings in the Egyptian context. Future development directions shall aim at further developing the proposed MAF framework using weighted criteria and scoring methods to be able to provide an indicative third-party verification and certification of the sustainable performance of the rehabilitated project. This contributes towards developing standard criteria that would act as an international common language for measuring and benchmarking green heritage building performance. It would also allow for unifying research targets and exchanging knowledge and expertise in related problematic research and development areas for historic preservation policy and practice.

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Investigating the Cooling Effect of Living Walls in Egypt Based on Design Builder Software

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Key words: Living wall; hot-dry region; cooling energy efficiency

Abstract

Building façades is the border between the indoor and the outdoor of a building, affecting the spaces of both sides. Initially, the main role of façades is to provide protection from the climate's inclemencies as well as from other humans or animals, as technology made progress, façades became more permeable allowing air and light to pass through them, leading to the very thin façades of glazing buildings. In accordance, façades requirements became more and more complex in order to improve indoor comfort conditions. The main aim of the research is to prove that Living Wall improves thermal comfort through decreasing the air temperature and increasing energy efficiency. The research analyses the energy performance of green vegetation in a high occupancy LEED Gold standard building in Egypt. Design Builder software was used to model the energy consumption for heating and cooling, and Energy Plus software was used to perform the detailed energy simulations. The developed simulation model was validated with the actual energy consumptions of the selected building. Green vegetation was simulated and the results show that green vegetation could considerably reduce the negative heat transfer through the building facade in summer and winter months. The results conclude that the use of green walls has an important effect on the increase of the quality of interior air, which increases the thermal comfort inside the space and decreases Annual Zone Sensible Cooling.

1. Introduction

Recently, the concept of Green design has been defined as a set of man-made elements which supply multiple functions both at building and urban scale. Among these functions, the building energy savings as well as the reduction of air temperatures and annual sensible cooling, some of the most important and interesting construction systems for this goal are the green facades and green walls [1]. In the Design Builder modeling environment, the green wall is presented as 'Eco-roof' material that forms the outer layer of the roof assembly (metal deck), Certain parameters pertaining to the vegetation layer or growing medium are present that help to define the green wall type [2].

Apart from the vegetation layer, the green roof comprises a growing medium (soil) of certain depth, a root barrier membrane, a drainage layer, insulation (may or may not be present) and a waterproofing membrane. The structural roof is a metal deck, same as in the base case of a cool roof [3].

Design goals and considerations for Green Facades are: Low cost and easy installation, using a climbing plant species that attach directly to the wall, grown in a planting bed at ground level, Seeking advice to ensure the best selection of plant types for building structure, a multi-story facade greening. Includes containers at different hieghts, cabling or lattice support structures for twining plants, ensuring access for maintenance, providing irrigation, considering secondary protection of plants against stem damage (e.g. wind protection trellis) [4]. Maximizing thermal benefits, use of deciduous species if heat gain is desired in winter; ensure very leafy plants, covering the entire wall for providing best shade in summer, particularly on north and west facing walls; providing a structure at least 100mm off the wall of a building for the plants to grow on, leaving an air gap between the building and green plants to maximize cooling effect [5].

2. Literature Review

Ottelé examined the main characteristics of vertical greening systems along with the environmental benefits on a neighborhood or city scale and the larger scale. A life cycle analysis shows the environmental impact in relation to the environmental benefits which conclude that the greening systems' design needs to take into account many aspects including the integration with the building envelope, a sustainable material choice, the environmental impact, and the symbiosis between the growing medium and the vegetation, which is a key element for the success of the greening system [6].

Many studies should be undertaken to quantify the environmental benefits of greening systems, especially on a macro-scale. Living wall systems (LWS) is the most viable greening system. This is a new field for investigation which regards insulation properties, durability aspects, maintenance, plants employed related to the climate conditions, materials involved, etc. [7]

2.1 Typologies of Green Façade

Green façade can simply be defined as the vertical integration of planting system on the façade of buildings or any other structure, the plants may be rooted in the ground or in planter boxes at different levels of the façade as shown in fig 1 [8].

These systems are improving across the world as living walls which could be used in the form of green walls, they could also be utilized actively in building systems as biological filters and could directly affect ventilation in buildings, On the other hand they can be used both inside and outside a building [9].

Living walls include modular systems of drainage and irrigation of plants in the form of vertical gardens with quick green cover for vertical surfaces, they are also a proper space for the uniform growth of plants [10].

Therefore, this quick green cover and their capability of being replaced and changed is their superiority for establishing green facades, Moreover, they are effective in improving the environment and ecological condition of buildings.

The open space between metal structures and walls are completely covered by vertical and horizontal shadowing tool from top, south and north. Therefore, air layers are not heated by direct sun radiation and natural ventilation does not occur in this space. The following figure shows the details of a living wall system [11].

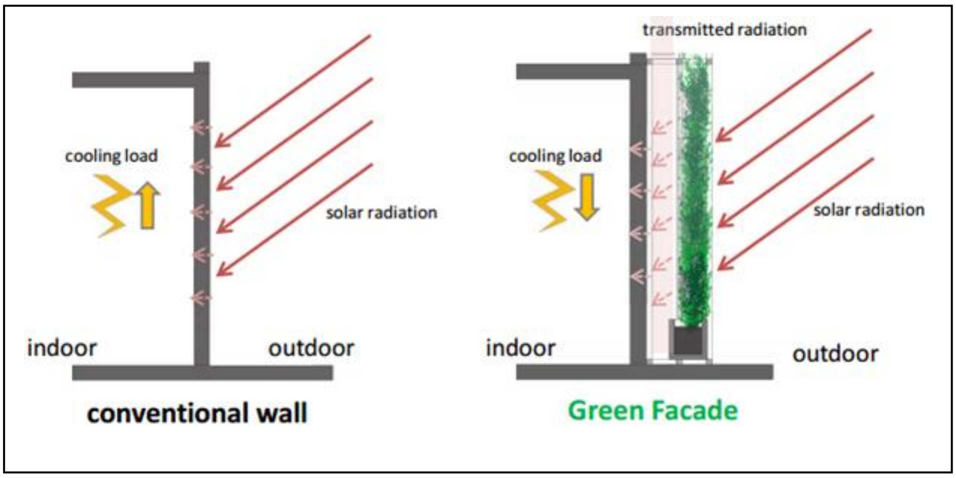


Fig. (1): Showing the difference between a conventional wall facade and a green façade [12].

This practice, which one might call a boom of vertical greening, is spreading all around the world as the following recent examples reflect. The figures below show examples from Jupilles, France fig 2(a) to Reston, USA fig 1 (b) to Tokyo [13].

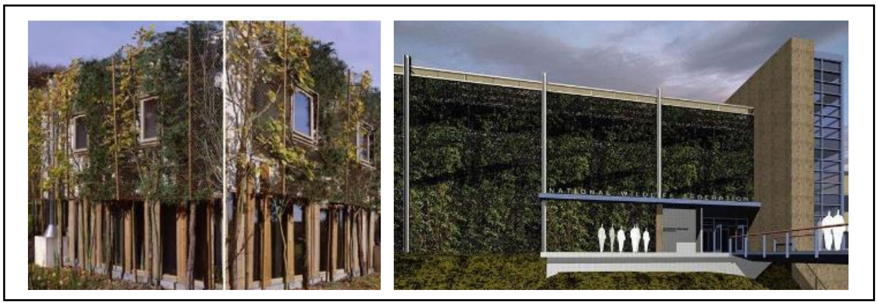


Fig. (2): (a)Houses in Jupilles, France, 1996 (b)National Wildlife Federation in Reston, USA, 2001 [12].

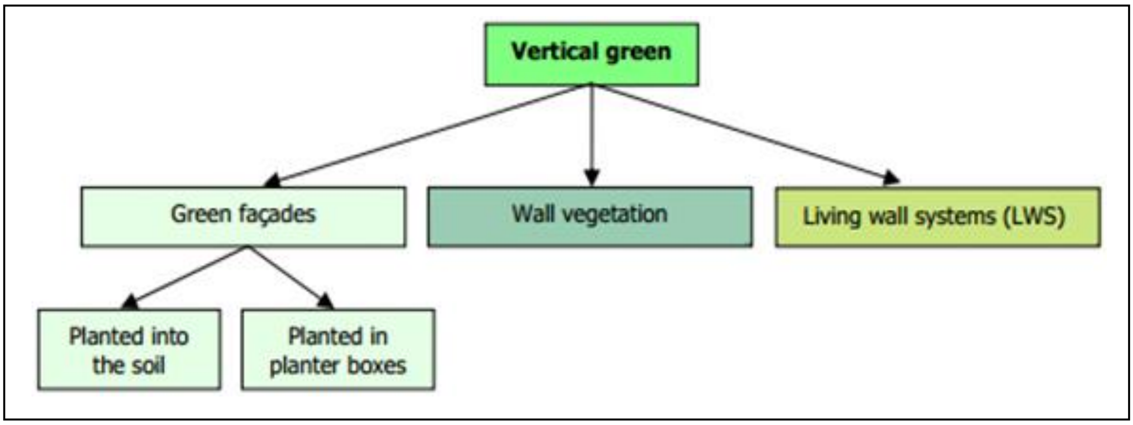
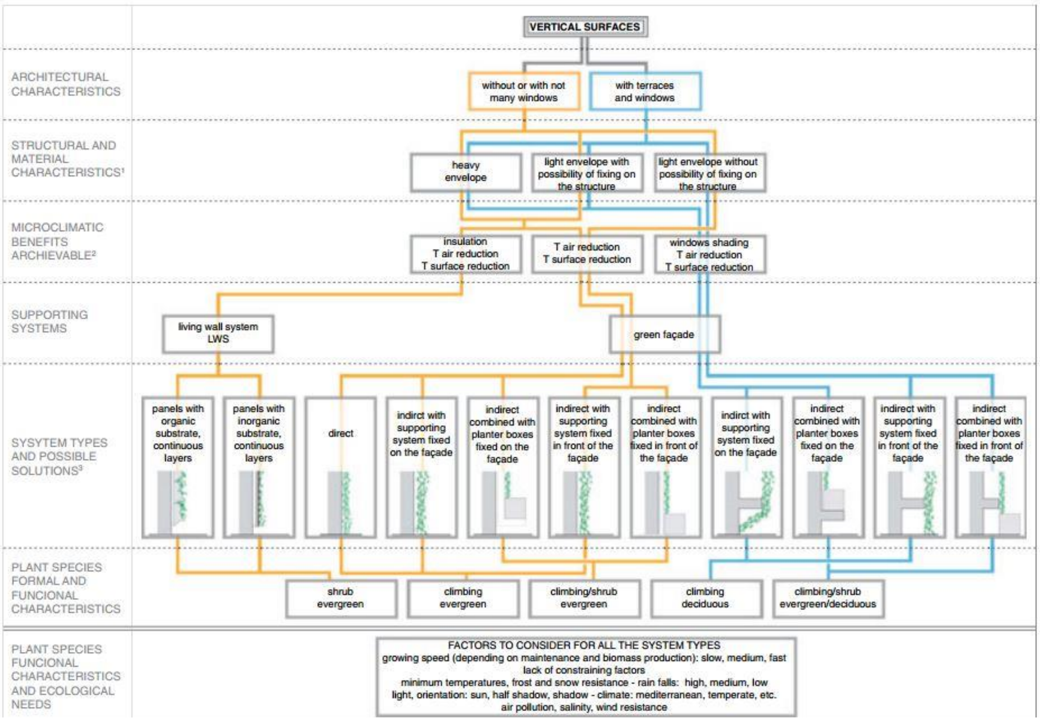


Fig. (3): Showing two different typologies of green façade [12].

Living wall systems can positively affect the thermal resistance of the building envelope according to the materials involved and the possibility of combining functionalities such as insulation material (see fig 3). Modelling of the targeted buildings reduction of air and surface temperature and, in the case of a façade with openings, also interior shading [13,6,7].The choice of plant species has to take into account many parameters including the supporting system type (climbing plants or shrubs), microclimatic benefits (evergreen or deciduous), maintenance needs, biomass production (growing speed), climate type, and environmental parameters (minimum temperatures, frost or snow, rain falls, wind resistance, etc.), façade orientation, and constraints within the urban area [14].

Geometry for each considered building was created in Design Builder, where the required data was extracted from the designed drawings and technical specifications [15]. The key façade parameters used in the building model were based on the ASHRAE 90.1 260c and 200c.

Weather data for EGY_AL QAHIRAH_CAIRO INTL AIRPORT_ ETMY has been customized using the basic weather file issued from Egyptian Typical Meteorological Year (ETMY)



2.2

Fig. (4): Process tree for green façades and living wall [13].

Energy Consumption, thermal comfort simulation and estimated software (Design Builder 4.1).

The simulation will be conducted with the aid of "Design-Builder" software tool, which mainly depends on (Energy Plus). The investigated aspects: energy consumption, and air temperature for proper evaluation of "Base-Case" & (investigated case study) [22]. Design Builder is used for the modeling of buildings from different perspectives such as the building materials, architecture, cooling and heating systems. It is capable of modeling all aspects of buildings. Except for the modeling heating and cooling in a building, the software is able to dynamically model buildings' energy consumption including thermal energy, light, hot water etc. Design Builder software uses the ecological profile of different cities to estimate the receiving, consumption and loss of energy precisely according to the location of the building in question. The role of this software becomes evident when the exertion of minor and major changes to the modeling and designing phases of a building affects the energy consumption or storage in the building [23].

2.3 Climate Information

A Weather data file represents the typical long-term weather patterns of the intended region, The weather data file used for this study is (EGY_AL QAHIRAH_CAIRO INTL AIRPORT_ ETMY as shown in Table 1 [16].

Table 1: Details of Weather Data File used for simulation.

Weather Data File	EGY_AL QAHIRAH_CAIRO INTL AIRPORT_ ETMY. epw
Type	Hourly weather data
Location	Cairo, Egypt, Africa WMO Region 1
Source	Egyptian Typical Meteorological Year (ETMY)

This study referred to ASHARE 55 standard guidelines that are recommended to satisfy the majority of office building occupants 200C to 23.3 0C in winter, and 22 ºC to 26 ºC in summer, and relative humidity of 30 to 60 percent summarized in Table 2.

Table 2: Temperature/Humidity ranges for comfort.

Conditions	Relative Humidity	Acceptable Operating Temperatures
Summer (light clothing)	30%,	24.5-28 ^{0}C
	60% ,	23-25.5 ^{0}C

Source : Adapted from ASHARE 55-2004

2.4 General Office Building Design Data

The typical office floor plan was divided into four (see Fig.6) equally office zones per floor, the two comparative models for both: "Base-Case" & Green wall Details on the studied configurations can be found in Table 3.

Table 3: Office Building Architectural Data.

Building type	Office building
Room 1	12 person/100 m2
Building floors numbers	Ground floor
Typical office floor height	4.0 m (slab to slab), 3.70 m ~ 3.0 m (clear height)
Ground floor area	20.0 m *10.5 m = 225 m2

3.	Ventilation system	-For "Base-Case" building For Green wall building

Modelling of Green Wall

The green wall models for office buildings were generated in Design Builder (Fig. 5), considering the outer surface of the exterior wall as a soil layer of 80 mm, acting as growing media for the plants, The soil properties used in the building model were based on the literature regarding vertical vegetation parameters [17,18].The leaf area index was estimated by referring to an ecological survey [19] the soil properties and the key façade parameters used in the building models were based on the ASHRAE 90.1 Appendix G Standards and the literature regarding vertical vegetation parameters [20].

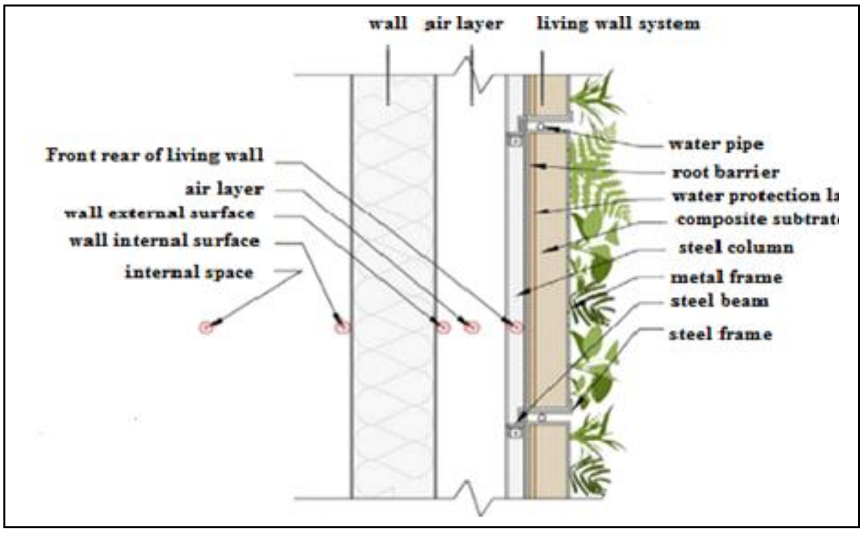
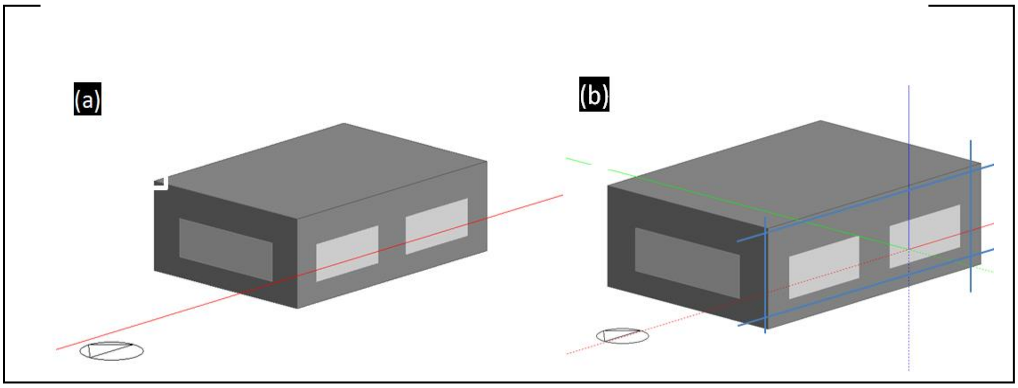


Fig. (5): Details of a living wall system



The Green wall system is located on the

Fig. (6): (a) Base-Case & (b) Green Wall Model, Design Builder Screen shoot [21].

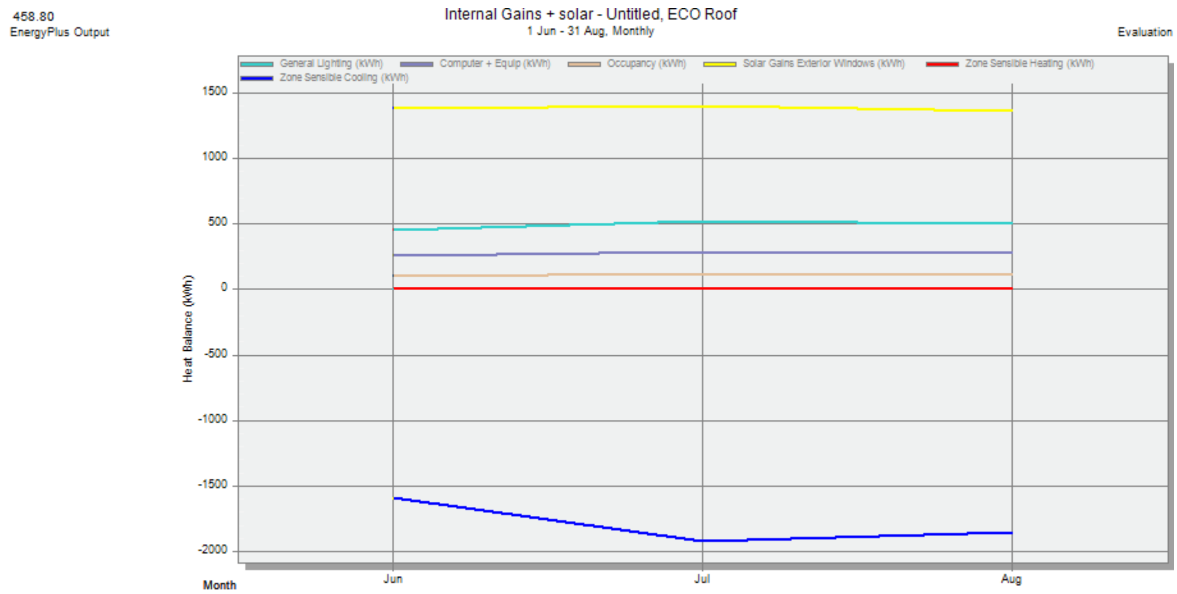
southeastern walls, as shown in Figure (6). This living wall is consisted of layers expressed in Table 1, Living walls are installed on exterior walls made of bricks with 37 cm width forming exterior and interior plaster.

3.1 Validation of the Simulation Model

In order to assure the validity of the simulation outcomes, the simulated annual energy consumption results (without vegetation) were compared with the actual monthly energy consumption data of the studied buildings (Fig. 7). Whole building energy consumption included all the electricity and gas uses in the building (by lighting systems, HVAC system, and appliances).

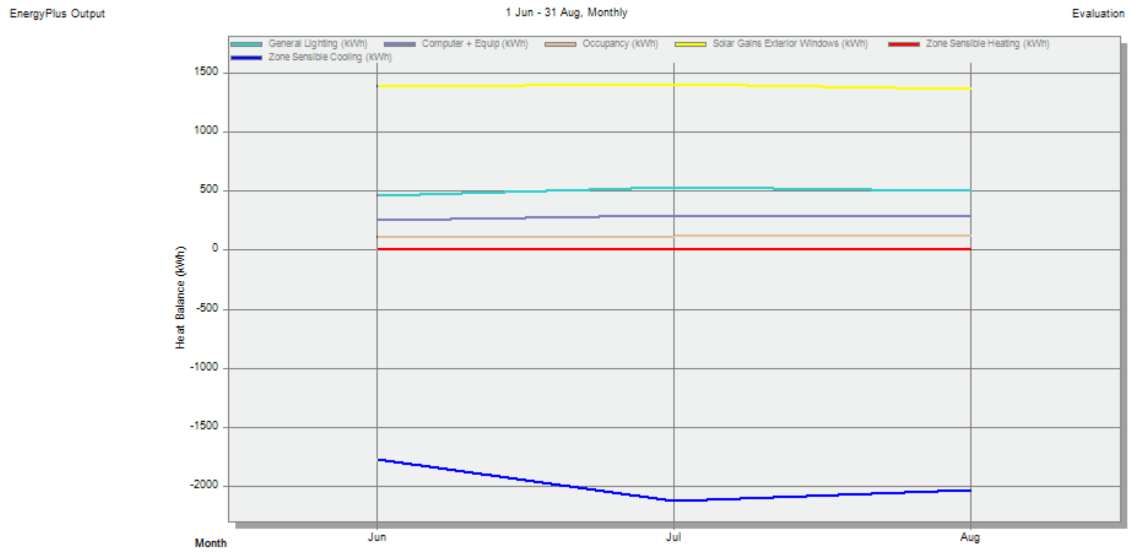
	Details given to Design Builder
The details of ordinary walls	• Plaster (15cm) • Brick (37cm) • Plaster (15cm)
The details of living wall	• grass/straw(15cm)(the e layer) • Cultivated peat soi moisture(20 cm) • Felt (5 ml) • PVC(1cm) • Airgap(20cm) • Plaster(15cm) • Brick(37cm) • Plaster(15cm) • wall air space resistance(1 • Plaster(15cm)

Fig. (7): Details of the type of living wall system.



Month	Jun	Jul	Aug
General Lighting (kWh)	458.80	527.62	504.68
Computer + Equip (kWh)	256.34	290.71	279.64
Occupancy (kWh)	104.60	120.29	115.06
olar Gains Exterior Windows (kWh)	1386.01	1407.74	1361.56
Zone Sensible Heating (kWh)	0.00	0.00	0.00
Zone Sensible Cooling (kWh)	-1589.69	-1917.12	-1854.03

Fig. (8): First system Simulation - Alternative 1 (no living wall), Design Builder graph Screen shoot [21].



Month	Jun	Jul	Aug
General Lighting (kWh)	458.80	527.62	504.68
Computer + Equip (kWh)	256.34	290.71	279.64
Occupancy (kWh)	104.60	120.29	115.06
olar Gains Exterior Windows (kWh)	1386.01	1407.74	1361.56
Zone Sensible Heating (kWh)	0.00	0.00	0.00
Zone Sensible Cooling (kWh)	-1769.85	-2114.78	-2026.24

Fig. (9): First system Simulation - Alternative 2 (using living wall), Design Builder Graph Screen shoot [21].

)

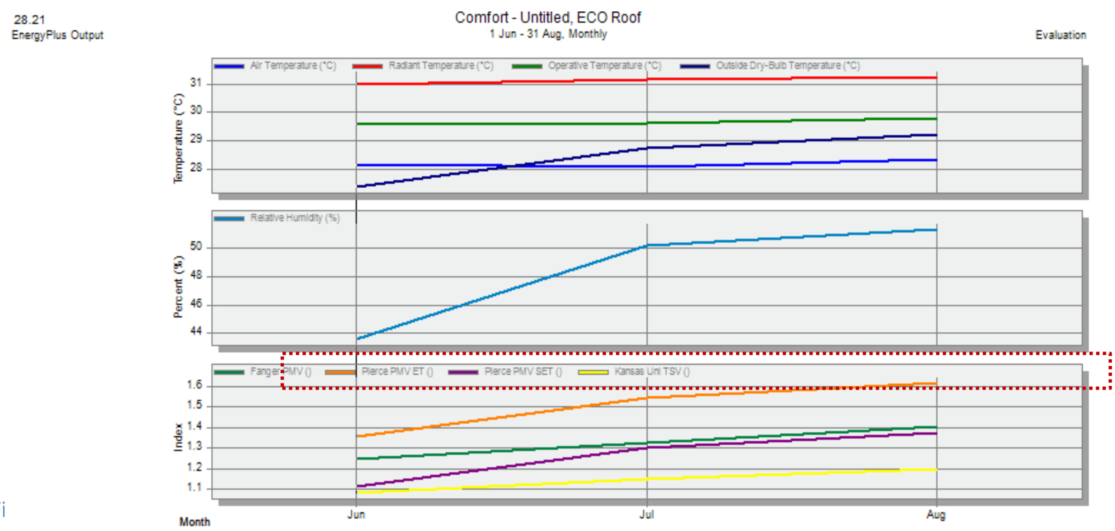
Considering the research building, the simulation result graph reported maximum energy use in July, whereas actual energy profile showed that August is the one having highest energy consumption (Fig. 8), which is explainable as August is the hottest month in Egypt However, in the weather data generated from Design Builder simulation, the mean air temperature of July and August is found to be quite similar. The data derived from Design Builder software in different months of the year shows the difference between temperatures of two alternatives (without using the details of living walls- using the details of living walls). Graph 1 (alternative 1) shows that the temperatures of exterior surface at June, July and august were respectively

37.43° C, 38.66° C, and 38.96° C. However, in the second alternative, shows that the temperatures of exterior surface at June, July and august were respectively 28.21° C, 28.11° C, and 28.34° C.

The previous graphs show that energy consumption on building without green wall is 19765 kwh, while the effectiveness of green wall on energy consumption became 1456 kwh. It is concluded that the green wall has great effect in saving energy.

Façade Greening to Improve Thermal comfort:

Though the cooling period in the simulation included June, July and August, however, a constant cooling requirements (Fig. 9) throughout the year can be explained by the fact that naturally South-facing façades receive the most sunlight which creates a possibility of overheating, particularly in summer months.



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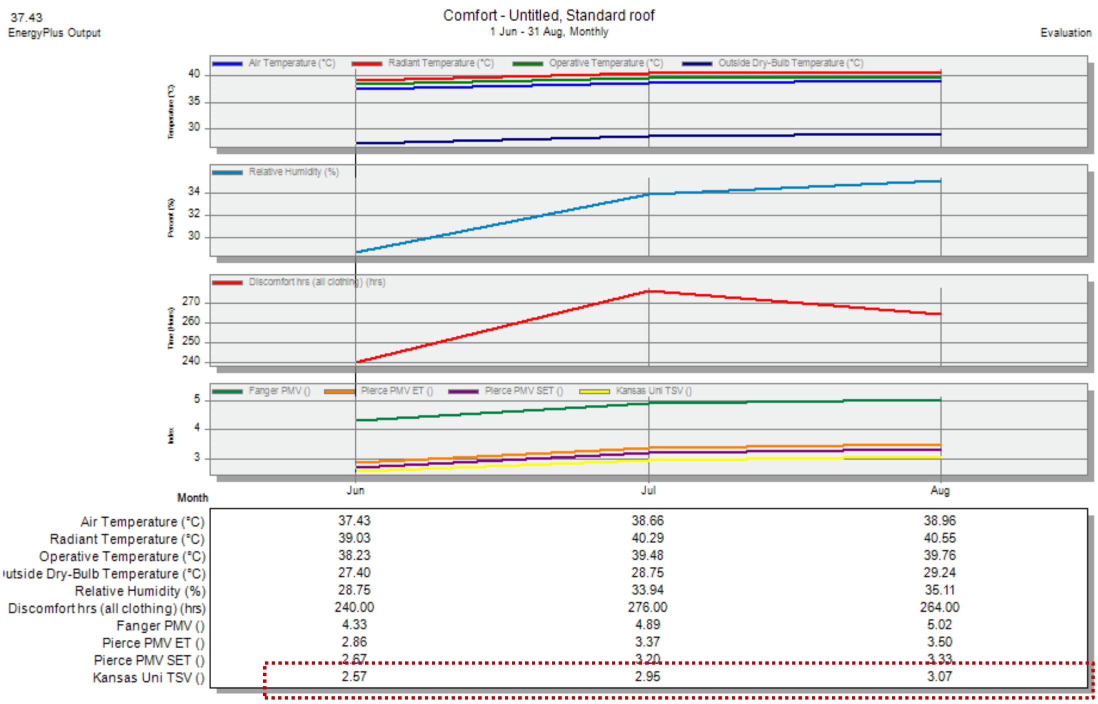
Month	Jun	Jul	Aug
Air Temperature (°C)	28.21	28.11	28.34
Radiant Temperature (°C)	30.97	31.14	31.24
Operative Temperature (°C)	29.59	29.63	29.79
utside Dry-Bulb Temperature (°C)	27.40	28.75	29.24
Relative Humidity (%)	43.59	50.24	51.37
Fanger PMV ()	1.25	1.33	1.41
Pierce PMV ET ()	1.36	1.54	1.62
Pierce PMV SET ()	1.11	1.30	1.38
Kansas Uni TSV ()	1.08	1.15	1.20



Month	Jun	Jul	Aug
Air Temperature (°C)	37.43	38.66	38.96
Radiant Temperature (°C)	39.03	40.29	40.55
Operative Temperature (°C)	38.23	39.48	39.76
›utside Dry-Bulb Temperature (°C)	27.40	28.75	29.24
Relative Humidity (%)	28.75	33.94	35.11
Discomfort hrs (all clothing) (hrs)	240.00	276.00	264.00
Fanger PMV ()	4.33	4.89	5.02
Pierce PMV ET ()	2.86	3.37	3.50
Pierce PMV SET ()	2.67	3.20	3.33
Kansas Uni TSV ()	2.57	2.95	3.07

Fig. (11): Second system Simulation - Alternative 2 (using living wall), Design Builder Screen shoot [21].

The previous graphs show the effect of green wall on air temperature, the building without green wall has 37c (operative temperature), while the building with green wall have 28c while the air temperature decrease more than 10c in air temperature when using green wall, the analysis of the second type of system also took place in the hottest months of the year in summer. The data obtained by the software shows the difference in the internal gain of the interior wall surface in the two modeled alternatives as could be observed in Graph8 and 9. The internal gain of exterior surface at June, July and August was respectively 1769 kwh, 2114 kwh and 2026 kwh in the first alternative. However, in the second alternative, shows that the temperatures of exterior surface at June, July and august were respectively 1589 kwh, 1917kwh and 1854 kwh. (see fig .10, 11).

4. RESULT AND DISCUSSION

Energy saving is a significant economic contribution brought by greenery in the cities. Green walls can improve the air quality by filtering out airborne particles in their leaves and branches as well as by absorbing gaseous pollutants through photosynthesis, Green walls can be built outside (green facade, living wall) or inside a building cover in many countries and under various weather. These structures are not limited by their viability, they are well designed and quick and easy to create. Green walls are developmental, there are several ways that can confirm a large variety of functions. Green facades can depend of the system, covering large facade section. A green facade will also bring vegetation into busy spaces.

Living walls are modified for both indoor and outdoor living condition. The difference between them is the media used to carry the plant. The structural media is the most common system, the strongest, but also the more expensive. Living walls have the same function as green facades and even more. They are called bio wall when they are used to treat polluted air; they can serve as a sound barrier. Green wall benefits consist of Environmental benefits, Economical benefits and Social Benefits.

The use of green walls was successfully adopted in Egypt to increase energy efficiency in buildings and reduce environmental impact. It also increases sound insulation and creates more pleasant indoor spaces and air quality improvements. The decreased temperature on the green facades are achieved by: a) decreased heat gain into the green wall due to incident radiations being blocked by the vegetation leaves, soil mass, and the assembly carrying the plants; b) the evaporative cooling caused by the irrigation water to the plants; c) heat resistance due to low thermal conductivity of the plants acting as heat insulators to the ambient heat gain by the walls. This technology can reduce day time indoor air temperature by 5°C for the month of July 2011, and reduce the air conditioning energy demand by up to 20%. Green wall technology contributes directly to LEED credits since it covers issues like sustainability, energy saving, air quality, and sound reduction.

5. Conclusion

The integration of vegetation on buildings and other structures façade can be of great benefit to the urban environment; it can also be used as a tool for passive thermal control of buildings. If carefully designed and maintained, green façade has the ability to moderate urban temperature, as from the research results after applying the simulation tool the main aim of the research proved that the living walls can improve the inner air quality, thermal comfort and decrease air temperature for the building, The results show temperature differences between the non living wall and living wall greening systems analyzed, up to 38.66 °C in July, while the living wall system 28.11°C in July which using living wall system decreases the air temperature by more than 10 °C.

Annual Zone Sensible Cooling while using green walls achieved 1917 khw compare to the base case. With no living walls the annual zone sensible cooling increased to 2114 khw.

Finally, the integration of greenery on building façade shows great potentials in attaining a sustainable built environment through reduction of energy efficiency, improving both indoor and outdoor air quality, in conclusion, the benefits of green façades can be categorized into two; private benefits and public benefits

Private Benefits:

• Green facade helps in improving indoor air quality: when used in the interior of buildings, the plants on the façade have the ability to filter the harmful gases from the furniture. The verdancy also decrease the air pollution like dust and other unwanted gases.

• Protecting the building structure: Mostly building facades are exposed to sun, water and other weather factors and with time most of the construction materials start to break down, due to heating and cooling which causes expansion and reduction of the materials. Green façade can protect the building façade from direct exposure to sun light.

• Energy efficiency: Green façade can work as a wind breaker during the summer; it can also reduce the air temperature through evapotranspiration process in winter. If applied internally it helps in reducing the amount of Zone Sensible cooling of the outdoor air for indoor spaces.

Public Benefits:

• Green façade helps in reducing urban heat island effect: this effect is caused by the replacement of green areas with hard surfaces, which lead to increase energy consumption, therefore green façade helps in natural cooling processes of buildings and environments and decreases air temperature in urban areas.

• Green façade helps in improving thermal comfort for outdoors: there is a lot of pollution in urban areas due to the presence of a high number of industries, vehicles that emit a lot of unwanted gases. One of the benefits of green façade is that the plants have the ability to absorb the airborne pollutants and other deposits on their leaves.

• Green façade helps in improving the appearance of a building, due to the nature of the plants used. They may have different appearance and texture which will give pleasant appearance.

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The Green Pyramid Worship House

To Be or Not to Be: The National Green Pyramid Rating System

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Abstract

Applying sustainable design and construction practices have always been faced by a lack of defined indicators and framework. This shows significant gaps in the existing body of literature. The Green Pyramid rating system (GPRS) represents a preliminary attempt to develop a national Green building rating system (GBRS) in Egypt. It has been developed by the Housing & Building National Research Center (HBRC) in 2010, yet, its application has faced many challenges owing to the lack of incentives and awareness. This study investigates the state of the art of applying the GPRS in Egypt. Moreover, it records a pilot attempt to integrate the effort of both governmental and non-governmental research institutes to disseminate green design and construction practices through a public competition. This presents a pilot attempt to provide direct results according to practitioners' feedback who belong to a variety of backgrounds; industry, research and academia. The study uses both qualitative and quantitative approaches to analyse the data gathered throughout the competition. The qualitative data indicates the nature of sustainable categories, as well as the types of adopted credits, and the compliance paths most commonly used. The quantitative approach indicates the number of obtained points compared to the total number for each category. This indicates the ease of use and suitability of the rating system to reach its sustainability targets. There are both tangible and non-tangible outcome results of such an initiative. This includes spreading sufficient sustainable knowledge and creating direct open channels between practitioners, researchers and decision makers. Moreover, a public data bank is available for all certified projects, including all attempted credits and compliance paths as well as process documentation. This provides the opportunity for gathering comprehensive background data concerning the pros and cons of using the GPRS for future use and development.

7. Introduction

The building construction industry aims at satisfying human comfort and wellbeing, yet on the other hand, it causes multiple adverse effects on the environment (Zuo and Zhao, 2014). This calls for the push for Green buildings to guarantee efficient use of resources and minimize emissions (Azhar et al., 2011). This is in addition to the need of following a standard assessment process to provide processes of; audit, analysis, goal setting, measuring and benchmarking, and finally aims at reaching results, evaluation and processes of quality and quantity assurance. This can take place in advance of the project initiation to predict impacts and proceed with the necessary decisions, or after construction to document the impacts and compare it against the design intent.

Green Building Rating Systems (GBRSs) aim at balancing the environmental, economic and social goals along the building process (Mateus and Bragança, 2011; Brandi McManus, 2010). They provide a set of sustainable guidelines and measurement metrics to cover quantitative and qualitative sustainable arguments (Kang et al., 2016). The former accounts for the following sustainable issues: energy, water, materials, resources, waste and emissions. The latter accounts for other issues such as sustainability of the site selection and indoor environmental quality in addition to other intangible sustainable criteria. Eventually, they present verified certifications to indicate buildings' sustainable performance of. There are many examples of GBRSs around the world, examples are; 1) Leadership in Energy and Environment Design (LEED) developed in the USA in 1993 and 2) Building Research Establishment Environmental Assessment Methodology (BREEAM) developed in the UK in 1990 (Jamilus et al., 2013). The use of such GBRSs has received lots of criticism related to their adaptability and applicability to other building types and contexts (Ismaeel, 2016).

The Housing and Building National Center (HBRC) in cooperation with Farouk ElBaz Centre for Sustainability and Future Studies (FECSFS) at The British University in Egypt introduced the Green Worship House Competition (GWHC). The aim of this competition is to design a worship house that complies with all the sustainable criteria in the Green Pyramid Rating System (GPRS). This comes as an initiative to expand the application of the GPRS on symbolic building types in different sites in Egypt.

Eventually, this allows the opportunity to gather comprehensive knowledge and information concerning the pros and cons of using the GPRS as a tool to guide a sustainable building process in the Egyptian context. It would also provide recommendations for development and upgrading according to practitioners' feedback.

8. Literature review

This section reviews previous national attempts of developing GBRSs and relate this to the GPRS in an attempt to understand the market mechanism in the Egyptian context.

8.1. International attempts at developing GBRSs

Building assessment rating tools aim at assessing building performance according to a number of sustainable criteria. There have been some international attempts to develop GBRSs in many countries. This has taken the form of tailoring foreign GBRSs to local contexts, or by initiating new ones according to novel approaches. The former includes examples such as Malaysia (Hamid et al., 2014; Abdul Samad & Azizan, 2010), Jordon (Ali & Al Nsairat, 2009) and Italy (Ismaeel, 2016). The latter includes examples such as CASBEE in Japan (Murakami et al., 2004), HQE in France (Vazquez et al., 2014) and DGNB in Germany (Dgnb, 2011).

8.1.1. The LEED system

The LEED rating system assesses the sustainable performance of buildings according to four levels of certification determined according to the number of obtained points; 40-49 points qualify the project for the 'Certified' level, 50-59 points for the 'Silver' level, 60-79 points for the 'Gold' level and above 80 points qualify the project for the highest 'Platinum' certification level. It is noted that this is the mostly adopted rating system in the national market. It has high market value and this attracts both international and national investments (Ismaeel, 2016). This is reflected in the increasing number of LEED registered and certified projects in Egypt. Nevertheless, it is noted that other Arab countries have precedence in adopting the LEED system as shown in Fig. (1-a). Studying the Egyptian market, it is found that the number of LEED-certified projects has reached 8 projects; 4 Gold and 4 Silver certified, while there are other 16 registered projects. The majority of these projects are registered under LEED BD+C version 3.0 as shown in Fig. (1-b) and more specifically, it is found that attempted LEED credits may change case by case according to the project's situation as shown in Fig. (1-c) (Ismaeel and Rashed, 2015).

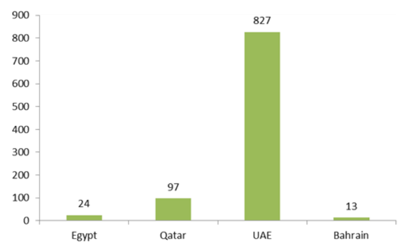

Fig. 1-a Adoption rate of LEED system in 4 Arab countries

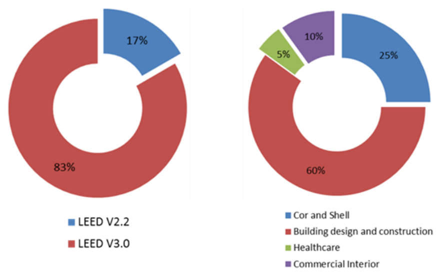

Fig. 1-b LEED rating system study in the national market

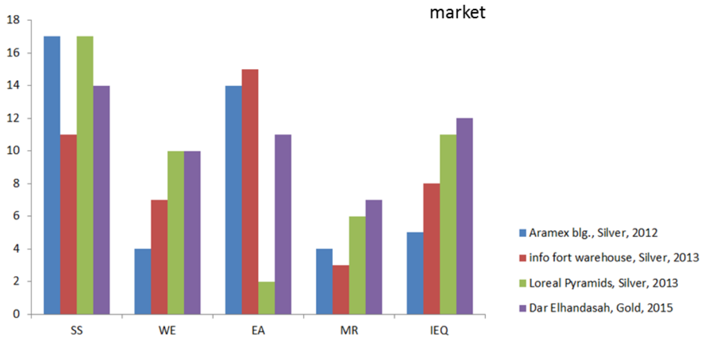

Fig. 1-c Comparing four LEED BD+C certified projects in the national market

Fig. (1): Investigating the LEED system in the Egyptian national market (Ismaeel and Rashed, 2015)

It is worth noting that the majority of LEED projects are commercial with no track record of residential projects in spite of the fact that the latter is the main reason of increased energy consumption on the local level. Also, up to the current time, the majority of investors prefer to use the LEED system despite its incapability to address many of the challenges faced in the national market or to address the peculiar local architectural and urban context (Ismaeel, 2016; S. Attia and Dabaieh, 2013). Yet, this may differ with the escalated level of difficulty of the new version which may push practitioners to look for other GBRSs alternatives especially after the LEED system has paved the way for the culture and vocabulary of the green design and construction processes. Accordingly, the local practitioners shall determine the most complying rating system to use among the other following two. This sets the responsibility on the other two national rating systems to respond to the local and international green market and to establish links with the national building industry sector (Ismaeel and Rashed, 2015).

8.2. Locally developed GBRSs

This section reviews two locally developed rating systems in the Egyptian construction market, these are; the GPRS and TARSHEED systems.

8.2.1. The GPRS

In 2009, the Egyptian Green Building Council (GBC-Egypt) was established to improve and act towards a better environment by adopting the green building approach. In April 2011, the first version of the GPRS) was introduced and the second version followed in 2017 building on the 3rd version of the LEED system. It was developed by the HBRC to adapt to the local context and achieve Egypt's vision 2030. The system presents the following levels of certification; Certified (≥30-<40), Bronze (≥40-<50), Silver (≥50-<65), Gold (≥65-<80) and Platinum (≥80) (HBRC, 2017).

Some studies discussed the application of the GPRS to assess the sustainable performance of buildings. It was also applied to an Islamic building in Old Cairo and obtained 65% of all available points which qualified it for certification (W. H. Ali, 2013), on the contrary, another study applied it on a winning Hassan Fathy prize building, and found that it failed to gain enough points for the certification (S. Attia and Dabaieh, 2013). Hence, the study along with Ammar (2012) recommended developing the structure and rating criteria to correspond with the national context; socially, environmentally and economically. Also, Ayyad and Gabr (2012) noted that some of the criteria in the GPRS do not comply with the national Egyptian building code and that the code does not refer to the rating system in any means, nor does the rating system refers to the local code although they were issued in proximate time. Hence, the study pinpointed the importance of creating a successful integration between the GPRS and the local building code to grant resilience and support the local green building initiatives in Egypt.
Sustainable design and construction practices in the GPRS are summarized in the following categories (HBRC, 2017);

1) Sustainable Sites (SS): this category discusses criteria related to the sustainable land use and site selection. This should consider the following criteria; selecting a site that has minimal ecological conservation value and environmental impact, providing proper public transportation and urban connectivity, preventing rainwater runoff through on-site collection methods and avoiding heat island effect.
2) Energy Efficiency (EE): this category discusses criteria related to energy efficiency of buildings. It includes the following criteria: improving the building envelope to reduce the energy demand, application of passive heat gain reduction, encouraging the use of renewable energy sources, selecting energy-efficient mechanical systems, selecting efficient artificial lighting systems and using energy-efficient vertical transportations.
3) Water Efficiency (WE): this category discusses criteria related to the efficient use of water in buildings. This includes the following criteria; developing and implementing a

comprehensive water savings strategy to reduce potable water uses by employing reused greywater, proper design of efficient irrigation system and proper selection of landscape elements with minimum irrigation requirements and reducing wastewater generation.

4) Materials and Resources (MR): this category aims at minimizing the negative environmental impact of using building materials with high environmental impact. It discusses criteria associated with material extraction, processing, manufacturing and distribution. This promotes the following criteria: avoiding the use of hazardous or toxic materials, using materials with high renewable content and using local materials to reduce transportation needs.
5) Indoor Environmental Quality (IEQ): this category discusses criteria associated with occupants' comfort such as ventilation and air quality, tobacco smoke control, indoor air delivery monitoring, thermal comfort, lighting quality, and acoustic performance. It includes the following criteria: enhancing ventilation performance, smoking control as well as providing thermal, visual and acoustic comfort.
6) Management Protocols (MP): this category discusses criteria related to sustainable building management that would mitigate its environmental impacts and ensure its sustainability. This includes the following criteria; creating a Building Information Model for a building to meet all sustainability goals, carrying life cycle environmental assessment of building materials and systems, providing energy and water use sub-metering systems to monitor the actual consumption of energy and water and detect leakages, promoting and educating users about the sustainable initiatives through providing a building user guide and providing facilities for the collection, storage and proper removal of the generated solid waste during building's operation.
7) Innovation and Added Value (IN): this category presents the opportunity to improve buildings' environmental conditions. Bonus points are awarded for projects that exceed the GPRS credits' requirements and demonstrate an added environmental value while considering particular building types and contexts.

8.2.2. TARSHEED

This is another recently developed national rating system by Egypt Green Building Council to adopt the efficient use of resources approach for achieving sustainable development. It is based on the Excellence in Design for Greater efficiencies (EDGE) system (EGC, 2015). This enables it to correspond to the local climatic conditions and different building types and operative systems. Its approach and assessment method focuses on three key sustainable categories, and this differs from the LEED and other rating systems in this regards. This includes energy efficiency, efficient water use as well as maintaining sustainable habitat. This approach aims at overcoming many challenges facing the green building industry and the desire to direct the national market towards the first step of reducing consumption through three levels of efficiency; 20%, 30% and 40% which also corresponds to the certification levels; TARSHEED 20, TARSHEED 30 and TARSHEED 40 (Ismaeel and Rashed, 2015).

8.2.3. Comparing the three rating systems in terms of performance indicators

The comparison presented in Fig. (2) shows the similarity of the LEED and GPRS and the difference in TARSHEED system in terms of their approach and criteria of assessment (Ismaeel and Rashed, 2015).

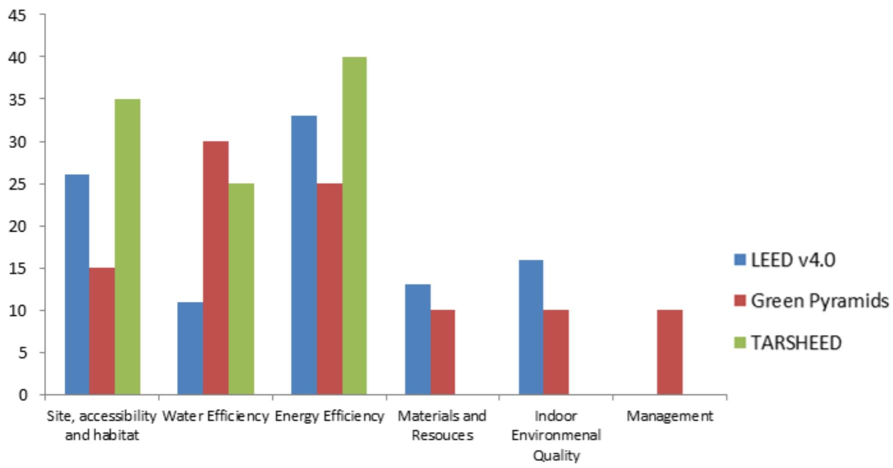

Fig. (2): comparing the three rating systems; LEED, GPRS and TARSHEED (Ismaeel and Rashed, 2015)

9. Method

This study adopts a qualitative and quantitative approach to investigate this pilot attempt at disseminating the GPRS's sustainable guidelines and assessment criteria among practitioners in Egypt.

9.1. The competition description

The GWHC was announced in August 2017 through a public seminar at the HBRC on 21 November 2017 and was made available online through the following link http://www.bue.edu.eg/index.php/competitions/green-worship-house-competition. Several workshops were held in public research and academic institutions to promote for the competition. The call was open for a wide variety of participants; individuals and groups, professionals, academics and students of various educational backgrounds. Twenty-five groups participated in the competition, 17 groups were finally able to meet the submission deadline with a total number of 130 participants as indicated in Table (1) and Fig. (3).

Table 2: Participants Statistics at the GPRS competition

Occupation	Number
Teaching Assistants	4
Lecturers	16
Architects	24
Students	84
Others	2
Total	130

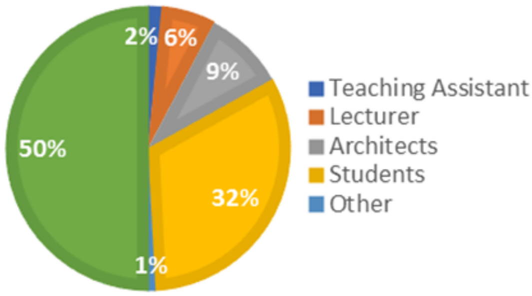

Fig. (3): Analysing participants' backgrounds

The philosophy of the competition and the reason for choosing this type of building is to appreciate its central role within societies; where the establishments of a building of worship express local and ecological identities.

The diversity in space and volume of the presented work is granted to all participants depending case by case and following the guidelines of the GPRS for sustainable site selection. This diversity is suitable for various design proposals to familiarize the public with the concept of green buildings and promote the culture of sustainability. Accordingly, the proposed project should consider the GPRS's guidelines along the project's lifecycle, including the phases of; design, construction, control, and management as well as sustainable innovation and creativity.

9.2. The requirements

The requirements are divided into the following components;

1) 40% of the marks are awarded for the green building report expressing design team's self-evaluation and checklist compliance with the criteria of the GPRS.
2) 30% of the marks are awarded for the design project; plans, elevations and sections.
3) 20% of the marks are awarded for the process documentation; explaining the concept behind the design approach as well as any associated challenges.
4) 10% of the marks are awarded for a seven minutes presentation using video or powerpoint show.

9.3. The assessment criteria

The assessment method is not based on the architectural design but depends on the level of understanding and achievement of the GPRS sustainable criteria.

The green building report is the main document of the competition and is carried out by the contestant to evaluate its proposal referring to the GPRS's assessment criteria. Accordingly, the level of the project is determined; platinum, gold, silver, bronze or certified, and for every level of evaluation award only the best of the level has received the prize.

The design projects have been evaluated according to the design principles of function, aesthetics and economic considerations.

The process documentation indicates the main reasons for applying for the competition and applying the GPRS as well as the challenges undertaken by participants to apply its principles in the Egyptian context. This traces the building process from early conceptual phases till design submittals, including; site selection, deciding on building type and scale, developing teamwork skills and coordination as well as applying advanced management techniques to guarantee optimum time and cost control.

The presentation is assessed using a voting system which evaluates the contest's vision for achieving the goal of promoting the culture of sustainability and achieving Egypt's 2030 vision in the presented work.

The assessment jury has been composed of a team of the HBRC and the FECSFS in addition to external respected experts. Hence, the assessment team guarantees developing robust results that truly participate towards pushing the national green building construction industry for the next decade.

9.4. The process

The process starts with the data gathering including the qualitative and quantitative criteria according to the requirements of the five aforementioned GPRS categories.

The next step includes the collection and manipulation of data to produce meaningful information about the sustainable categories and credits attempted. The unit of measurement and the baseline case is determined for each credit. The obtained data can be analyzed using Microsoft Excel and validated using the Statistical Package for the Social Sciences (SPSS) software package to provide robust results to the developers of the rating system. This determines the adoption rate of credits which indicates those which are more difficult to obtain than others owing to the complexity of credits' requirements or financial reasons. A similar study was conducted by Lavy & Fernández-Solis (2009) studying the LEED system using self-administered questionnaires and interviews. The study concluded that the adoption rate of credits increases with reduced initial capital cost and simpler credits' requirements.

A final step includes a process of evaluating the supporting documents for each credit to determine the certification level of each project referring to the presented documents, calculations and simulations. After participants' self-evaluation is assessed, it is compared to the final award to be able to define any discrepancies in understanding credits' requirements, as well as determining the adoption rate of sustainable categories and credits.

The outcome results of the competition provide significant indications in terms of the following criteria;

- Exploring the suitability of the GPRS tool to evaluate sustainable building performance in Egypt.
- Evaluating the adaptability of the tool by comparing the criteria and benchmark to the Egyptian market and building construction practice.

- Determining the suitability and adaptability of the tool to the worship house project through practical projects application and obtaining experts' reviews.

10. Results and discussion

This study looked into the possibilities and potentials of the GPRS through the study of the GWHC to present a set of outcome results and recommendations for development. The results of this initiative can be both physical and non-physical. The former can be spotted in more dissemination of the sustainable knowledge among practitioners and decision makers through workshops and seminars. This also leads to more interaction and creating direct open channels between researchers and practitioners. The later can be spotted in the direct outcome of the competition; these can be categorized into three main components as shown in Fig. (4); reports, projects and process documentation. It is noted that the report holds the maximum score weight in the assessment criteria (40%) to stress the importance of the green assessment process. This develops the first national platform of data bank with these three main components for further study and analysis; data bank of all attempted credits, the first archive of nationally certified projects under the GPRS and process documentation which summarizes the potentials and challenges faced by each design group through their attempt to design a green-certified project.

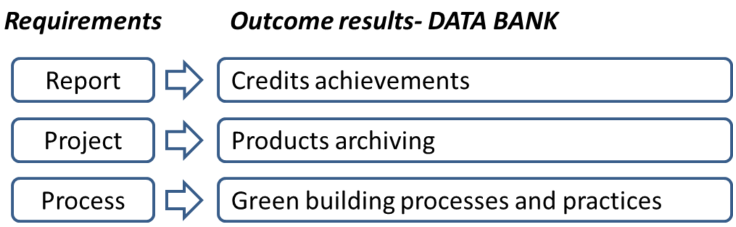

Fig. (4): The GWHC outcome

The final result of the competition shows that the majority of the grades were obtained through the architectural design product and project presentation, while the competing teams were not able to gain more scoring at the GPRS report or at the process documentation. This indicates that more workshops and better information dissemination need to be held to guarantee better self-evaluation, preparing the GPRS report and conducting efficient process monitoring, documentation and follow up procedure.

10.1. Outcome (1): Credits' achievement

The results in Fig (5) show that the adoption rate of categories varies; it is highest in WE followed by MR and SS, then EE, EQ, MP and least in IN categories. It is notable that SS.01: Site Selection has the highest adoption rate for the SS category. EE.02: Passive Heat Gain Reduction, EE.03: Renewable Energy Sources and EE.05: Efficient Artificial Lighting Systems has the highest adoption rate in EE category. The adoption rate of all WE credits is very similar. MR.01: Renewable Materials and Materials Manufactured Using Renewable Energy and MR.03: Reduction of Overall Material Use has the highest adoption rate for MR category. All EQ credits have high adoption rate except for EQ.03: Thermal Comfort. Moreover, all MP and IN credits have very low adoption rate, particularly IN.02 Exceeding Benchmarks. On the contrary, the average percentage error calculation is greatest in the MP category, followed by the WE then the EE categories and the least in the MR followed by the SS categories as shown in Fig. (6). Also, in average practitioners misevaluated their report self-evaluation score weighting with a percentage of 40% as shown in Fig (7).

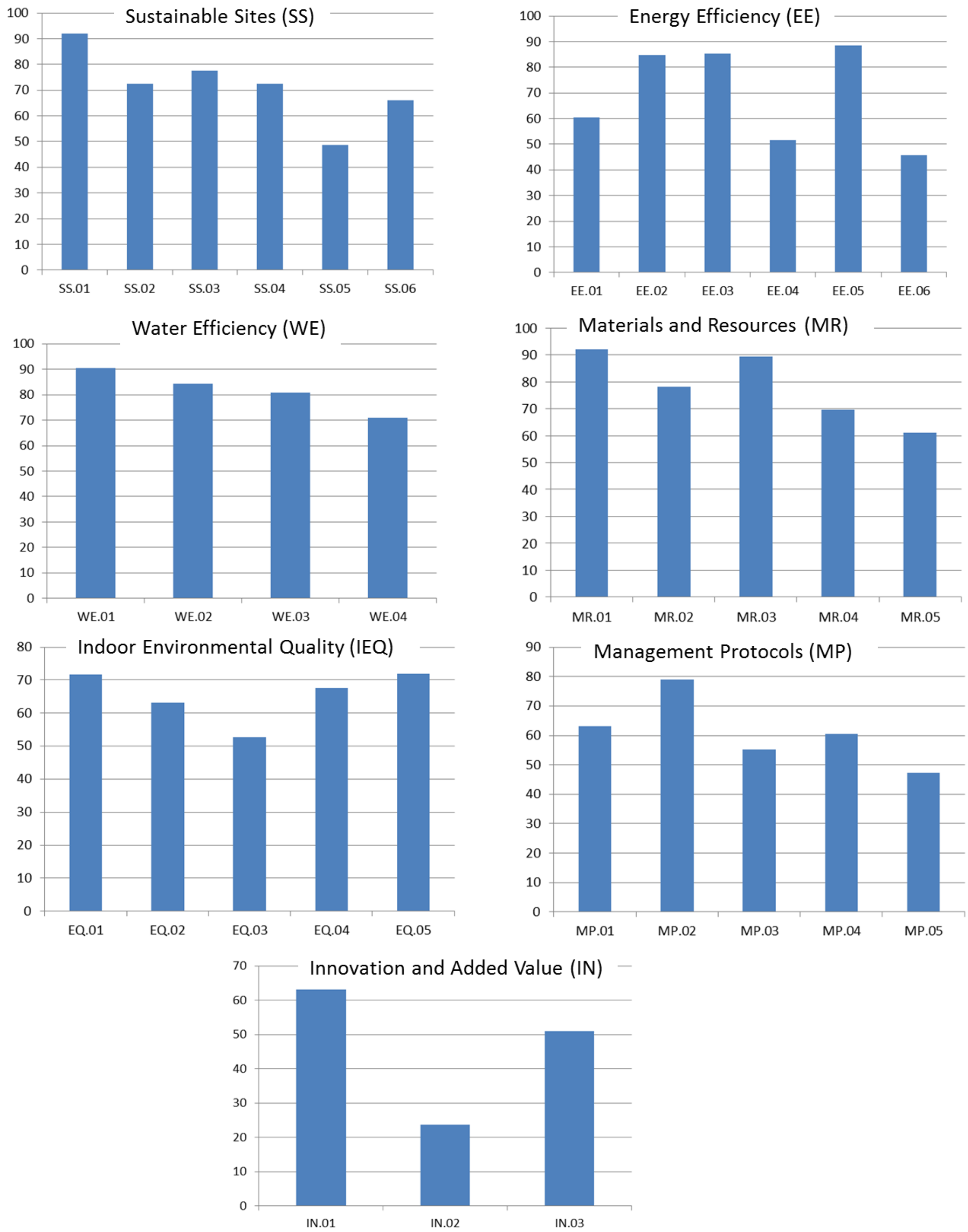

Fig. (5): Breakdown of credits’ rate of adoption

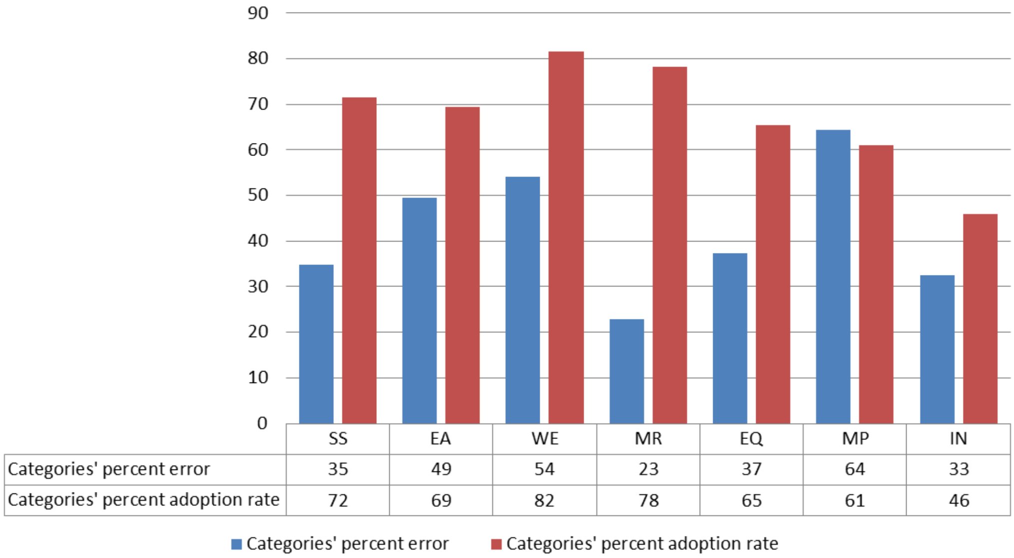

Fig. (6): Comparing the average adoption rate and percentage error for the GPRS's categories

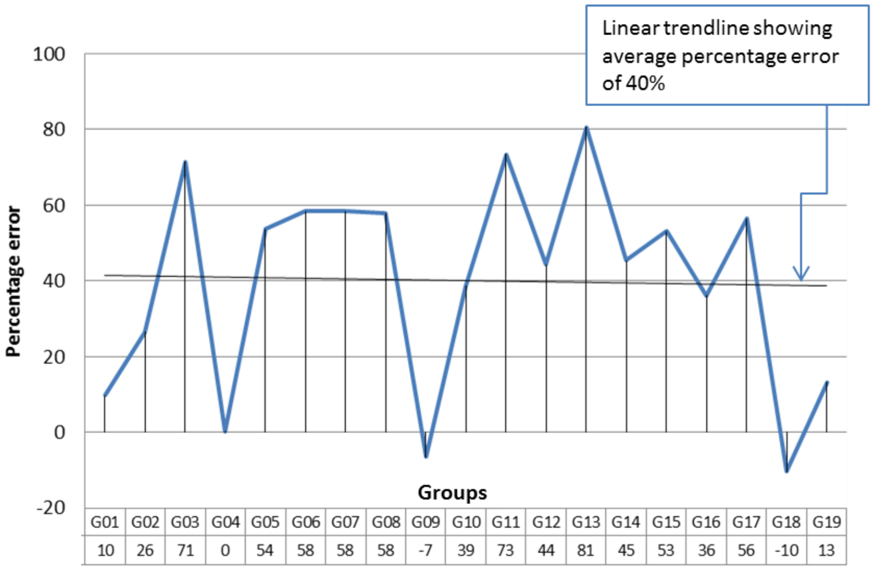

Fig. (7): The percentage error for groups' total marks showing their linear trendline

10.2. Outcome (2): Products' achievement

As for the winning prizes, there were one platinum, 2 Gold and 1 Silver prizes. The winning Platinum project prize of GWHC05 is shown in Fig. (8) and (9).

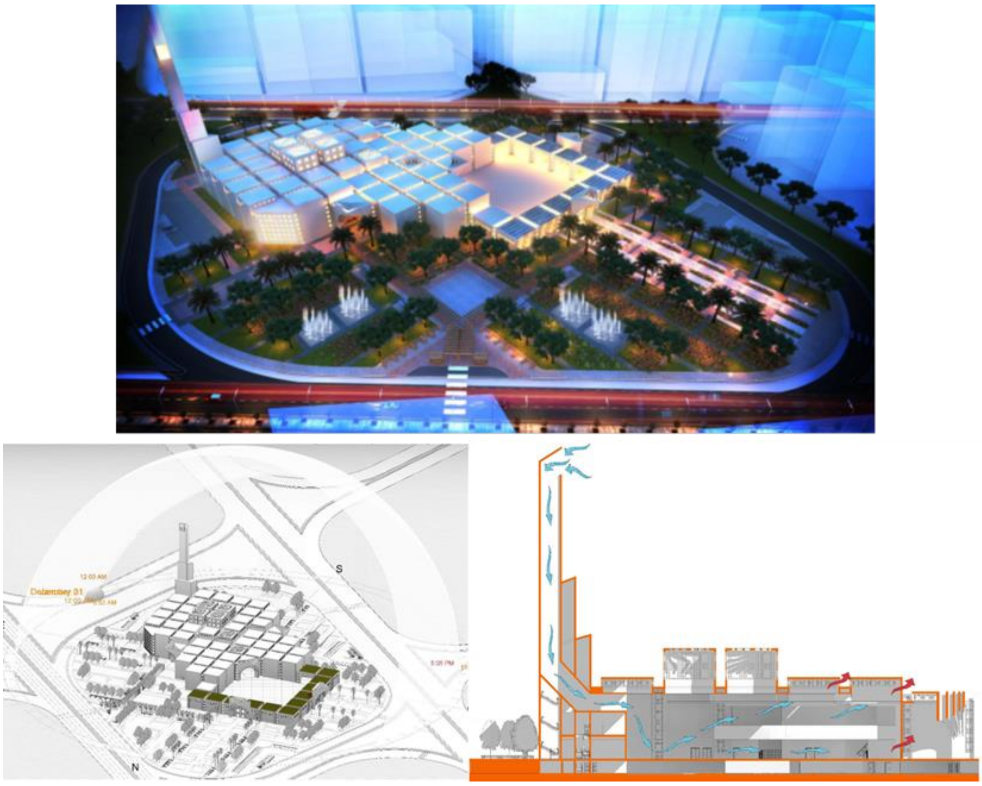

Fig. (8): Different studies for the winning platinum project

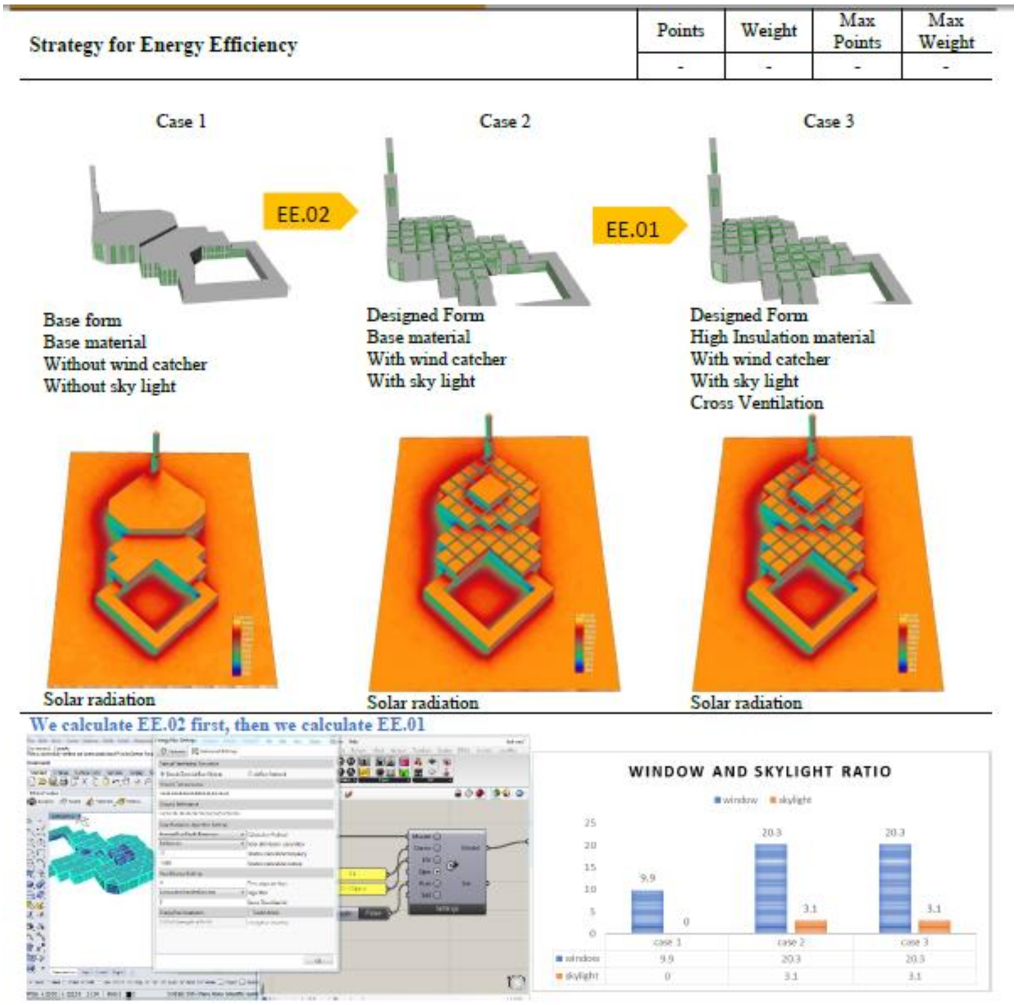

Fig. (9): a part of the energy simulation studies for the winning project

10.3. Outcome (3): Archiving green building processes and practices

It is noted that the credits which require measuring and calculating energy consumption and water use have lower adoption rate due to the lack of practitioners' knowledge and experience. Performing the Life Cycle Assessment of green materials had a lower adoption rate as well. Construction credits were hypothetically assessed according to the plans set by each participating group. This includes waste management of recycled, reused and landfilled waste with a clear description of the type of waste; solid, liquid or gaseous, in addition to its contamination level. Also, practitioners pinpointed the following challenges during their attempt to carry a sustainable design process using the GPRS;

- The governing point scoring mechanism structure using the GPRS.
- It was challenging to achieve a balance between the quantitative and qualitative assessment criteria.
- The competition revealed significant variations in the level of understanding of the GPRS criteria among practitioners and students. This made it challenging for some participants to follow the assessment and benchmarking method which require calculations and simulations. This indicated insufficient knowledge and expertise to perform the required energy simulations and lack of green certified materials' specifications in the local market.
- The guideline criteria of the GPRS lack considerations for the tangible and intangible benefits & values of special building types that carry religious and spiritual values.
- The guideline criteria of the GPRS lack considerations for the regionally specific and local issues compared to the traditional building process.
- More time has been required to follow the GPRS's principles and conduct the required measurement criteria. This indicates the urgent need to develop various means of promoting sufficient knowledge and information concerning green buildings and the culture of sustainability.

11. Conclusion and directions for future research

Sustainable design and construction process must follow a comprehensive approach and this is considered an enormously complex process. GBRSs such as the GPRS are considered recently developed tools to streamline the sustainable building process. This is in addition to providing guidelines, assessment and benchmarking methods to support a long-term decision-making process, yet it cannot be considered comprehensive. This necessitates additional effort from all team members to develop the required knowledge and awareness, overcome challenges related to its application and create standard criteria for assessing building performance in the national market. This is maximised by following an early integrated process; involving all interested parties, while clearly defining sustainable goals, required information and the needed expertise. This requires consideration for the whole built fabric as well as individual buildings.

This competition is a self-evaluation assessment criteria using the GPRS checklist and scoring criteria. This creates two-way feedback loops between practitioners representing the industry side and the HBRC which represents the research and development side. The results pinpoint the drawbacks in applying the GPRS in the national market. Recommendations follow Ismaeel and Rashed (2015) to provide insights for developing the GPRS assessment criteria according to participants' feedback and set the base for promoting green building knowledge and awareness. The GPRS should also integrate with the potentials and limitations of the local market and open channels and feedback loops with the industry. This includes addressing local building codes and regulations, considering buildings types in the local context as well as considering the local building materials and systems. This can be through workshops, questionnaires and interviews with representatives of the industry side in addition to the better development of the user interface to streamline the process of documentation and simulation. Further steps may include developing a public database of all manufacturers and suppliers of green materials and products and promote green materials certifications. This is in addition to developing local benchmarking criteria according to the local context.

Moreover, a development plan should be set for the GPRS, this may benefit from the following studies;

- Conducting regular questionnaires and interviews with practitioners and decision makers.
- Using the Analytical Hierarchy Process as suggested by Ali & Al Nsairat (2009) to develop GBRS for developing countries.
- Using the Simos' procedure as suggested by Marzouk et al. (2014) to develop a GBRS for special types of buildings and large construction projects.
- Developing the system's user interface to streamline the process of design and documentation (Neama 2012; Attia et al. 2011).
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TOWARDS A FOSSIL FREE ENERGY PRODUCTION USING GIS MULTI-CRITERIA DECISION-MAKING SUPPORT TOOL

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Keywords: GIS, Sinai, Overlay Analysis, MCDM, Fossil Free Energy

Abstract

Egypt's Sustainable Development Strategy: Vision 2030 calls for renewable energy plans and the adoption of a sustainable development approach. Given the government's gradual removal of energy subsidies for local citizens and the current energy crises, the study in hand aims to detect potential investment zones for free fossil fuel energy production. Site analysis for renewable energy allocation using GIS to identify potential capability to locate a renewable energy source was applied in the Sinai Peninsula in Egypt. The study used an accumulative co-relation matrix between different development sectors, Sinai's geographical location and promising future investment scenarios. A set of data analysis process was developed to examine potentials and constraints. The analysis revealed that 36% of the area is suitable for the development of solar farms and a further 4% for wind farms. These findings could help decision makers to fill the gap between the country's future energy needs and its available natural sources. Applying this methodology across the different areas offering similar potential in Egypt would help to identify more likely locations for renewable energy production. Wider replication of the method could also point to the significant contribution that different zones in Egypt, and even in other zones within the Middle East region, could make towards a more sustainable future.

1. Introduction

Using non-renewable fossil fuel for energy production has a direct negative impact on the environment as well as indirect health impacts on human beings. Renewable energy is becoming one of the more viable solutions for the majority of fuel related environmental problems faced today. In several studies it has been proved that total emissions exponentially decrease with the setting up of renewable energy systems (Khoshnevis Yazdi and Shakouri, 2018). Promoting the use of renewable energy carries several environmental, economic and social benefits. Environmental benefits are evident in the reduction of environmental pollution of air, water, etc. (Akella et al., 2009). Such actions increase self-reliance and regional/national energy independence in addition to promoting more technological developments, particularly in energy development and maintenance services. Using renewable energy is, therefore, linked to sustainable development (Dincer, 2000). The growing significance of sustainable development has brought with it considerable growth in renewable energy research and applications. Additional benefits include significant work opportunities, the possibility to diversify the economy, and the benefits that flow from the cost effectiveness of some renewable energy applications. This leads to money saved from reduced fuel use and electricity bills, diversification and maintaining security for supply sources of energy, and encouraging the deregulation of energy markets; also, support electrification in off grid areas particularly in developing countries (Dabaieh et al., 2016). The International Renewable Energy Agency (IRENA, 2015) has declared that the installed global renewable energy capacity had reached 1,829 GW by 2014. According to Watson and Hudson (2015), wind and solar photovoltaic (PV) are considered among the fastest growing technologies in electricity generation.

Egypt's Sustainable Development Strategy: Vision 2030 aims to maximize the use of domestic energy resources and develop the capacity of its energy sector in both the Eastern and Western deserts of Egypt as well as in the Sinai Peninsula. This would in turn adjust domestic and international developments in the fields of energy and innovation; and promote the use of renewable energy. The fact of having almost 96% of the country as undeveloped desert makes the Peninsula an excellent potential location for the deployment of such renewable energy resources. As identified by the Egyptian Electric Utility and Consumer Protection Regulatory Agency, solar and wind generation are considered the two main sources for renewable energy in Egypt. The Agency observes that two-thirds of the geographical desert area within the country has more than 6.4 kWh/m^2/day of solar energy intensity. Accordingly, Egypt could receive up to 3,000 kWh/ m^2/year, which would represent one of the country's main future development mega project goals. The potential for wind generation in many areas such as the Red Sea is also significant as wind speed can achieve as much as 10 m/sec. This led the New and Renewable Energy Authority (NREA) to develop different wind energy projects with a total installed capacity of 550 MW in Zafarana and Hurghada in 2010. There are also current projects under construction with a capacity of 1120 MW (Egyptian Electric Utility, 2016). Additionally, some existing off grid resorts and tourist villages by the Red Sea and in the Sinai region operate using mainly Independent Power Producers (IPPs), which indicates considerable potential for wider development (Georgy & Soliman 2007).

Referring to the likelihood that sooner or later the Egyptian government will depend mainly on renewable energies if it is to benefit from clean and fossil free energy sources, this research study puts forward a pilot methodology that can be applicable throughout Egypt to locate suitable places for renewable energy production. Sinai was chosen as a pilot case for this study methodology application (see figure 1). The techniques to choose optimum locations for the generation of solar and wind energy were applied throughout to create criteria to build up a site analysis system using GIS (the Geographic Information System). These criteria were generated with the help of a matrix library of queries in GIS to locate the most efficient locations for wind and solar generation. Other spatial resources and constraints were also taken into consideration. Hence, this study will focus on the aspects of improving the decision-making process, and on the geographical management of renewable energy production, as a part of larger scale of sustainable urban development. The results and findings for potential zones for both solar and wind energy production will be discussed together with recommendations for further and wider applications.

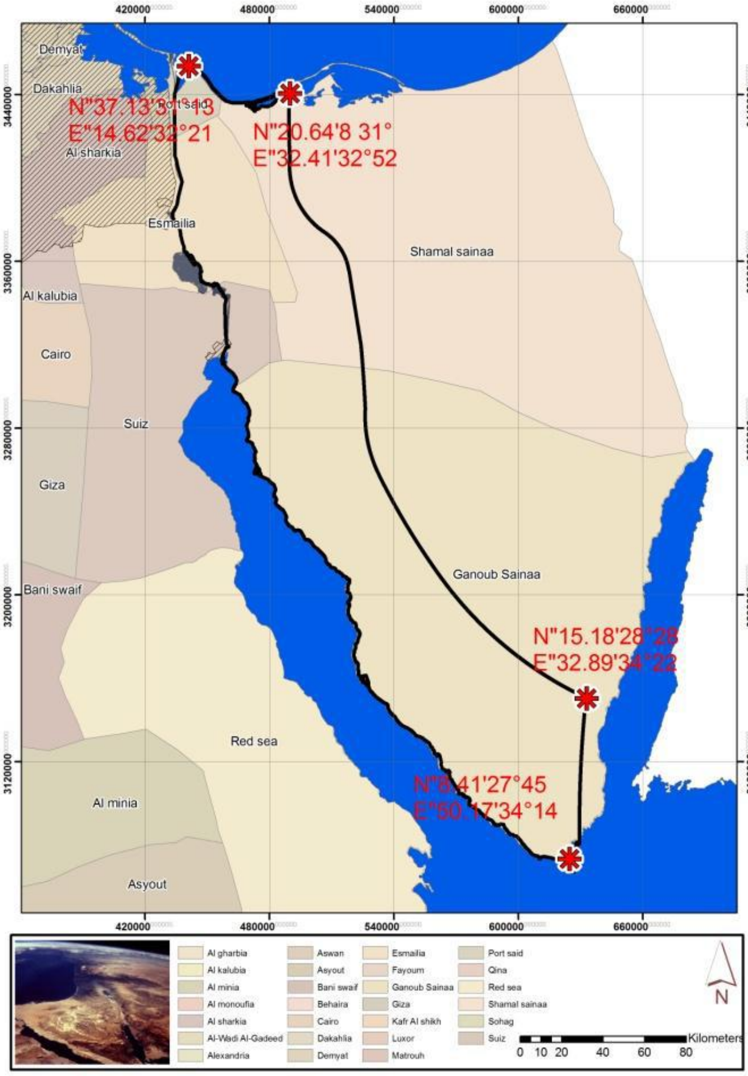

Figure 1: Sinai Peninsula showing the restrictions on development in Sector (A) laid down by the Camp David Agreement in 1978.

1.1 GIS SCIENCE, SPATIAL ANALYSIS, & MULTI-CRITERIA DESCISION MAKING.

The Geographical Information System (GIS) and Multi-Criteria Decision Making (MCDM) programs are the two main tools used to resolve various geospatial problems, including the allocation of sites for wind and solar farms. A geographic information system is a computer application supplied by the ESRI (Environmental Systems Research Institute, based in California). GIS can be integrated with economic and strategic value studies for deeper types of analysis. According to ESRI, the benefits of using GIS include the following: cost savings as the result of achieving greater efficiency, a better decision-making process, improved communication activity, and better archiving, record keeping, and geographical management (ESRI, 1998). The term Multiple Criteria Decision-Making allows systematic analysis of complex, usually conflicting criteria. The development of this science increases in importance with the advance of computer technology, which has generated a huge amount of data and information (Xu, 2012). Due to the complementary nature of both tools, it has been possible to integrate them into different studies to create a key new tool in sustainable energy studies (Sánchez-Lozano et al., 2013; Pohekar and Ramachandran, 2004).

1.2. APPLICATIONS USING GIS FOR MCDM

The use of GIS for multi-criteria decision analysis can be traced back to 1900 according to Malczewski (2006). The system on its own has been used for many research purposes and applications but Meng and Malczewski (2015) have developed a GIS based Multi-Criteria Decision-Making approach which they applied to evaluate ease of access to Canada’s public parks in Calgary, Alberta using a combination of both the weighted linear method and the entropy weighting method. Temiz and Tecim (2009) used GIS and MCDM to highlight the areas capable of coping with forest fires, based on their proximity to water resources, streams and settlement areas. They used Boolean Analysis and Analytic Hierarchy Process (AHP) for the studied area, and the results were visualized on a digital map. A susceptibility analysis carried by Dragicevic, Lai and Balram (2015) was conducted to identify areas at risk of landslide in Canada’s Metro Vancouver region, British Columbia. Their study used an integration of both multi-scale analysis and fuzzy sets with GIS-based multi-criteria evaluation (MCE).

More specifically to the focus of this research, Watson and Hudson (2015) discussed renewable energy mainly solar and wind as a key to minimizing the adverse environmental impact of development in England using GIS and MCDM and incorporating an analytical hierarchy process (AHP) involving expert stakeholders. Their study included an assessment of the proposed suitability model through a sensitivity analysis. Nguyen et al. (2015) developed the land suitability analysis using GIS-based multi-criteria subdivided into four different stages. Their analysis began with the selection of land characteristics, followed by a design of criteria to evaluate and score their selection. These criteria form partial performance indices for their feasibility analysis of a location’s agro-ecological suitability, environmental impact and socio-economic aspects. The Nguyen et al. study concludes by determining the overall land suitability class of the proposed land use according to the classification of the performance indices of the land’s aptitude, impact, and feasibility. A number of research papers have used the GIS-based MCDA approach for site selection and a suitability assessment of renewable energy production.

For solar energy production, Sánchez-Lozano et al. (2013) based their study on the combination of GIS and MCDM methods to evaluate the optimal location and placing of photovoltaic solar power plants in the area of Cartagena, Spain. Wanderer and Herle (2015) carried out a similar study using a web-based Spatial Decision Support System based on MCDA. These locations were used as input data to set the development scenario for a subsequent study using integrated Environmental Impact Assessment. The criteria identified in GIS-based MCDA involved technical aspects, including direct normal irradiation (DNI), slope, and population density as well as economic aspects including proximity to a street network, the electric grid, and land cover. In the Karapinar region of Konya, in Turkey, Uyan, (2013) used GIS and the analytic hierarchy process (AHP) for the site selection of solar farms.

The GIS-based MCDA approach has also been used to assess the suitability of sites for wind farms (Atici et al. 2015). Grassi et al. (2014) performed a GIS based assessment of the wake effect of onshore wind farms on energy production. Sliz-Szkliniarz and Vogt (2011) presented a GIS-based approach to evaluate the potential for wind energy in a study area in Poland. Ramachandra and Shruthi (2005) discussed GIS mapping for wind energy potential in Karnataka in India. Other studies used the same method for hybrid forms of renewable energy production (Watson & Hudson 2015). Yeo and Yee (2014) used an integration of an environment and energy geographical information system (E-GIS) database (DB) and an Artificial Neural Network (ANN) to propose a site location-planning model applicable to environmentally friendly urban energy supply plants. Aydin et al. (2013) have also used a research methodology based on using GIS-based site selection for hybrid renewable energy production systems. Their study assessed the environmental and economic aspects of viable locations through a fuzzy decision-making procedure using an algorithm based on ordered weighted averaging for multiple objectives. Moreover, Yue and Yang (2007) integrated cost and returns on investments analyses, as well as legal incentives for potential evaluation to develop a decision support system with the aid of a geographic information system (GIS). The research carried by Greene et al. (2010) targeted investing in MCDA to provide background for GIS users, analysts and researchers to allow for more accessibility to decision makers.

This review of earlier studies indicates that the current research arena for using a GIS system in the urban development field is by integrating it with various types of multi-criteria decision-making analysis such as the Analytic Hierarchy Process (AHP) and fuzzy logic. The research methods adopted in these research studies start by defining the study area and use data input in the form of renewable energy potentials and constraints with a predefined ordered weighted average. Some studies take into consideration the weighted average of an environmental qualification of alternative inputs; others include economically feasible locations as well. Thereafter, the data output from overlay analysis are standardized using fuzzy logic or analysed using the AHP process. This allows for multi criteria analysis using the GIS system to determine optimum spatial locations for feasible renewable energy production.

1.3. THE USE OF GIS IN THE MIDDLE EAST & NORTH AFRICA

There has been valuable research in the Middle East and North Africa. Broesamle et al. (2001) discussed the assessment of the production of solar electricity in North Africa based on the integration of satellite data and GIS. In 2010, a research project for wind farm analysis integrated with GIS site selection support in Egypt was funded by the STDF (STDF, 2011). Zoghi et al. (2015) used the fuzzy logic model and weighted linear combination method to optimize the solar site selection process in arid and semi-arid regions, illustrated by a case study of Isfahan, in Iran. Tsikalakiset al. (2011) reviewed the best examples of the application of solar electricity resources in particular counties in the Middle East and North Africa (MENA) region. Mustafa and Mohamed (2012) analysed the integration of photo voltaic panels on building rooftops in the Dokki District in Cairo, Egypt, using a GIS application. Effat (2013) used the SRTM and Multi Criteria Analysis to discuss the site selection of solar energy farms in the Ismailia Governorate in Egypt. Later, she used an integration of both Remote Sensing and the Geographic Information System to discuss the spatial modelling of possible zones for wind farms in the Red Sea area, Egypt (Effat 2014). Mentis et al. (2015) have used a GIS-based approach to assess the technical aspects of the potential of wind energy in Africa.

This review of the literature reveals a knowledge gap that this research attempts to fill, by exploring the potential for renewable energy in Egypt. Accordingly, this study aims to identify renewable energy sources in the Sinai Peninsula as a case application, with a view to building up a site analysis system for renewable energy allocation; it will use GIS with the help of an accumulative co-relation matrix between different development sectors and areas of potential and constraints.

2. METHODOLOGY

This research adopts a multi strategy mixed approach design, using GIS as a multi-criteria decision making tool. The selected methods comprise a set of organised categories of substantial amounts of qualitative and quantitative data. Sinai was chosen as the location for the application of the methodology used in this study. A set of data analysis processes developed after Robson (2011) in three phases was applied as follows:

1. Data reduction: where we summarized a set of quantitative (maps, statistics) and qualitative data (information on the potential and constraints in the study area) using statistical descriptive, and thematic analysis methods.

2. Data display design: where we used maps, charts, tables and matrices for regional, climate, topographic, landscape, geological, hydrological, eco-system, habitats, demographic, socio-economic, infra-structure, services, and land-use datasets, imported in a single geodatabase.

3. Data overlay: where maps were overlaid inside the geodatabase in a one feature class to illustrate the multi criteria decision making query phase.

2.1 CASE STUDY BACKGROUND

Sinai is considered the heart of the world due to its central location between Africa, Asia, and Europe; it is distinguished by the presence of the Suez Canal, that is generally accepted as the shortest link between these continents. This is why this study has chosen Sinai as the pilot area in which to apply the research methodology. Due to political and governmental constraints, only one sector of Sinai is applicable for development: this is the triangular Peninsula of about 60,000 km^2 located at 29.5000° N, 34.0000° E (figure 2). To the north, Sinai overlooks the Mediterranean; to the south, it overlooks the Red Sea. It is the only part of Egypt located in Asia. Accordingly, this gives Sinai the opportunity to be the central focal point between the three continents. Administratively Sinai Peninsula is divided into two governorates (North Sinai and South Sinai). Its total population is about 500,000 inhabitants (CAMPAS, 2016). The area is rich in natural resources, such as manganese, marble, steel, white sand, clay, etc. The average solar irradiation for the region ranges between 6 KWh/m^2/day to 6.4 KWh/m^2/day; the average wind speed ranges between 6-8 m/s with slope greater than 11.3 degrees. Hence, the area has great potential for renewable energy production, and particularly solar and wind, compared to other regions in Egypt.

Figure 2: Sinai map retrieved from arc info 10.1

According to Egypt’s Vision 2030 (see above), forward looking planning should henceforth adopt a sustainable development approach. The Sinai area is of significant importance nationally, regionally and internationally because of the spine of the Suez Canal bisecting the area, which is considered to be the most important linear development across Africa and Asia. It is also the shortest artificial sea-level waterway in Egypt, connecting the Mediterranean and Red seas. The existence of current national development plans for the area, such as the New Suez Canal project, is expected to create an urban flux for the whole nation. This allows this study to be considered within the Egyptian national plan because the strategic location of Sinai offers, additionally, the potential for the export of renewable energy.

2.2 THE MULTI-STRATEGY DESIGN MIXED APPROACH

This study used ArcMap 10.1 to process and analyse the qualitative and quantitative data. The ArcMap system is capable of applying the large number of orders that are associated with MCDM. The data used for this study were categorised into potentials and constraints for renewable energy production, according to the suitability of the location. An Excel matrix was adopted to create the quires to be used in GIS to determine the land areas suitable for wind and solar farm development. This coloration matrix uses binary code values to define the suitability for renewable energy production (wind, solar) according to the contextual conditions and design specifications. The binary codes indicate the suitability of land for renewable energy production (Code=1) or not (Code=0). The matrix is designed to be flexible in order to allow the addition of various activity types and design constraints.

2.2.1. DATA ANALYSIS PROCESS

The practical part of this study began by collecting all the qualitative and quantitative data for the area of study through three consequent phases as follows:

Data reduction

The data was inserted into the Arch GIS according to the (WGS 1984 UTM Zone 36N) coordinate system. It was exported to the GIS in a single geodatabase that was systematically and logically divided into structured datasets, each containing GIS feature classes. The database was populated either by ‘Shapefile Conversion’ or ‘CAD’ into their corresponding datasets, or by vectoring the maps using Arc map editing; finally the required fields were added and the data populated.

Data display design

The database consists of a single Geodatabase that contains eleven feature datasets (see figure 3), which are categorized into the following categories: region, climate, topography & landscape, geology, hydrology, eco-system & habitats, demography, socio-economic, infra-structure, services, and land-use. Each dataset contains a number of feature classes that hold the same theme as the dataset.

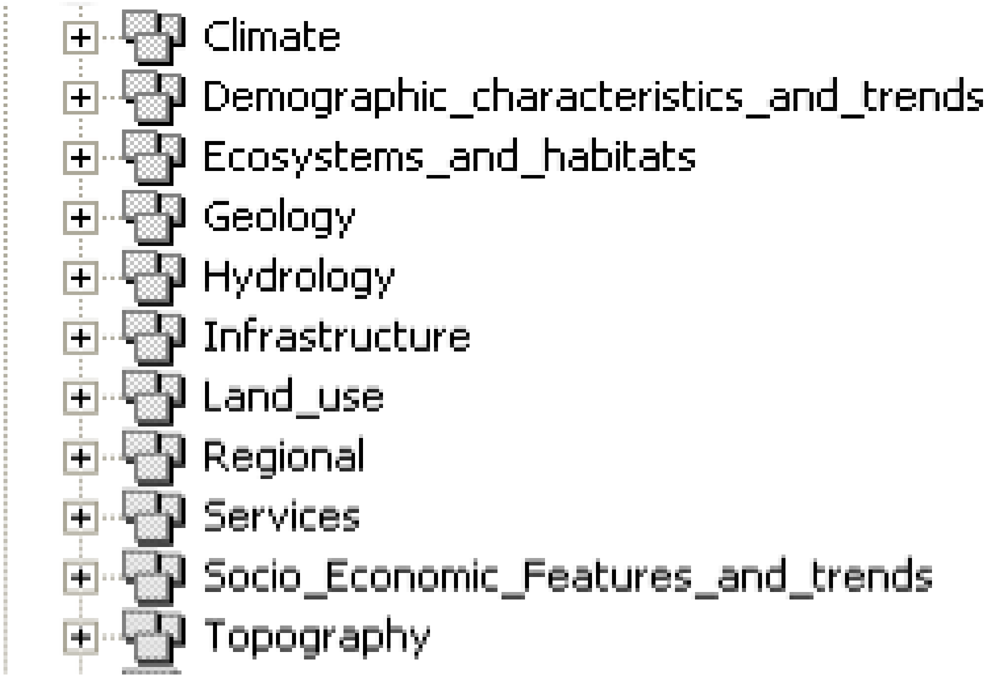

Figure 3: Feature datasets used for creating the geodatabase

The imported feature classes in each regional dataset contain national level data such as government borders, regional roads, regional railways, Egypt's either natural or manmade borders, and political national agreements. The rest of the feature datasets hold specific data for the Sinai region. Starting with the climatic dataset, this holds data of peak seasonal changes in the months of January and July for the following points: wind speed, direction and intensity, annual solar radiation, cloud cover, maximum and minimum temperatures, rainfall, and humidity. This is followed by the topographical and landscapes dataset that holds data for the following points: contours, robbers, railways, and slopes. For the geological dataset, the prevailing lithology, major fault lines, locations vulnerable to earthquakes, potential building materials, metallic and non-metallic materials, and ground water and rocks formation data were imported.

A different type of specific feature class was imported into each set. For example, the hydrological dataset includes surface water and ground water extraction, chemical ground water classification, dams and weirs, and areas vulnerable to flood risk. The ecosystem and habitats dataset hold data for the location of natural habitats and conservation areas. The infrastructure dataset comprises Sinai utilities e.g. roads, railways, ports, marinas, oil gas pipelines, telecommunications, and electricity high voltages lines. The current land use for Sinai imports data on existing urban development, vacant and agriculture land, educational and recreational facilities, and other services.

Two more datasets were created to represent population data. The first holds the demographic characteristics and trends dataset with feature classes for population size, and population density. The second feature class holds the socio-economic and trends datasets, which contain data concerning the allocation of the labour force and economic activities. Figure 4 shows the Sinai base map, to clarify the data just listed.

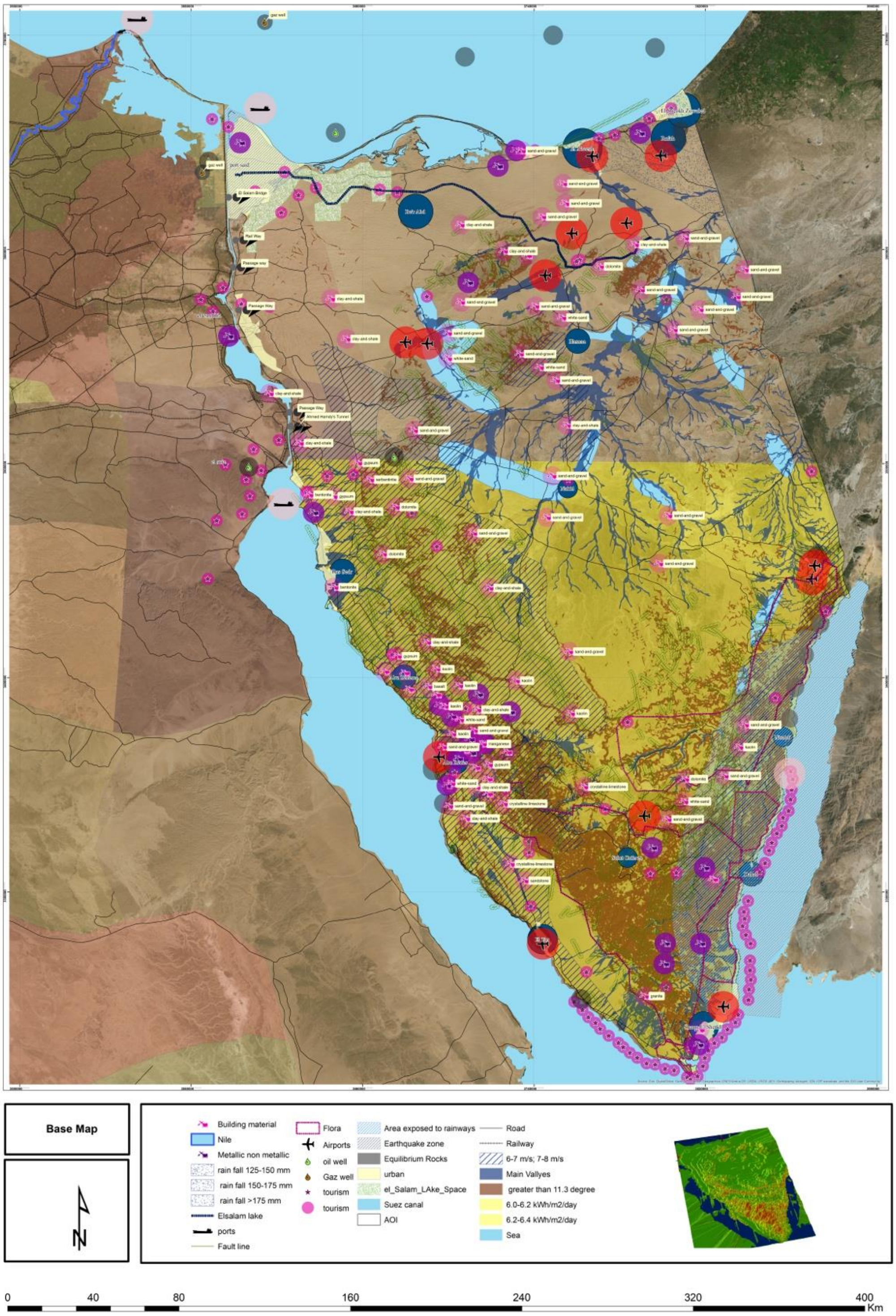

Figure 4: Sinai base map

Data overlay

In this phase, the preparation of the database required converting all the feature classes into polygon feature classes, using the buffer command in GIS which represents the range of services or vulnerable risk areas due to the presence of this feature class. Integrated analysis could be created from the overlay technique, which is used to combine common scale of different vector. Specific urban development could be identified through the overlay models. The overlay technique often requires the analysis of the different elements that represent the potential or constraints of an area of interest. For example, choosing the site for renewable energy production means assessing several factors, including land use, climate, slope, land geology and hydrogeology, etc. The map in figure 5 shows the overlay map for Sinai. Allocating different activities to its appropriate locations using the database and coloration matrix, was achieved by relating the database to the coloration matrix using attribute queries in GIS. Concluding the activities allocation alternatives according to varying priorities for each activity until the appropriate locations for each activity was finally determined.

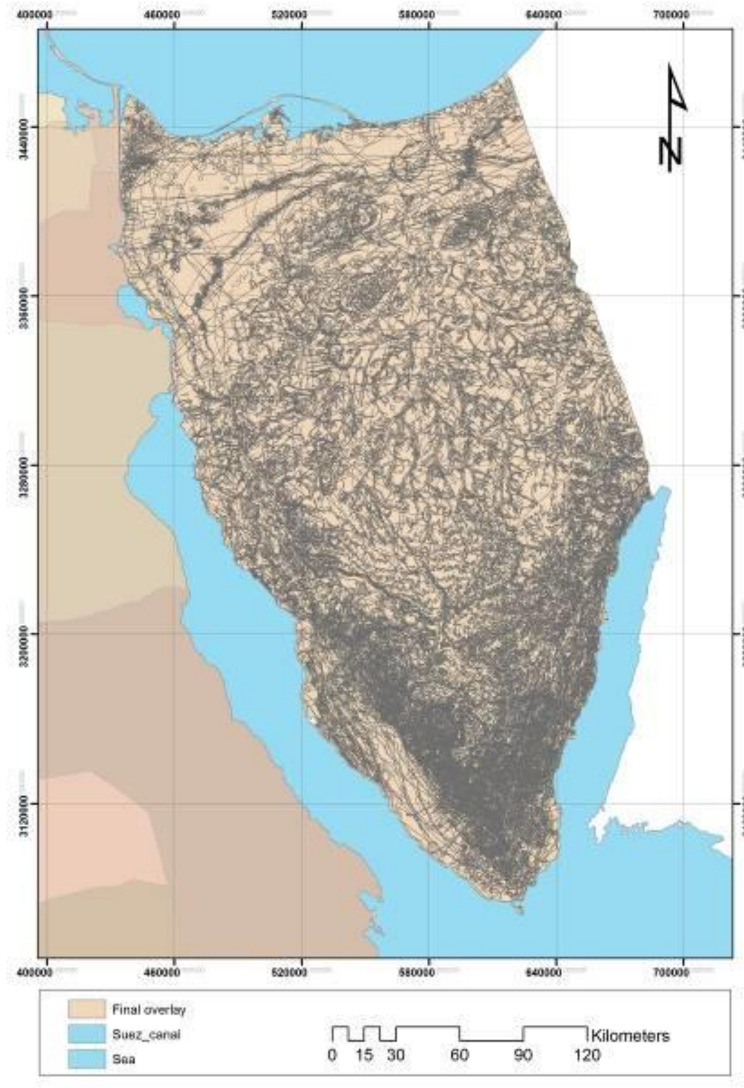

Figure 5 Overlay map for Sinai

3. Results & Discussion

After combining both the matrix and the GIS overlay the results were retrieved from the GIS database. As shown in figure 6, the overlay of all feature classes shows that 36% (22446.2 km^2) of the area is suitable for developing solar farms and only 4% (2532 km^2) for wind farms; 2% (1268.1km^2) of the total area has the potential to be developed for either solar or wind farms.

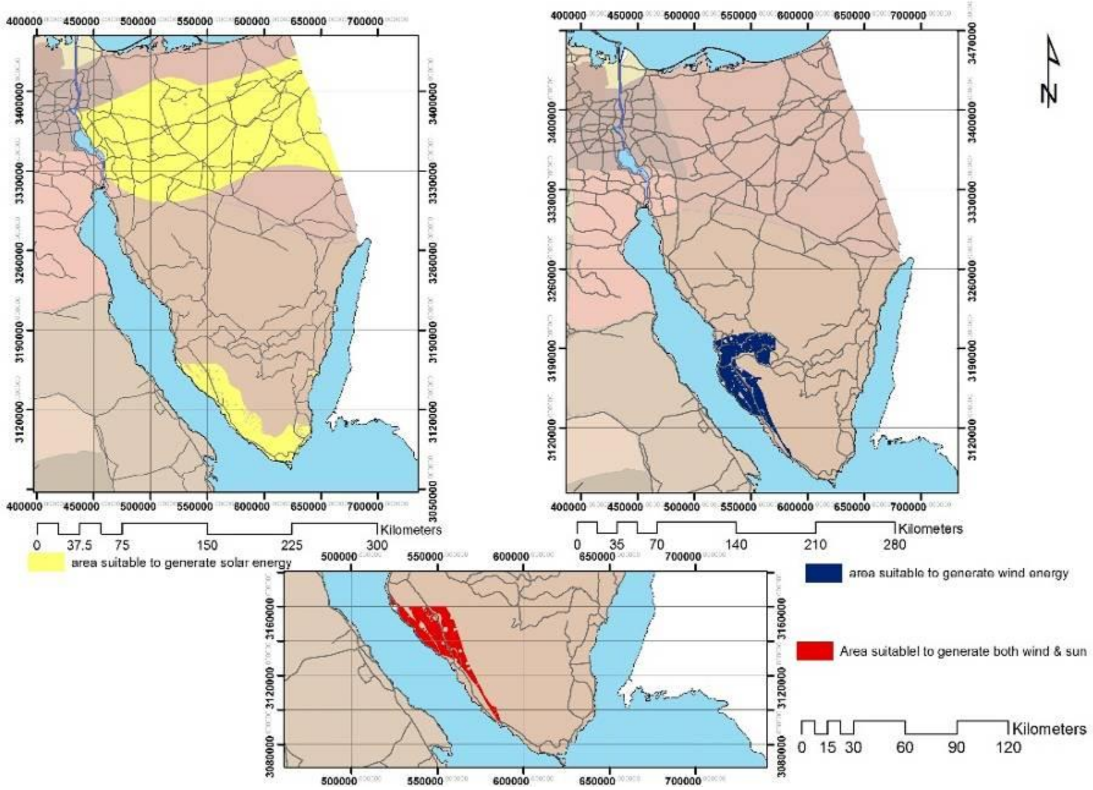

Figure 6 Potential locations for wind and solar energy

Sinai has the potential to fulfil the criteria for land suitable for solar energy. Starting with the annual mean for the sunshine duration in Sinai, the sun path analysis indicates that the sun rises from 10 to 11 hours daily in 53% of the total area, while it rises from 9 to 10 hours daily in the rest. The average solar radiation in summer is 20.7% over the total Sinai area; it is pronounced in the north, where it is characterized by 7.5-8 kWh/ m^2 day; the solar radiation destruction for the rest of the area is 8-8.5 kWh/ m^2 day. In winter, the solar radiation in 10.5 % of the total area in the north is from 2.5-3 kWh m^2 day, and in the rest from 3-4 kWh m^2 day. A percentage of 79.1% of the total area of Sinai has the potential for wind power generation because the annual mean hours within the wind speed ranges from 100 to 500 hours. In the middle part of Sinai, which represents 18.9% of the total area, the wind speed ranges from 10 to 50 hours; in the rest of the area it ranges from 100 to 500 hours. 71% of the land the wind speed ranges from 0 to 6 m/s, and the rest of the area ranges the wind speed ranges from 6 to 8 m/s.

Constraints that excluded parts of Sinai Peninsula lands from solar and wind energy generation included land exposed to rain ways, earthquake zones, equilibrium rocks, gas well buffers, metallic buffers, building materials buffers, water well buffers, steep slopes, conservation land, and land in current use. Table 1 shows wind speeds and annual mean hours of sunshine, listed by area size. All the listed constraints are the same for both wind and solar farms other than steep slopes, which are suitable for the development of wind farms only.

Table (1) Wind speed and annual hours of sunshine

Annual mean number of hours	Wind speed (m/s)	Area (km^2)
10 to 100	0 -5	6478
	5 -6	32878.5
	6 -8	14261.2
100 to 300	0 -5	609.7
	5 -6	2213.3
	6 -8	2191.3
300 to 750	0 -5	51.2
	5 -6	1131.6
	6 -8	914.3

According to CAMPAS (2016), in 2014 the total population in Egypt was 87 million people, who used 143,585 million.kw/year. Therefore, the average energy consumption per person is 1840kw/year. Based on the findings in this study, one-meter square with average solar intensity 6.4 kWh/m^2/day can produce up to 3,000 kWh m^2/annum and 1.5 MW/annum for turbines with an average 660 kW speed. Accordingly, an area of 22,446 km^2 can produce up to 67.6 million MWh/year. As laid down by the Camp David Accords, there are areas in which development is prohibited, which reduces the calculated area to 10,933.6 km^2 with the potential for solar energy production, which could produce up to 32 million MWh/year. An area of 2,099.4 km^2 has the potential for wind energy production capable of producing 3310.6 MW/annum, (see figure 7).

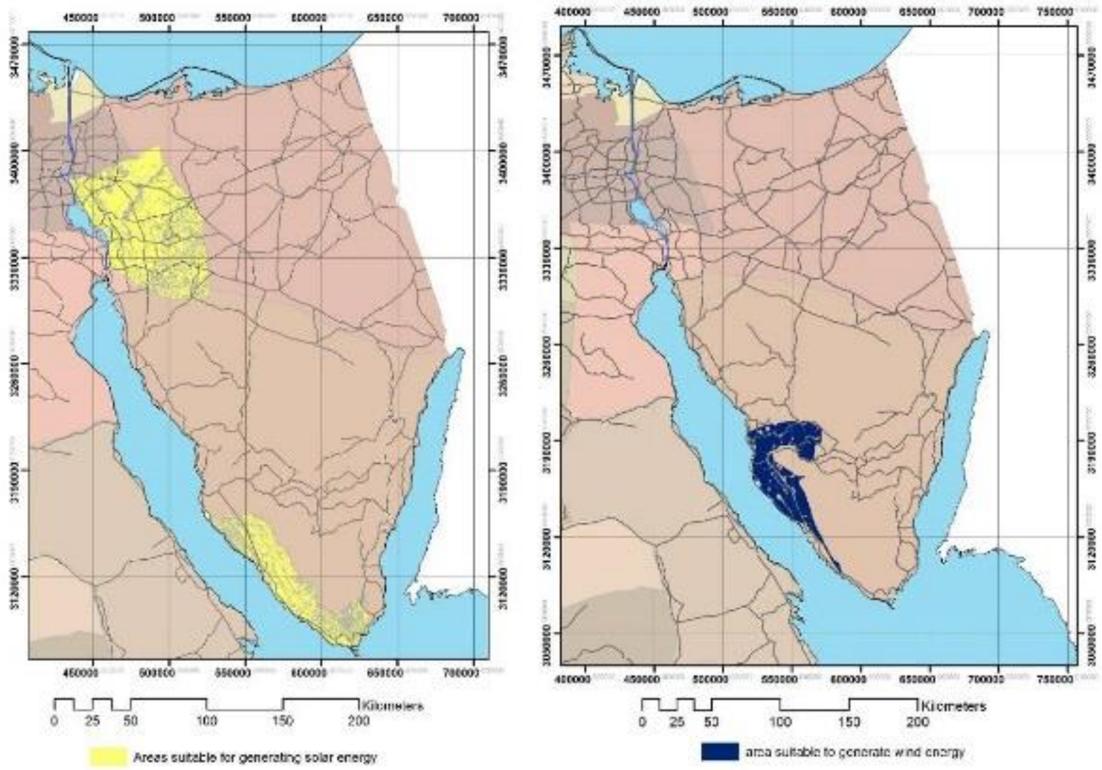

Figure 7 Areas suitable for wind or solar production, allowing for the current international political restrictions

An exercise querying the created database established that 73% of this area is suitable for other types of economic development: urban development, agriculture, industry, and the tourism and residential sectors. To summarize, the final available suitable net area for solar farms is 2,934.7 km^2, which can produce up to 8.8 million MWh/year; the figure for wind farms is 158.2 km^2, which can produce up to 249.4 MWh/year (see figure 8).

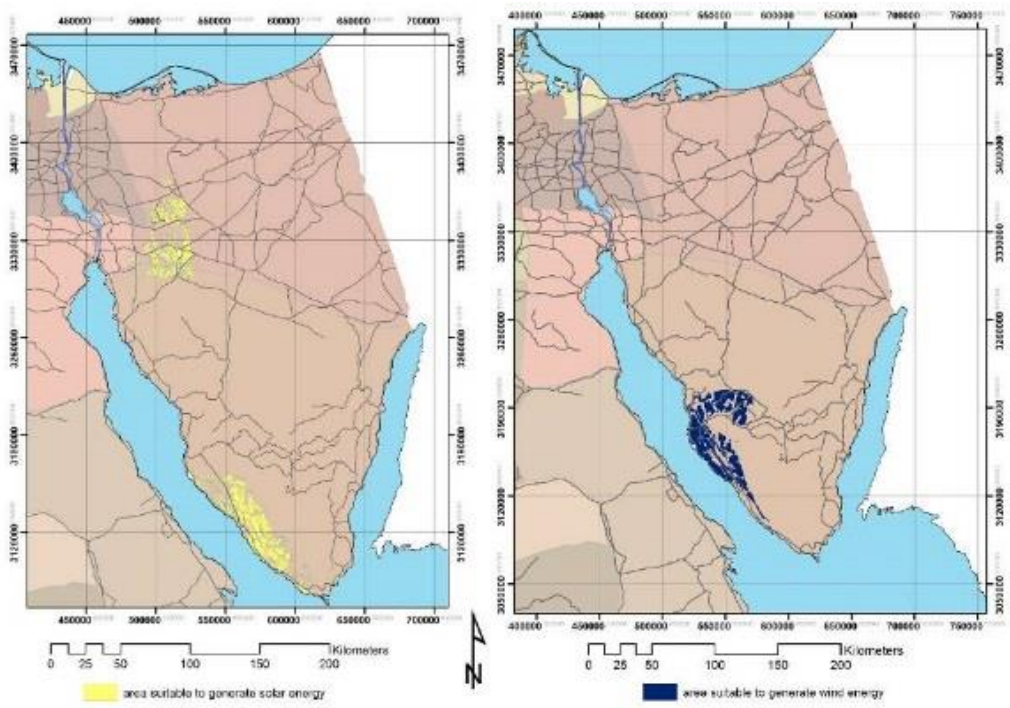

Figure 8 Map of the proposed areas that are suitable for solar or wind power generation

4. Proposed alternatives for renewable energy in Sinai

Based on annual population growth rates in Egypt of 2.4%, the population is expected to reach up to 100 million by 2020. Aligned with Vision 2030 mandates, the Egyptian government plans to increase power production from renewable energy by 20% and gradually completely remove the current subsidy on the supply of electricity. Based on the current figures, that the individual consumes 1.840 MW/year, it is expected that the need by 2020 will reach up to 1.8 million MW/year. According to Bryden et al. (2013), projected renewable energy power generation by 2020 is 8,520 MW but actual production up to 2012 is only 585 MW according to RCREEE (2013). The targeted production has a large gap to bridge, between consumer need and the government development plans. The average cost of kWh for conventional electricity production is estimated to be 55 Egyptian piasters (PT) by 2019. The current actual cost of kWh for renewable electricity production (solar and wind) is also 55 PT. With the advance in renewable technology and despite the removal of local subsidies on electricity, it is expected that the price of renewables will be lower than that of conventional fossil fuels. This possibility opens up further opportunities for investment in renewables and a greater potential for the export of clean energy to Europe in competition with the international prices.

5. Conclusion

Due to the current environmental crises, dependence on the traditional ways of generating energy cannot last much longer; there is no other way to satisfy our energy needs than to invest in renewables. In this study, we have detailed a methodological approach that serves as a decision-making support tool, using GIS as a multi-criteria decision program. This tool offers a feasible means of assisting planners and policy makers to take proper decisions related to the selection of a suitable context for the development of renewable energy. The method allows the choice of optimum locations for each type of renewable energy source, without obstructing other development plans or impinging on the suitability of the land for other activities. Moreover, the study can guide the government in setting goals or in siting renewable investments in the locations most likely to achieve maximum power production. This can smooth the way to starting other development projects based on the availability of green and clean renewable sources alongside the likely future urban densification in the Sinai Peninsula and other remote desert areas in Egypt. The methodology is sufficiently flexible to be applicable in other zones in Egypt and on a wider scale in the Middle East region.

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