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Sustainable design strategy optimizing green architecture path based on sustainability

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ABSTRACT

The vision is still not clear to the designers to identify the sustainable design strategy parameters. Also, most green building rating systems focus on the environmental aspect without the rest of the sustainability aspects, which reduces the opportunities of their use in the design and assessment process and the construction industry in general. Thus, the research aims to assess, develop, and adjust the path of green architecture rating systems based on a green basis has the sustainable feature to produce, generate, and optimize design concepts and thoughts. Hence, the concept of environment and sustainability are emphasized. The principles on which rating systems were built; were collected and outlined. Then, Green Pyramid Rating System (GPRS) was assessed through an analytical comparison with sustainability to find out the obstacles of GPRS, and GPRS requires more support, treatment, and promotion. Also, a procedural definition of sustainable green design was deduced, which supports activating rating systems by examining the relationship of overlap between green architecture and sustainable design. Finally, a sustainable design strategy was formulated that helps to guide designers toward generating and employing design concepts based on sustainable green thought. This strategy was validated using the Delphi method.

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KEYWORDS Green architecture; Green Pyramid Rating System (GPRS); economic; social; environmental; sustainability; sustainable design strategy; delphi method

Introduction

In recent decades, many architectural trends have emerged that have adopted the concept of sustainability under different names but with convergent contents that point in the same direction. It focused on the principles, features, dimensions and elements of sustainable design, but it lacked a comprehensive framework approach to the subject [1–4]. Thus, the designer's vision is not clear to define the design strategy parameters based on environmental sustainability [5,6]. Since the mid-eighties of the last

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century, the international community began to realize the need for a combination of political and scientific efforts to solve environmental problems [7]. Then, sustainable development became a cognitive model for development in the world. Sustainability emerged as a concept through which the general framework is drawn for solving a series of complex and overlapping environmental problems [8]. Therefore, this concept, in turn, was not affected by this complexity and overlap, which was reflected in the field of architecture, environmental design, and the construction industry in general [1]. The studies concerned with green rating systems in the field of architectural design and sustainability have identified, in one of their most important outcomes, the main elements, the most important of which are: site sustainability; accessibility; the usage efficiency of energy, water, materials, and resources; management quality; internal and external environmental quality; and innovation and added value as in the Green Pyramid Rating System (GPRS) [1,9–11]. The external environment is often linked to energy and emissions, leaving the internal environment as an independent element because energy, water, and materials are inputs and have outputs represented in emissions and liquid and solid waste, some or all of them may be added to the list of elements, or they may be implicit [12,13]. Then, they add to these elements, in one way or another, the societal elements, such as culture, heritage, economy and others, while maintaining the dominance of the material nature. The process of treating each of these elements is often described or called (strategic or operational plans), for example, water treatment strategy and rationalisation, strategic exploitative use, material recycling, etc [10,14,15]. Regardless of the correctness of these nomenclatures, it is a mistake to treat the whole component or part as a system by default independent; the research is concerned with sustainable design strategies at a more comprehensive level than the elements and sub-systems [16,17]. Here, the active and influential role of sustainability with its three aspects appears to be the criteria for evaluating the performance of green architecture axes and categories in global or local rating systems. After considering these factors, the research moves to achieve its purpose in formulating a strategy to be the conceptual framework that can evaluate projects and architectural designs, identify, or diagnose design strategy adopted and set up from an environmental basis to be a sustainable green basis. Achieving this purpose is an important step in changing the traditional view of the role of the environment in architecture. This can be described as the implicit purpose of the study that will achieve the transition concept of green design from the case that environmental treatments are considered as a standard or a design variable competes with the other variables to the level that green design is considered sustainable environmental design concept. This sustainable environmental design concept gains its value via the innovation degree is achieved in satisfying the requirements and conditions for aspects of

environmental, social, and economic sustainability using mechanisms based on the axes of green buildings within rating systems and formulas by which are achieved the sustainability concept.

Research problem

Most green building rating systems focus on the environmental aspect and do not care about other aspects of sustainability [1]. Which weakens and reduces the opportunities for its activation and use in the design process and the construction industry in general. The evaluation process is carried out through credit points and not indicators, variables or criteria that direct the designer toward employing design concepts [10]. Thus, the designer's vision is not clear to define the parameters of a design strategy based on an environmental basis that has a characteristic of sustainability [18,19]. As in its aspects of sustainability and as a case study on the local reality, it clearly appears in Egyptian Green Pyramid Rating System (GPRS) [20–22]. This is very useful in not throwing the dependence of the failure in applying the environmental concept, as the concept may be good and investable, but the application formulas were not successful [6,23].

Research aim and objectives

The research aims to assess, develop, and adjust the path of green architecture rating systems depending on sustainability through a practical design strategy is based on generating, evaluating, developing, and optimizing sustainable environmental concepts and thoughts; maximizing their role; and, clarifying the designer's vision. This aim can be achieved by the following objectives:

To focus on the environment and sustainability concept and its aspects to understand the ideologies adopted for formulating a sustainable environmental design;

To demonstrate and collect the principles and axes of green architecture to know the basics and rules on which rating systems are built;

To assess GPRS based on aspects of sustainability and their indicators to identify which aspects of sustainability and indicators that focus on GPRS; or GPRS is part of sustainability and requires further support, optimization, and promotion;

To investigate the relationship of overlap between green architecture and sustainable design to derive a procedural definition of sustainable green design supports activating GPRS in the construction industry; and

To formulate and propose a sustainable design strategy for assessing, developing, and adjusting the path of green architecture rating systems based on sustainability to produce, employ environmental concepts, clarify the designer's vision, and generate thoughts.

Research methodology

The inductive approach was used to identify the approved basics to formulate an environmental design by investigating the environment and sustainability concept. Besides, standing on the criteria on which rating systems are formulated by outlining and collecting the principles and axes of green architecture. The analytical approach was applied to conduct the analytical comparison to evaluate GPRS based on the aspects of sustainability and its indicators that were collected from previous studies to clarify, illuminate, and ensure that it is part of the comprehensive sustainability. OR GPRS focuses on one of the aspects of sustainability or some of its indicators or not. Other important notes are taken concerning GPRS to optimize. Based on this comparison, a procedural definition of sustainable green design was formulated that supports GPRS activation by analyzing, shedding light, and examining the relationship of overlap between green architecture and sustainable design. The deductive approach was utilized to deduce and propose a design strategy for assessing, developing, and adjusting the green architecture path based on sustainability to generate, employ, and optimize sustainable design concepts and thoughts; Besides, clarify the vision of a designer, activate, and promote rating systems. Finally, this strategy was validated using the Delphi method, as in [Figure 1](#).

Environment concept

For humans, the environment is the frame in which they live their life and carries out their various activities. On the physical level, they are all these surround them as living, non-living elements, and components such as soil, water, air, and all kinds of living organisms and other things [8]. The name (environment) means habitation or dwelling, and it may come with the meaning of the status, so it is said the political environment and the geographical environment. It may come with the meaning of an environment, and the environment here means the assets that surround a human. It also means the set of conditions and natural and social factors or the interaction of all living and abiotic factors of an area [24]. The human relationship with his environment represents a process of interaction among his nature, social organization, view of the world, way of life, social and psychological needs, individual and collective needs, physiological needs, and between the environment represented by physical conditions such as location, climate,

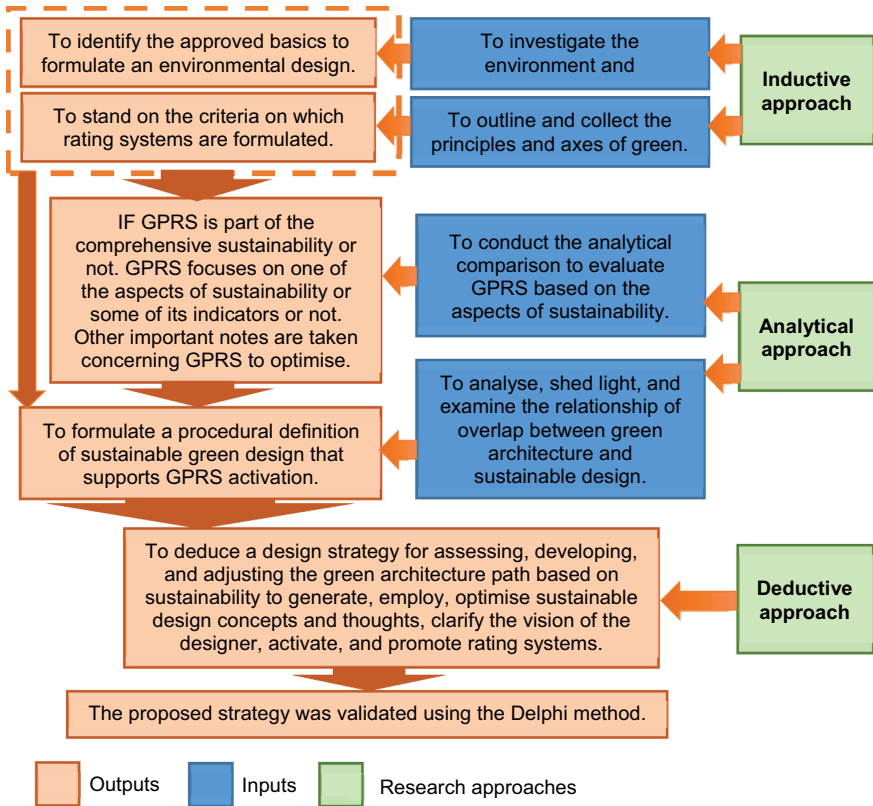


Figure 1. The research methodology.

resources and others [25,26]. Through the clear separation between the two interacting parties in this equation whereby making the moral (nonphysical) content in the human aspect while the other aspect environment included explicit tangible aspects that are expressed as physical [16,27].

Sustainability or sustainable development

In the year 1987, the World Commission on Environment and Development (WCED) produced a report known as the Brundtland Report, which included a definition of sustainable development, which became the most popular 'Meet the needs of the present without compromising the ability of future generations to meet their needs' [1]. This definition was conveyed by many sources concerned with the issue of sustainability. Hardly one of them is devoid of mentioning it. Despite the many opinions and criticisms that were issued after it; however, most of them remain in the orbit of this definition, but from different viewpoints. Through this definition, the Brundtland

Committee has tried to link economic development with the trends of preserving the environment and natural resources that are called sustainable development by relying on two basic concepts [1,5–7]. The first: the concept of needs per the surrounding conditions to maintain an acceptable level of living standards for all human beings. The second: the concept of limits to the ability of the environment to meet the needs at present and in the future, which are linked with social organization and technological developments. Therefore, the definition of ‘the World Commission on Environment and Development’ concludes that to ensure our common future, needs must be met without exceeding the limits of resources. All this leads us to the need for political, social, economic, and technical development plans to be drawn up in the light of sustainability data based on these two concepts [15]. Any development plans that fulfil the needs if they do not exceed the resource constraints. This definition that becomes more common in the world; has converted the cornerstone for all the definitions that were developed after that, which if differed in their formulation according to the purpose of putting; however, they share in the content.

Pillars and aspects of sustainability

Sustainability has three basic aspects, as in [Table 1](#), which overlap to achieve a decent human life, according to what is known in many kinds of literature concerned with sustainability, with the Triple Line (Bottom Line) or the three pillars of sustainability [1,10]. As Robertson recently pointed out, ‘from the dictionary definition of sustainability, it is concerned with the formulation of human economic activities, and culture that does not violate the environment’ in referring to (environment, economy, justice) [8].

Sustainability science is a branch of study dedicated to addressing the issues of sustainable development in the transformation to sustainability. This field is multidisciplinary, ‘defined by the dilemmas that it addresses rather than by the disciplines it uses’. Its study focuses on balancing the human population, reducing hunger and poverty, and preserving the life support systems on which are relied, as well as the interactions between these systems. Understanding the dynamics of these interconnected natural and social systems is at the heart of sustainability science [1,6].

The principles, elements, and axes of green architecture

In a study entitled Sustainable Building Classification Systems, K.M. Fowler and E.M. Rauch mentioned the environmental principles or axes that must be taken into account when designing a classification system for green buildings, as follows [36]: maximize the site’s potential; use energy-efficient products; protect and conserve water; use environmentally friendly products;

Table 1. Three sustainability aspects, their indicators, and variables [2,4,6,15,23,25,27–35,43].

	Social			Economic		Environmental	
	Indicators	Variables	Indicators	Variables	Indicators	Variables	
1	Functional, esthetic & innovative design approach	Usability, functionality & esthetic aspects Architectural considerations, cultural heritage integration and harmony level with local heritage values	LCC values	Life cycle cost Capital cost	Environmental comfort	Visual Comfort Acoustic comfort	
3	Innovation & design process		Affordability, Manageability & Adaptability	Affordability and Economic Performance		Hydrothermal comfort	
4	User comfort and safety	Indoor environmental quality		Manageability aspects and Flexibility	LCA (Life cycle assessment or Life Cycle Analysis)	Resources depletion	
5	Health and well-being			Adaptability and Flexibility		Water efficiency Examine the life cycle impacts (Materials-Energy)	
6	Safety				Climatic quality	Indoor air quality	
7	Accessibility				Emissions & Radiations	Climatic change	
8	Open space availability				-	-	
9	No. of facility users				-	-	
10	Providing community amenities				-	-	

improve IEQ (Indoor Environmental Quality); and, improve operational and maintenance practices. The concept of green building as defined by GPRS, entails [37,38]: the suitable location of projects; the provision of transportation infrastructure; water and energy supplies; the materials used in their construction; the nature of their construction; their resource consumption across the whole of their life; and, how they manage for the benefit of their users and occupants. Green construction aims can be summarized as efficient, effective, and long-lasting: site location (including transportation demands); structural, façade, and fenestration design; water, energy, and material consumption; operation and maintenance; interior environmental quality; and, waste, pollution, embodied energy, and carbon emissions are all reduced [37,38]. Green architecture encompasses all classifications of environmentally friendly building and includes some general acceptance [6]. It may have many of the following characteristics: ventilation systems that are meant to be energy efficient in terms of heating and cooling; lighting and appliances that use less energy; plumbing fixtures that save water; landscapes designed to capture as much solar energy as possible; natural habitat is not harmed as much as possible; solar or wind power are examples of alternative energy sources; nontoxic, non-synthetic materials; responsibly harvested timbers; locally sourced woods and stone; adaptive reuse of older structures; the utilization of recovered architectural salvage; and, space efficiency. Conservation of Materials and Resources; Sustainable Site Design; Energy and Environment; Water Conservation and Quality; and, Indoor Environmental Quality, which are the five major elements of green building design, and the previous points summarize key principles, strategies, and technologies associated with them [39]. The following will review the classification and evaluation systems for local green buildings in Egypt and their relationship to environmental principles, axes, and fields through which all green building rating and evaluation systems have been established.

Green Pyramid Rating System (GPRS)

GPRS the first approved version of the Egyptian classification system was called Green Pyramid in April 2010. The Egyptian Green Building Council relied on the Egyptian energy efficiency codes; and proven systems and technologies in the United States, Europe, South America, and the Middle East in formatting the Egyptian GPRS. The modified version of this system was announced in 2017 by the Building Research Center according to the state's announced vision for the year 2030, and the weights of the classification items have been modified to comply with this vision also requirements' environment, as in [Table 2](#) the change in weights between the two versions.

Table 2. The difference in weights between the two versions of GPRS [18,37,38,40].

Green Pyramid Categories	GPRS VI 2011	GPRS V2 2017
Sustainable Site, Accessibility, Ecology	15%	10%
Energy Efficiency	25%	32%
Water Efficiency	30%	20%
Materials and Resources	10%	12%
Indoor Environmental Quality Management	10%	16%
Innovation and Added Value	Bonus	Bonus
Total	110%	105%
The Different Certification Levels of the GPRS according to five levels	GPRS Certified: 40–49 credits. Silver Pyramid: 50–59 credits. Gold Pyramid: 60–79 credits. Green Pyramid: 80 credits and above. Uncertified: less than 40 credits.	One pyramid acceptable from 30–40. Pyramids from 40 to 50% (Bronze). Three pyramids from 50 to 65 (silver). Four pyramids from 65 to 80% (gold). Five pyramids for buildings that get more than 80% (platinum).

GPRS is distinguished from other international rating systems in the presence of a set of items that did not appear before; such as respecting historical sites and cultural interests, which has great weight in Egypt. Although, some items related to regional characteristics in the buildings did not appear within the additional items [20,40,41]. GPRS is distinguished by the presence of a provision on cultural heritage. Thus, it focuses on one of the human psychological needs that some other rating systems lack; the development of desert areas; and the trend toward remote areas, while other systems focus on reducing the percentage of polluted lands [21,42].

Assessment of gprs based on the sustainability aspects

The approach and method followed to conduct the GPRS assessment

- (1) The evaluation process is done by comparing the main and sub-categories of GPRS with the three aspects of sustainability, their indicators, and the variables of each indicator to identify which aspects of sustainability GPRS is trying to achieve or focus on without the other. As well as what indicators it deals with and addresses. What are the aspects and indicators that GPRS has not been exposed to, as in [Table 6](#);
- (2) It must be emphasized that the aspects of sustainability and the indicators, as in [Table 1](#), on which the evaluation and comparison process will be depended and carried out from previous studies are important and influential; and



Table 3. The comparison and assessment of GPRS with Environmental sustainability indicators, their variables, and sub-criteria.

Environmental sustainability			Green Pyramid	
Indicators	Variables	Sub-criteria	Category	Sub-category
Climatic quality	Indoor air quality	Air suspension of solid particles	5 Indoor Environmental Quality	5.2 Controlling emissions from building materials
		Carbon (monoxide-dioxide) Formaldehyde	5.M.1 Minimum Ventilation and Indoor Air Quality 5.M.2 Control of Smoking in and around the building	2.10 Energy and Carbon Inventories 5.2 Controlling emissions from building materials
Environmental comfort	Climatic change	Ozone	5.M.3 Control of Legionella and other health risks	2.M.3 Ozone Depletion avoidance
		Organic volatile compounds	4 Materials and Resources 2 Energy Efficiency	4.M.2 Elimination of exposure to hazardous and toxic materials. 2.2 Passive External Heat Gain/loss Reduction
Environmental comfort	Hydrothermal comfort	Global heating potential	2 Energy Efficiency	5.3 Thermal Comfort
		Relative humidity Winter and Summer thermal performance	5 Indoor Environmental Quality	
Environmental comfort	Visual comfort	Natural lighting		5.4 Visual Comfort
		Artificial lighting		
Environmental comfort	Acoustic comfort	Airborne sound insulation		5.5 Acoustic Comfort
		Reverberation time Impact sound insulation		

(Continued)

Table 3. (Continued).

Environmental sustainability		Green Pyramid	
Indicators	Variables	Category	Sub-category
Emissions and Radiations	Destruction of the stratospheric ozone layer	5 Indoor Environmental Quality 6 Management	5.2 Controlling emissions from building materials 6.2.5 Control of emissions and pollutants
	Eutrophication potential (lack of oxygen) Ground Formation Ozone level Acidification potential Inert waste for disposal Hazardous waste for disposal	1 Sustainable Site, Accessibility and Ecology 2 Energy Efficiency 6 Management	1.3.1 Protection of habitat Not included 2.M.3 Ozone Depletion avoidance Not included 6.1.1 Containers for site materials waste 6.1.2 Employing waste recycling workers on site 6.2.1 Project Waste Management Plan 6.2.2 Engaging a company specialized in recycling and disposal 6.2.4 Waste from mixing equipment

(Continued)



Table 3. (Continued).

Environmental sustainability		Green Pyramid		
Indicators	Variables	Sub-criteria	Category	Sub-category
LCA (Life cycle assessment or Life Cycle Analysis)	Resources depletion	Land use	1 Sustainable Site, Accessibility and Ecology	1.M.1 Project Design and Implementation Plan 1.1.1 Desert area development 1.1.2 Informal area redevelopment 1.1.3 Brownfield site redevelopment 1.1.4 Compatibility with National Development Plan 4.1.3 Use of readily renewable materials 4.1.4 Use of salvaged materials 4.1.5 Use of recycled materials 4.1.6 Use of lightweight materials 4.1.7 Use of higher durability materials 4.1.8 Use of prefabricated elements 4.1.9 LCC analysis of materials in the project
		Resources depletion of Materials	4 Materials and Resources	2.M.2 Energy Monitoring & Reporting 3 M.1 Minimum Water Efficiency 3 M.2 Water Use Monitoring 3.1 Indoor Water Efficiency Improvement 3.2 Outdoor Water Efficiency Improvement 3.3 Efficiency of Water-based Cooling 3.4 Water Feature Efficiency 3.5 Water Leakage Detection 3.7 Passive Distillation Systems 3.6 Storm Water Harvesting 3.8 Waste Water Management Not included
Water efficiency	Water efficiency	Fossil fuel depletion Drinking water use	2 Energy Efficiency 3 Water Efficiency	
		Rainwater use		
	Examine life cycle impacts (Materials-Energy)			

Table 4. The comparison and assessment of categories and sub-categories of GPRS with social sustainability indicators, their variables, and sub-criteria.

Social sustainability		Green Pyramid	
Indicators	Variables	Category	Sub-category
Functional, esthetic & innovative design approach	Usability, functionality & esthetic aspects	Indicators	
		Level of compliance with customer requirements	Not included
		The project stakeholders' view about usability	Not included
		The vision of stakeholders in a project about functionality. The opinions of stakeholders about the esthetic aspects	Not included
Architectural considerations, cultural heritage integration and harmony level with local heritage values	Expert opinions if the building is a world heritage or a nearby world heritage	7 Innovation and Added Value	7.1 Cultural Heritage
		Personal opinions of stakeholders	1.3 Ecological balance 1.3.2 Respect for sites of historic or cultural interest
Innovation & design process	Society satisfaction from the cultural value of a building	Level of commitment with available and affordable techniques	7.3 Innovation
		Future-proof of the building determined by experts	
		Personal opinions from a design team	
		Availability of daylight illumination	
User comfort and safety	Indoor environmental quality	5 Indoor Environmental Quality	5.4 Visual Comfort 2.9 Optimized balance of Energy and Performance
		2 Energy Efficiency	
	The number of times to change the air during an hour on the inside	5 Indoor Environmental Quality	5.M.1 Minimum Ventilation and Indoor Air Quality 5.1 Optimized Ventilation

(Continued)



Table 4. (Continued).

Indicators	Variables	Indicators	Category	Sub-category
Social sustainability				Green Pyramid
		The production rate of airborne pollutants	2 Energy Efficiency	2.10 Energy and Carbon Inventories
		Personal opinions of project stakeholders	5 Indoor Environmental Quality	5.M.1 Minimum Ventilation and Indoor Air Quality 5.M.2 Control of Smoking in and around the building 5.M.3 Control of Legionella and other health risks 5.1 Optimized Ventilation 5.2 Controlling emissions from building materials 5.3 Thermal Comfort 5.4 Visual Comfort 5.5 Acoustic Comfort
	Health and well-being	Construction Consultants		
		Health care index		Not included
		Pollution index		1.1.4 Compatibility with National Development Plan 1.2.3 Alternative methods of transport 1.3 Ecological balance 1.3.1 Protection of habitat 1.3.3 Minimizing Pollution during construction 6.2 Site Environmental 6.2.2 Protecting water sources from pollution 6.2.4 Control of emissions and pollutants Not included
		Personal opinions of project stakeholders		
		Construction Consultants		Not included

(Continued)

Table 4. (Continued).

Social sustainability		Green Pyramid	
Indicators	Variables	Indicators	Sub-category
Safety	Level of compliance with safety standards	6 Management	6 M.3 Where the Project involves demolition work, a Method Statement with clear evidence of the use of suitable methods of demolition
	Safety index Personal opinions of Project stakeholders		6.M.2 Compliance with Health & Safety and Welfare regulations Not included Not included
Open space availability.	Available open space	Construction Consultants For seating	Not included
	No. of facility users.	1 Sustainable Site, Accessibility and Ecology For ventilation and daylight Per occupant Inhabitable spaces	1.1.4 Compatibility with the National Development Plan Service personnel
Not included		A building's occupants	Not included
		Max. No. of users (The building occupants) per inhabitable space	Not included Not included

(Continued)



Table 4. (Continued).

Social sustainability		Green Pyramid	
Indicators	Variables	Category	Sub-category
Accessibility	Indicators	Accessibility for a disabled (if necessary)	Not included
		Access to the clinician and hospital	Not included
		Access to services	1 Sustainable Site, 1.2.1 Transport infrastructure connection 1.2.2 Catering for remote sites 1.2.3 Alternative methods of transport 6 Ecology 6 Management
	Variables	Distance from the city center (a city)	Not included
		Level of compliance with customer's requirements	Not included
		Traffic indicator (a city)	Not included
		Stakeholders' view on amenities	Not included
		Stakeholders' satisfaction	Not included
		Life quality index	Not included
		Community amenities	

Table 5. The comparison and assessment of categories and sub-categories of GPRS with economic sustainability indicators, their variables, and sub-criteria.

Economic sustainability		Green Pyramid		
Indicators	Variables	Indicators	Category	Sub-category
LCC values	Capital cost	All costs required for buying and extend building assets, procure tools, and to begin operating	4 Materials and Resources	4.M.1 Schedule of Principal Project Materials 4.1.9 Life Cycle Cost (LCC)
	Life cycle cost	Operation, occupancy, utility, maintenance, and guarding Costs	2 Energy Efficiency 6 Management	2.3 Energy Efficient Appliances 2.6 Renewable Energy Sources 2.8 Operation and Maintenance 6.3.7 Providing a Periodic Maintenance Schedule
Affordability, Manageability & Adaptability	Affordability and Economic Performance	Project stakeholder opinion The burden of housing or containment costs Price to income ratio		Not included Not included Not included
	Manageability aspects	Stakeholder's opinion. building design complexity No. of indoor & outdoor spaces Gross floor area External wall area		Not included Not included 6.3.6 Providing a Building User Guide
	Adaptability and Flexibility	Area of outdoor spaces Ease of major changes (Professional opinion) Ease of minor changes (Professional opinion) No. of rentable zones No. of indoor spaces Stakeholder's opinion	6 Management	6.3.6 Providing a Building User Guide
				Not included Not included Not included Not included Not included
				Not included Not included Not included Not included



Table 6. The environmental, social, and economic sustainability indicators, their variables and sub-criteria that are not included in GPRS.

Environmental sustainability		Variables	Sub-criteria
Indicators			Formation of the ground Acidification potential
Emissions and Radiations			
LCA		Examine the life cycle impacts (Materials-Energy)	
Social sustainability			
Indicators		Variables	Indicators
Functional, esthetic & innovative design approach	Usability, functionality & esthetic aspects	Level of compliance with customer requirements The project stakeholders' view about usability The vision of stakeholders in a project about functionality. The opinions of stakeholders about the esthetic aspects	Health care index Personal opinions of Project stakeholders Construction Consultants
User comfort and safety	Health and well-being		
	Safety	Safety index Personal opinions of	Project stakeholders Construction Consultants Service personnel
	No. of facility users.	No. Inhabitable spaces of	A building's occupants Service staff per inhabitable space Occupants per inhabitable space
	Accessibility	Accessibility	Accessibility for a disabled (if necessary) Access to the clinician and hospital
	Community amenities	Community amenities	Level of compliance with customer's requirements Traffic indicator (a city) Stakeholders' view on amenities Stakeholders' satisfaction Life quality index
Economic sustainability		Variables	Indicators
Indicators			

(Continued)

Table 6. (Continued).

Environmental sustainability		Sub-criteria
Indicators	Variables	
Affordability, Manageability & Adaptability	Affordability and Economic Performance	Project stakeholder opinion The burden of housing or containment costs Price to income ratio Stakeholder's opinion.
	Manageability aspects Adaptability and Flexibility	Area of indoor spaces Ease of major changes (Professional opinion) Ease of minor changes (Professional opinion) No. of rentable zones No. of indoor spaces Stakeholder's opinion

- (3) From this appraisal, conclusions can be drawn about the relationship of GPRS to sustainability in its deep conception in achieving the three aspects (Line Bottom Triple (TBL)) as in the following [Tables 3](#), [Tables 4](#), [and Tables 5](#), and notes after comparison, examination, and investigation, as shown in [Table 6](#).

The results of the GPRS assessment

- (1) GPRS cares and focuses on achieving environmental sustainability more than social and economic sustainability, which indicates that it did not seek to achieve a balance among the aspects of sustainability, which is considered the most important aims of sustainability or sustainable development in Egypt 2030 plan, as in [Table 6](#);
- (2) GPRS has not forced or suggested upon the projects required to be evaluated the importance of applying POE mechanisms with existing buildings and under evaluation because of the difference in dealing with buildings in the design phase against existing buildings and under-occupancy. However, it deals with existing buildings or designs through a set of categories or criteria; which is incompatible with sustainability trends in general;
- (3) GPRS did not consider the opinion of stakeholders while evaluating following the principle of collaborative or collective design or participation in projects by all parties;
- (4) GPRS did not establish the principles of users' satisfaction as one of the accreditation points or evaluation indicators;
- (5) GPRS did not explicitly mention or support the measurement and evaluation of LCA (Life cycle assessment or Life Cycle Analysis) despite its importance. Although, GPRS mentioned some of its elements scattered within its categories and neglected the importance of developing a plan and a principle from cradle-to-grave or according to the nature of the project to be a cradle-to-cradle principle;
- (6) Relying on ANSI/ASHRAE standards in Energy, Water, and Environmental Quality, and at the same time relying on Egyptian standards, while Egyptian standards and specifications must be adhered to, which suit the local environment, and help achieve sustainability;
- (7) The importance of developing GPRS according to the local conditions in Egypt. As there is a great similarity between it and the LEED system, which makes it not commensurate with Egypt's environmental or technological conditions in terms of being one of the developing countries. With the need to add elements specific to the social and

economic aspects of sustainability such as those collected in the current research or any other elements that appear or are developed later; and

- (8) GPRS was not interested in encouraging, adapting, and adopting BIM; taking advantage of its enormous potential in all stages of project life, and managing the information and data required to conduct a building evaluation by GPRS; despite the recent presence of the Egyptian code for building information modeling.

Procedural definition of sustainable green design supports activating and utilizing GPRS

From the relationship of overlap between green architecture and sustainable design, it can be reached a procedural definition of sustainable green design supports activating and utilizing GPRS in the construction industry in the future generally. The building influences the local and global environment during its existence through a series of interactions of human activity and natural processes [14]. In the first stage, the development of the site and the structural structure affect the basic characteristics of the ecosystem; as the requirements of the structural structure and human presence on the site of the building, it reflects on the local ecosystem [2]. As for the process of manufacturing and purchasing materials, its impact extends to the global environment. When construction is completed, the building's operating systems continually affect the environment [43]. Many countries have turned to green architecture to enhance sustainability in the construction sector, and the world is currently witnessing a revolution in the field of green buildings that work to achieve sustainability [44]. Describing architecture as 'green' means that it becomes a source of resources, materials, energy and water, rather than being a consumer [42]. This means that green buildings emphasize healthier, more environmentally friendly, and more efficient and less disruptive use of land, water, energy, and resources [45]. Green architecture is defined as 'architecture compatible with the environment that aims to reduce negative impacts, achieve energy efficiency, optimal use of renewable energy sources, efficient use and reuse of materials and resources, adaptation of the site to climatic conditions and providing comfort to users'. [6]. This definition illustrates the relationship of green architecture to sustainability; as it is clear that green architecture places great emphasis on achieving environmental sustainability, it does not neglect either social or economic sustainability, but it is concerned with achieving environmental goals more clearly as it is concerned with the conservation of energy, water, materials and land [7]. In other words, green architecture is part of the overall sustainability system. The concept of sustainable architecture has been formulated in several ways, including sustainable design, environmentally sensitive design, design with

the environment or green design [45]. The design processes are integrative relationships with the components of the surrounding environment; sustainability is a design approach whose principles are based on the characteristics of nature intertwined with the concept of (ecology), which allows understanding of those characteristics [26]. It also goes beyond the features of green architecture. For example, the term 'solar architecture' which preceded the term 'sustainable architecture' expressed the architectural thought to the concept of reducing the consumption of natural resources and fuel. In other words, designer attempts were aimed at the possibility of conserving fuel sources by simultaneous utilization of the available solar energy; through the appropriate design [43]. The development of this trend led to the broad meaning of the concept of 'sustainable architecture', which describes the design that takes into consideration the environmental orientation, green, and energy sources. This design ideology is not new in architecture, as many aspects of sustainability have been around since the dawn of dynasties. The great technological progress of the twentieth century and the subsequent separation of man from nature have led to the forgetting of a large part of the methods of sustainable design that were known in the past. Therefore, attention should be paid to the supporting design based on energy saving, the use of alternative resources, and materials. The architectural designer should not only care about the buildings, but also the resources, environment, economy, and local culture [12]. One of the most important aims of sustainable design is to create a sustainable green built environment that supports the natural environment, or at least with a minimum level of damage. The global environment is in continuous deterioration that should be halted and preserved, in the sense of shifting from a depleting or harmful burden to one that supports or is friendly to the environment. The most

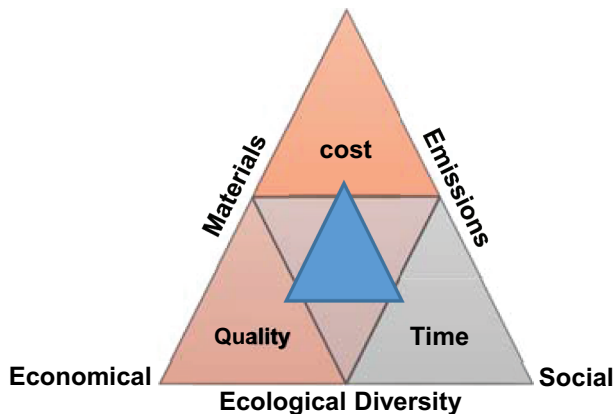


Figure 2. The design orientation and its elements toward the sustainable model.

important aspect of sustainable design lies in the links between the various components of design and the realization of the essence of sustainability, which cannot be separated into parts [17]. It invites thinking in a range of issues that including durability, appropriate materials, and a sense of place [18]. It also encourages finding a balance between environmental considerations and economic constraints; considering the ecosystem needs are supported by some considerations to make sustainable architecture is in wide application. The possibility of achieving the integration of natural systems with human patterns for creating continuity and uniqueness to produce a place through the balance of ecological factors, human factors, and ecosystems [14]. Sustainable architecture describes the design orientation toward models that reduce the consumption of natural resources or live in a way that extends the life of the availability of those resources that means it is an environmentally conscious green architectural design, as shown in Figure 2.

From the previous, sustainability is not an independent word rather. It is an adjective added to a description that is often in the process of suffering from actual, critical problems that need to be addressed by doing so. It moves what is described in a new state, which is supposed to be healthy, correct, and clearly different from the previous ones. Only then can the new designation or adjective be obtained. The stumbling development turns into sustainable development; the polluted environment turns into a sustainable environment; the sick building turns into a sustainable building, and so on. Accordingly, it can obtain a procedural definition of sustainable green design. It is a new system that has specific parameters and visions through which design problems are dealt with to solve their complexities, functional, economic, and social specificities this system consists of elements and relationships. These elements and relationships consist of axes and evaluation criteria; the most important of which are the principles, features, and fields of green architecture combined, and the criteria for their evaluation are aspects of sustainability with their indicators, as in Table 1. This system depends on how to employ these axes to achieve the highest sustainable performance at the lowest cost without depleting any of them. The target is the human and his relationship with the environment, which many studies have agreed on its main axes with some difference in the details concerning the project studied.

Proposed sustainable design strategy optimizing the green architecture path based on sustainability

Based on what was previously discussed and addressed in the study sections, especially the procedural definition of sustainable green design, a sustainable design strategy can be formulated and deduced, as in Figure 3. This strategy

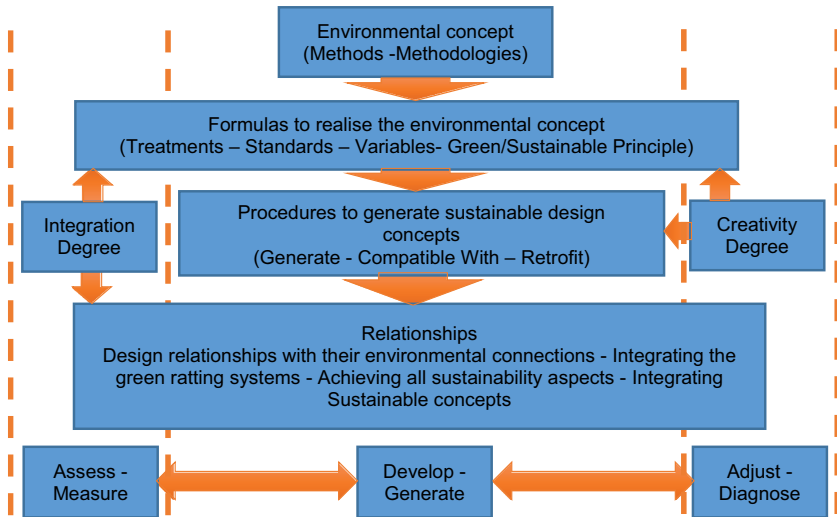


Figure 3. The stages of the proposed sustainable design strategy for optimizing (assess, develop, and adjust) the green architecture path based on sustainability.

is based on the environmental basis that has the sustainability feature to optimize (assess, develop, and adjust) the path of green architecture rating systems based on the comprehensive or integrated sustainability to produce, generate, employ sustainable concepts, and support activating rating systems. Finally, designers have clarity of vision and are directed toward employing design conceptions and thoughts in achieving sustainability. In addition, maximizing the role of sustainable environmental concepts and thoughts and generating them. The stages of this proposed strategy:

The first stage: the environmental concept stage, as in [Figure 3](#); the data and elements mentioned in this research and adopted design methods are utilized; also, methodologies such as the passive or active design in formulating a new methodological framework. Which employs the main elements, axes, and categories of green architecture available in rating systems such as GPRS to achieve a sustainable environmental design system, but in a manner that stems from the essence of the environmental concept around which the design revolves. The second stage: the stage of formulas for realizing the environmental concept. This stage works to achieve the aim of moving the environmental design of the case of considering environmental treatments as a mere standard or design variable that competes with other variables to the level of considering the architectural design as an environmental design that acquires its design value from the creativity degree. This degree has been achieved with the help of design mechanisms and formulas through which the environmental concept is achieved in the next third stage, the stage of

the procedures. The third stage: the stage of the procedures for generating sustainable design concepts that are compatible with the studied project in the design or the development stage, or the existing project in the improvement and retrofitting stage. Fourth stage: the stage of relationships is clearly reflected on the design relationships with their environmental connections, the integration degree between the green architecture rating systems under consideration or through which the project is required to be evaluated, and the vocabulary formulas for realizing the environmental concept (The second stage) and treatments to achieve these axes and categories in the project. On this basis, the main vocabulary and the important axes of green architecture and secondary indicators are identified, represented in the treatments and design solutions for these axes to support the achievement of this proposed strategy and the achievement of all aspects and criteria of sustainability, [Table 1](#), and environmental concepts through their integration together. Based on the four phases of the proposed strategy and the objective to be activated, as shown in [Figure 3](#). This method opens the way for each project that has a sustainable, or diagnosable, environmental orientation; even if the project failed in employing it to benefit from it in defining or formulating an execution plan to implement a sustainable environmental design that can be employed in other similar projects or vice versa. To produce new and renewed outcomes, if successful, based on rating systems such as GPRS; achieve the sustainability concept at the heart of the design process and the project; all of this, in the end, depends on the process of generating and producing thoughts and concepts.

Delphi survey method to verify the efficiency and validity of the proposed sustainable design strategy

To approve and verify the efficacy of this practical strategy as an effective and applicable tool and it is useful for generating sustainable thoughts and concepts and the clarity of designers' vision. The study utilized the Delphi Method based on the group of experts is sent several rounds of surveys; after each round, the anonymous results are compiled and shared with the group. In the following rounds, the experts are free to change their replies based on their interpretation of the group responses that have been presented to them. The Delphi approach aims to get the proper result by consensus by asking many rounds of questions and informing the panel of what the group believes or agreed, as in [Table 7](#). Forty-three experts were invited. Ultimately, only 24 professionals (consisting of 8 academics and 16 practitioners) engaged in the questionnaire. The election of the members based their work through designing, retrofitting, and building green projects; whatever, the academic or applied practice of rating systems to attain

Table 7. The outcomes utilizing the Delphi survey method through three rounds to approve and consent on the proposed strategy to assess and adjust the green architecture path based on sustainability for generating sustainable concepts and activating rating systems.

Test Statistics	Rounds		
	First	Second	Third
Kendall's (W) Test			
N (No. of questionnaires)	24	24	24
(W)	.490	.647	.781
Chi-Square	82.264	108.677	131.219
df (degrees of freedom = n-1)	7	7	7
Asymp. Sig.	.000	.000	.000
Kendall's concordance coefficient (W): (For $W \geq 0.7$, there is a strong agreement or consensus; for $W = 0.5$, there is a moderate agreement; and for $W 0.3$, there is a weak agreement.			
n: No. of the survey questionnaire questions (Eight questions).			
Asymp. Sig.: The p-value is less than 5%. It points to that there is a considerable degree of agreement among the experts. (Significance level)			

sustainability. The research used the Likert Scale for judging, namely: 5 = strongly agree; 4 = agree; 3 = undecided; 2 = disagree; and, 1 = strongly disagree. The proposed strategy was updated and optimized to be in its current outline, as in [Figure 3](#), through the survey from the feedback through three rounds.

The survey results based on Delphi Survey Method confirmed the following:

- (1) Although, the design strategy intended in the research may be concentrated around an element, a sub-system or even part of a system such as the roof of a building or an exterior facade that is part of the building envelope system or its external elements. The reason for this possibility is the linkage of the targeted strategy with the main or core green environmental concept of a project. This does not mean canceling or marginalizing the rest of the elements and systems, but quite the opposite, that their integration remains essential in the evaluation process;
- (2) The strategically oriented evaluation system considers all the known and diagnosed elements and systems. It is looking for more if it is available to be recorded and entered inside the sustainable valuation calculations to take its appropriate place and weight;
- (3) Therefore, the research assumes no inevitable relationship between the strength of the design concept, its quality, or its esthetics, the success of the project or design in the evaluation process, or to get as close as possible to being sustainable green;

- (4) The designer's decision to adopt traditional methods or simulating a heritage model; should be based on sufficient knowledge and good assimilation of all the vocabulary of the target reference to avoid falling into design errors that may be difficult to correct or solve later;
- (5) In addition to losing many important advantages that can be learned from, even in the case of the designer or the beneficiary's desire to move away from contemporary styles for one reason or another. Otherwise, the hybridization between the old after its digestion and absorption and the modern with its technological capabilities and its multiple options all can offer very creative and efficient alternatives;
- (6) Like other rating systems, an appropriate method will be developed to evaluate the success of the project in achieving the environmental concept from which it is based. Consequently, this strategy will achieve a double benefit:

Conclusions

The main conclusion of this study is the sustainable design strategy. This strategy is based on an environmentally sustainable basis for optimizing (evaluate, develop, and adjust) the path of green architecture rating systems based on comprehensive or integrated sustainability to generate, employ sustainable concepts, and support the activation process of rating systems. Finally, designers have a clear vision and directed them toward employing green design concepts in achieving sustainability and maximizing the role of sustainable environmental design concepts and thoughts. As well as coming up with a procedural definition of sustainable green design that supports activating GPRS in the construction industry in general; after examining the relationship of overlap between green architecture and sustainable design. Then, GPRS was investigated and evaluated through the analytical comparison with sustainability to benefit from the results of this comparison in identifying GPRS obstacles that require more support, diagnosis, treatments, and promotion; hence, helping designers take advantage of it, and serving the design trends itself. To address the problem that most green building rating systems focus on the environmental aspect without the rest of the sustainability aspects or give it less importance; which weakens and reduces the opportunities of its activation and use in the design process and the construction industry in general. Therefore, the principles and rules on which the rating systems were built; were established through highlighting and collecting the principles and axes of green architecture. Then, understanding and outlining the basics and ideologies adopted to crystallize sustainable environmental design by addressing and analyzing the concept of environment and sustainability and its aspects. To have a clear vision of designers to

define the parameters or outlines of a sustainable design strategy to produce, generate, and employ concepts are based on a sustainable green environmental basis; and increasing opportunities to activate local and global rating systems for achieving sustainability and its aspects in the construction industry. This type of strategy can evaluate projects or architectural designs and diagnose the design approaches adopted and based on a green environmental basis to be sustainable. This is very useful in not throwing the failure consequences when applying the environmental concept; since the concept may be fit and investable, but the application formulas were not successful.

Disclosure statement

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References

1. Robertson M. Sustainability principles and practice. 3rd Edition. London: Routledge. 2021. <https://doi.org/10.4324/9780203768747>
2. Lützkendorf T. Assessing the environmental performance of buildings: trends, lessons and tensions, *Build. Res. Inf.* 2018;46:594–614.
3. Mateus R, Bragança L. Sustainability assessment and rating of buildings: developing the methodology SBToolPT-H, *build. Environ.* 2011;46:1962–1971.
4. Bragança L, Mateus R, Koukkari H. Building sustainability assessment. *Sustainability.* 2010;2(2010):2010–2023.
5. Ghernaout D. Environmental principles in the holy koran and the sayings of the prophet muhammad. *Am. J. Environ. Prot* 2017;6(3):75.
6. Ragheb A, El-Shimy H, Ragheb G. Green architecture: a concept of sustainability. *Procedia Soc Behav Sci.* 2016;216:778–787.
7. Elshater AM. Urban design redux: redefining a professional practice of specialization, *Ain Shams Eng. J.* 2015;6:25–39.
8. Wu W, Luo Y. Investigating the synergies of sustainability and bim through collaborative project-based learning, in: *ASEE annu. Conf. Expo. Conf. Proc* 2015;26.1043.1–13. DOI:10.18260/p.24380
9. Ding Z, Fan Z, Tam VWY, et al. Green building evaluation system implementation, *build. Environ.* 2018;133:32–40.
10. Illankoon IMCS, Tam VWY, Le KN. Environmental, economic, and social parameters in international green building rating tools. *J. Prof. Issues Eng. Educ. Pract.* 2017.143(2):05016010. [https://doi.org/10.1061/\(ASCE\)EI.1943-5541.0000313](https://doi.org/10.1061/(ASCE)EI.1943-5541.0000313)
11. Shamseldin AKM. Evaluate the continuity of meeting items requirements when assessing buildings environmentally. *HBRC J.* 2017;13(2):233–243.

12. Cabeza LF, Rincón L, Vilariño V, et al. Life cycle assessment (LCA) and life cycle energy analysis (LCEA) of buildings and the building sector: a review. *Renewable Sustainable Energy Rev.* 2014;29:394–416.
13. Soust-Verdaguer B, Llatas C, García-Martínez A. Critical review of bim-based LCA method to buildings. *Energy Build.* 2017;136:110–120.
14. Moldan B, Janoušková S, Hák T. How to understand and measure environmental sustainability: indicators and targets. *Ecol Indic.* 2012;17:4–13.
15. Ahmad T, Thaheem MJ. Developing a residential building-related social sustainability assessment framework and its implications for BIM, Sustain. *Cities Soc.* 2017;28:1–15.
16. Mustafa FA. Performance assessment of buildings via post-occupancy evaluation: a case study of the building of the architecture and software engineering departments in Salahaddin University-Erbil, Iraq. *Front. Archit. Res.* 2017;6(3):412–429.
17. Russell-Smith SV, Lepech MD, Fruchter R, et al. Sustainable target value design: integrating life cycle assessment and target value design to improve building energy and environmental performance. *J Clean Prod.* 2015;88:43–51.
18. Daoud AO, Ahmed A, Othman E, et al., et al. Towards a Green Materials Procurement : investigating the Egyptian Green Pyramid Rating System TOWARDS A GREEN MATERIALS PROCUREMENT : INVESTIGATING THE EGYPTIAN GREEN PYRAMID RATING SYSTEM PhD Researcher, School of Built Environment and Architecture, L, Green Herit. *Int. Conf. Cairo, Egypt.* (Chance – Change –Challenge). (2018) 575–590. http://researchopen.lsbu.ac.uk/2542/1/GHC0901_Daoud 2018_Green Materials Procurement Final Version.pdf.
19. Attar MEA, Moubarak LM, Gimaily ZHA. The current methodology of assessment of sustainable buildings in egypt between probabilities and obstacles. *JES. J. Eng. Sci* 2018;46:263–281.
20. Daoud AO, Othman AAE, Ebohon OJ, et al. Overcoming the limitations of the green pyramid rating system in the Egyptian construction industry: a critical analysis. *Archit. Eng. Des. Manag* 2020;1–14. DOI:10.1080/17452007.2020.1802218
21. Dev PK. Evaluating green pyramid rating system: potentialities & Revival, SSRN *electron. J.* 2018. DOI:10.2139/ssrn.3163396
22. Ammar MG. Evaluation of the Green Egyptian pyramid. *Alexandria Eng J.* 2012;51(4):293–304.
23. ALwaer H, Clements-Croome DJ. Key performance indicators (KPIs) and priority setting in using the multi-attribute approach for assessing sustainable intelligent buildings, *build. Environ.* 2010;45:799–807.
24. Nguyen BK, Altan H. Comparative review of five sustainable rating systems. *Procedia Eng.* 2011;21:376–386.
25. Montarroyos DCG, de Alvarez CE, Bragança L. Methodology for environmental assessment in Antarctic buildings. *Environ. Impact Assess. Rev* 2018;73:104–113.
26. Cochran FV, Brunsell NA. Biophysical metrics for detecting more sustainable urban forms at the global scale. *Int. J. Sustain. Built Environ* 2017;6(2):372–388.
27. Almahmoud ES, Doloi HK. Social sustainability health check : a model for integrating stakeholders ' interests in evaluating and optimising social sustainability performance of construction projects. *CIB Int. Conf* 2012.98–105. http://www.irbnet.de/daten/iconda/CIB_DC24074.pdf.

28. Chong HY, Lee CY, Wang X. A mixed review of the adoption of Building Information Modelling (BIM) for sustainability. *J Clean Prod.* [2017;142:4114–4126.](#)
29. Malmgren L, Mjörnell K. Application of a decision support tool in three renovation projects. *Sustain.* [2015;7\(9\):12521–12538.](#)
30. Ahmad T, Thaheem MJ. Economic sustainability assessment of residential buildings: a dedicated assessment framework and implications for BIM, *Sustain. Cities Soc.* [2018;38:476–491.](#)
31. Lavy S, Garcia JA, Dixit MK. Establishment of KPIs for facility performance measurement: review of literature. *Facilities.* [2010;28\(9/10\):440–464.](#)
32. Maltese S, Tagliabue LC, Cecconi FR, et al. Sustainability assessment through green bim for environmental, social and economic efficiency. *Procedia Eng.* [2017;180:520–530.](#)
33. Wong JKW, Zhou J. Enhancing environmental sustainability over building life cycles through green BIM: a review, *Autom. Constr.* [2015;57:156–165.](#)
34. Shoubi MV, Shoubi MV, Bagchi A, et al. Reducing the operational energy demand in buildings using building information modeling tools and sustainability approaches. *Ain Shams Eng. J.* [2015;6:41–55.](#)
35. Sirija M. Application of green technologies in architecture. *Recent Res. Sci. Technol* [2014;6:65–69.](#)
36. Fowler KM, Rauch EM. Sustainable Building Rating Systems Summary. *Contract;* [2006.](#) p. 1–55.
37. Housing T, National B, Egyptian T, et al. The Egyptian Green Building Council The Green Pyramid Rating System (GPRS) Version. Vol. 1. [2011.](#) p. 1–41.
38. Housing T, National B, Egyptian T, et al. The Egyptian Green Building Council The Green Pyramid Rating System (GPRS) Version. Vol. 2. [2017.](#) p. 1–69.
39. Elshimy H, Samir N. Green building between tradition and modernity study comparative analysis between conventional methods and updated styles of design and architecture processors. *Renew. Energy Sustain. Dev* [2017;3\(1\):155–163.](#)
40. Moussa RR. The reasons for not implementing green pyramid rating system in egyptian buildings. *Ain Shams Eng. J.* [2019;10\(4\):917–927.](#)
41. Abd El-Hafeez M, El-Mokadem A, Sallam I, et al. Adapting the green pyramid rating system for assessing zero energy concept on neighborhoods level. *Port-Said Eng. Res. J* [2014;18\(1\):153–160.](#)
42. Hazem N, Abdelraouf M, Fahim IS, et al. A novel green rating system for existing buildings. *Sustain.* [2020;12\(17\):1–15.](#)
43. Najjar M, Figueiredo K, Palumbo M, et al. Integration of BIM and LCA: Evaluating the environmental impacts of building materials at an early stage of designing a typical office building. *J Build Eng.* [2017;14:115–126.](#)
44. Finkbeiner M, Schau EM, Lehmann A, et al. Towards life cycle sustainability assessment. *Sustainability.* [2010;2\(10\):3309–3322.](#)
45. Fernández-Solís JL, Mutis I. The Idealization of an Integrated BIM, Lean, and Green Model (BLG), in: *green Technol. US: IGI Global.* [2011.](#)1979–2011. DOI:[10.4018/978-1-60960-472-1.ch809.](#)