A Novel Green Rating System for Existing Buildings

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Received: 11 July 2020; Accepted: 25 August 2020; Published: 1 September 2020

Abstract: Green buildings are becoming an essential part of sustainable development. There have been several research trends for green buildings since 1995. The present study presents a roadmap for green/sustainable research trends and proposes a new green building rating system for existing buildings. A questionnaire was established and answered by experts, where answers were analyzed using the decision-making tool Analytical Hierarchy Process. Analytical Hierarchy Process is responsible for weighing and ranking the weights of alternatives. A novel checklist for existing buildings was structured and consisted of seven main categories, each comprised of different subcategories with different weights according to their importance and priority. The newly proposed rating system and Leadership in Energy and Environmental Design (LEED) for maintenance and renovations were both used to evaluate a Nile University building in Egypt in order to identify how the environment affects the results of each rating system. The results showed that each rating system has its own criteria in evaluating the sustainability level of the building, which are each based on the country’s cultural and environmental conditions.

Keywords: green buildings; sustainability; construction; research trend; energy efficiency; green pyramids; Analytical Hierarchy Process (AHP)

1. Introduction

Sustainability and green buildings have become vital to maintaining a certain life quality level for future generations. Accordingly, several international governments have started to develop new rating systems and sustainable development standards, such as Leadership in Energy and Environmental Design (LEED), to boost their development plans, goals, and objectives.

Since 1990, there have been extensive debates on the definition of green or sustainable building [1]. According to Zabihi et al. (2012), several attempts have been made to define green buildings worldwide in terms of sustainable construction, sustainable building, green construction, and high-performance buildings [2]. For instance, the Organization of Economic Cooperation and Development defines sustainable buildings as those with the least negative impact on the environment, aiming for enhanced economic, social, and environmental quality [3,4]. Additionally, Yudelson (2008) defined sustainable construction as “a high-performance property that considers and reduces its impact on the environment and human health” [5,6]. The above definitions show that green building and sustainable construction comprise the entire life of the building, taking into account different aspects (e.g., environmental and...
operating) and future economic value in order to minimize negative impacts and maximize the positive to achieve an environmental, economic, and social balance [2,7].

In the early twentieth century, many reviews focused on green building research trends [8]. Countries started to pay more attention to the field of green building research because its outcomes help greatly in accomplishing their sustainable development plans and goals. Publication of such reviews is critical as they provide a better understanding and insights for areas and sectors that need improvement [9]. According to Hong et al. (2012), the degree of industrial growth in a specific area/sector of a country is influenced by the number of research outcomes published on this area/sector in that country [10]. Therefore, it is essential for developing countries, such as Egypt, to keep a record of the research being done on green buildings for better implementation of sustainable development.

In 2016, a critical review of green building research was completed by Darko and Chan through examining and analyzing green building-related studies published in several selected construction management journals in developed and developing countries [9,11]. They found that 90% of the articles were published by researchers from developed countries, such as the US, Hong Kong, the UK, Singapore, and Italy. On the other hand, developing countries in the Middle East and North Africa region, such as Egypt, had the least input, reflecting the lack of research on green buildings in these countries.

According to the UN, Egypt is facing many environmental challenges, starting with population increase, which results in less water per capita each year [12]. With the aim of supporting sustainable building and construction, Egypt has begun to promote sustainable buildings/construction as a step towards saving energy, reducing water usage, and implementing green buildings through setting green standards and regulations for new buildings [13]. Egypt has two rating systems, Green Pyramid Rating System (GPRS) and TARSHEED. In 2011, the Housing and Building Research Center developed the GPRS, followed by a second version in 2017 that is based on the third version of LEED [14]. The GPRS consists of seven main categories: Sustainable Sites, Energy Efficiency, Water Efficiency, Materials and Resources, Indoor Environmental Quality, Management Protocols, and Innovation [15,16]. Recently, the Egypt Green Building Council established TARSHEED, a national rating system that consists of three main categories: Energy Efficiency, Efficient Water Usage, and Sustainable Habitat [17].

Although Egypt has initiated steps towards achieving greenness and sustainability through introducing green building rating systems, and there are several LEED-certified buildings, LEED and GPRS are quite similar as GPRS is based on the US LEED, even though there are considerable differences between the two countries in many spatial features. However, the LEED rating system cannot be applied in Egypt due to the great environmental and cultural differences between the US and Egypt. For instance, solid waste management falls under the Materials and Resources category, although it should be stated individually in a separate category as it is one of the main challenges facing Egypt. On the other hand, the TARSHEED rating system focuses on three key categories to assess the performance of sustainable building [16]. The latter rating system ignores some categories that are one of the challenges facing Egypt, such as waste, health, and management. Moreover, no rating systems for existing buildings have been established yet in Egypt, although there have been some research efforts using the decision-making tool Analytical Hierarchy Process (AHP) to create a rating system focusing on specific categories, whether in new construction or existing buildings. None of these studies have addressed all categories for existing buildings.

Abdel Azim et al. (2017) recommended criteria for energy performance evaluation of existing office buildings in Egypt [18]. They reviewed various international rating systems to sum up their energy criteria. The most essential and relevant international energy criteria that cover all the energy use aspects and environmental impacts of existing buildings were gathered. The opinions of engineering specialists in Egypt concerning the applicability and importance of the identified energy criteria were acquired using a questionnaire in order to rank these criteria into prerequisites (mandatory) and credits (optional), and then credit weights were obtained using the AHP. Based on the above, research efforts in Egypt using the AHP to create a rating system have so far only focused on specific categories, whether
in new construction or existing buildings; however, none have addressed all categories for existing buildings as well as established new categories essential for Egypt.

The present study seeks to fill the research gap in the green building rating systems field in developing countries through introducing a new rating system for existing buildings in Egypt that suits the environmental aspects of the country. The aims of this study were to: (1) propose a new rating system for existing buildings in Egypt covering all categories, (2) use the AHP tool to prioritize categories and credits as well as their scoring and weights, (3) introduce an assessment by applying LEED to existing buildings, particularly the operations and maintenance rating system to a private Nile University (NU) building, (4) use the proposed rating system for existing buildings in the assessment of the NU building, and (5), based on the results of the assessment of the NU building, a comparative analysis was performed between these results in order to identify the degree of similarities and differences between the results of the two rating systems. The present study begins with a literature review referencing publications on green building research and the topics/subtopics covered, followed by description of the methodology used in the current study to establish a rating system for existing buildings that suits the environment in Egypt and calculates the weights. Then, the results of the current study are presented and interpreted, followed by a conclusion.

2. Literature Review

2.1. Annual Trend of Publications on Green Buildings in Egypt

Green building research has recently become one of the most critical topics in the construction management field. To increase awareness in this field, academic organizations have started to introduce green building elements into their programs of study [9]. From 1995 to 1999, one study was published discussing solid waste management, suggesting that the concept of green building was not flourishing at that time. From 2000 to 2004, the number of relevant publications increased to nine because awareness in enhancing the concept of green architecture, recycling wastes, and developing sustainable materials increased during this period. The period from 2005 to 2009 produced almost the same number of publications, but they discussed managing wastes through sustainable guidelines; since then, the sustainable development concept has started to boom. Since 2010, there has been significant growth in publications, reaching 40 in 2013. Publications during this period discussed more areas, including energy efficiency, evaluation of newly developed rating systems of the time, and development of new rating systems in Egypt. A brief review of the literature reveals a significant increase in green building research in the last 20 years, in line with establishing GPRS and TARSHEED rating systems.

3. Author Contributions and Current Status of Research Topics

A significant number of Egyptian researchers have published in the field of green buildings in international journals. Of the 134 authors found who contributed to this research in Egypt, the majority were Egyptian. Therefore, a list of international journals was studied as well as the number of publications in each journal. Most of the resulting papers were published in Sustainability and Buildings and Energy Procedia journals. Then, the number of publications decreased gradually from five to two in Developing Country Studies, while the rest of the journals had only one publication. There are 13 papers published in national journals. This small number of publications in each journal indicates that there is a need for more studies to be conducted in this research area. Figure 1 shows the classification of topics covered by previously published papers, where the least covered topic is AHP. These topics were further classified into subtopics in Figure 2.

One-third of the papers focused on management and technology. This topic covered three main subtopics, the first of which involved introducing framework and guidelines for achieving sustainability in Egypt from different perspectives, including construction, architecture, urban development, sustainable industrialization, tourism, and cost. The second subtopic was developing ecological design principles for green buildings, and the last subtopic was using simulation and modeling
technology to encourage sustainable designs. The green rating systems topic was the second most popular topic, aimed at improving sustainability concepts, proposing global evaluation standards for new and existing green buildings, and discussing the obstacles of applying the GPRS and LEED on projects in Egypt. Energy efficiency came in third after green rating systems, covering the following subtopics in sequence: (1) using technologies for improving energy efficiency, (2) using renewable energy as an energy source, and (3) proposing a policy framework for implementing green building codes and developing energy rating systems for existing buildings as well as enhancing energy credits in the GPRS.

Figure 1. Green building (GB) research topics covered in Egypt. AHP, Analytical Hierarchy Process.

Figure 2. Green building research subtopics covered in Egypt. AHP, Analytical Hierarchy Process; GPRS, Green Pyramid Rating System; LEED, Leadership in Energy and Environmental Design.

Of the selected research papers, 10% discussed the topic of waste management, which was tackled from different perspectives. The first perspective was recycling concrete, industrial waste, and demolition waste. The second perspective was reducing project wastes through achieving sustainability, while the third was evaluation of solid waste management, which is important in deciding the best options. The other three topics were green materials, the AHP tool, and review papers. Some papers considered using alternative building materials to improve construction, with some of
the proposed alternative materials being produced from wastewater. Others proposed development of frameworks for evaluating sustainable materials.

AHP tools have been used to develop rating systems for Egypt and the Middle East and North Africa region. Figure 2 shows that developing rating systems using the AHP is one of the least discussed topics, followed by developing energy rating systems for new and existing buildings; renewable energy is the least discussed. Accordingly, more research attention should be focused on these fields by proposing new rating systems using different tools. The present study proposes a new rating system for existing buildings using the AHP as a step towards applying green concepts in Egypt and other developing countries.

4. Methodology

The following process was conducted in the present study to assist in proposing a new rating system for existing buildings in Egypt:

4.1. Systematic Desktop Searches

A systematic, powerful desktop search using major scientific databases to obtain insight into available publications and author contributions in the green building field was conducted, and a valued platform in this field, specifically green building rating systems, was created.

4.2. Study of Selected Rating Systems

The development of a new green building rating system that suits the local environment of Egypt requires the study of related rating systems. Accordingly, two rating systems were selected: (1) the GPRS, as it is the first established and most famous rating system in Egypt, and (2) LEED for maintenance and renovations because there is no rating system for existing buildings in Egypt.

4.3. Comparative Analysis between Selected Rating Systems

The comparison was done between the main categories of the selected rating systems as there are categories that exist in some rating systems that are absent in others according to the local context of each country. Furthermore, a comparison was carried out between some subcategories that exist as a mandatory credit in some rating systems and are optional in others. A preliminary checklist was developed consisting of seven categories: (1) Sustainable Sites, (2) Water Efficiency, (3) Energy Efficiency, (4) Materials and Resources, (5) Indoor Quality Management, (6) Waste Management, and (7) Innovation. The entries (subcategories) of the checklist were identified based on the desktop search and comparative analysis.

4.4. Questionnaire

A questionnaire was developed from the established categories and subcategories list to perform the AHP analysis. Professionals in the industry were asked whether the questionnaire was valid or not and to apply any required modifications regarding categories, credits, and format. A pairwise scale, which represents the importance of variables, is illustrated in Table 1, where the scale ranges from 1 to 5. Each number represents the importance of each criteria to the other alternatives.

| Important Scale | Definition of Important Scale                  |
|-----------------|-----------------------------------------------|
| 1               | Equally important preferred                   |
| 2               | Moderately important preferred                |
| 3               | Strongly important preferred                  |
| 4               | Very Strongly important preferred             |
| 5               | Extremely important preferred                 |
Table 2 is an example of the AHP questionnaire, demonstrating the relative importance of options A and B:

- If the option “Construction Activity Pollution Prevention” in column A is strongly more important than the option “Site Selection” in column B, then mark 3 with an (X) on the left-hand side.
- If the option “Community Services and Connectivity” in column B is moderately more important than the option “Construction Activity Pollution Prevention” in column A, then mark 2 with an (X) on the right-hand side.

| A Options                                      | B Options                        |
|-----------------------------------------------|----------------------------------|
| Construction Activity Prevention              | Site Selection                   |
| Extremely                                     | 5                                |
| Very Strongly                                 | 4                                |
| Strongly                                      | 3 *                              |
| Equally                                       | 2                                |
| Moderately                                    | 1                                |
| Strongly                                      | 2 *                              |
| Very Strongly                                 | 3                                |
| Extremely                                     | 5                                |

* means that the marked option is more important than the other.

4.5. AHP

Based on the filled questionnaire, the AHP method was applied. This process is a decision-making tool that gives the weights of each category and subcategory as well as prioritizes and ranks the credits according to their importance in order to determine which criteria are mandatory (i.e., prerequisites) and which are optional (i.e., credits) [18]. A final checklist for the new rating system for existing buildings was established that included the main categories and subcategories with their mandatory and optional credits and their corresponding weights. The AHP analysis was applied using the following steps:

(1) The questionnaire was emptied in a matrix, where the results of the questionnaire were converted into numbers 1, 2, 3, 4, and 5 and 1/2, 1/3, 1/4, and 1/5 based on the importance of each criterion to the other alternatives, and a pairwise comparison matrix was developed for each criterion (Table 3).

(2) The resulting matrix was normalized (Table 4), which meant calculating the priority of each criterion according to its contribution to the overall goal. This was applied through two steps:

(a) The values in each column of the pairwise comparison matrix were summed.

(b) Each element in the pairwise comparison matrix was divided by the sum of the values in each column. The resulting matrix was called a normalized pairwise comparison matrix.

(3) Consistency analysis was applied to ensure original preference ratings were consistent, and a consistency ratio was calculated, and its value checked. If the consistency ratio is very large (Saaty suggests >0.1), then the questionnaire is not consistent enough, and it is best to go back and revise the comparisons [19,20]. The following steps were followed to calculate consistency:

(a) Each value in the first column of the pairwise comparison matrix was multiplied by the priority of the first item; the same was done for the rest of the columns (Table 5).

(b) Values across rows were summed to get a vector of values called “Weighted Sum”.

(c) Elements of the Weighted Sum vector were divided by the corresponding priority for each criterion to get Sum/Weight.

(d) The average of the values in Sum/Weight was calculated and expressed as $\lambda_{\text{max}}$. 

(e) Then the Consistency Index (CI) was calculated:

\[ CI = (\lambda_{\text{max}} - n) / (n - 1) \]

where \( n \) is the number of items (criteria) being compared (Table 5).

(4) The geometric mean (GM) was calculated for all participant answers (Table 6). Each questionnaire was consistent, which means participant answers were consistent, meaning that if \( A > B \) and \( B > C \), then \( A \) must be greater than \( C \). If the answer is not \( A > C \), then there is inconsistency in the comparisons.

\[ GM = (a_{1ij} \times a_{2ij} \times \ldots \times a_{kij})^{1/k} \]

where \( k \) is the number of participants.

Table 3. Sample of Analytical Hierarchy Process comparison-paired matrix.

| Item Description | 1   | 2   | 3   | 4   | 5   |
|------------------|-----|-----|-----|-----|-----|
| 1                | 1.00| 2.00| 2.00| 4.00| 5.00|
| 2                | 0.50| 1.00| 3.00| 4.00| 4.00|
| 3                | 0.50| 0.33| 1.00| 4.00| 5.00|
| 4                | 0.25| 0.25| 0.25| 1.00| 4.00|
| 5                | 0.20| 0.25| 0.20| 0.25| 1.00|
| Sum              | 2.45| 3.83| 6.45| 13.25| 19.00|

Table 4. Sample of Analytical Hierarchy Process normalization.

|   | 1   | 2   | 3   | 4   | 5   | Weight |
|---|-----|-----|-----|-----|-----|--------|
| 1 | 0.41| 0.52| 0.31| 0.30| 0.26| 36.10% |
| 2 | 0.20| 0.26| 0.47| 0.30| 0.21| 28.85% |
| 3 | 0.20| 0.09| 0.16| 0.30| 0.26| 20.22% |
| 4 | 0.10| 0.07| 0.04| 0.08| 0.21| 9.84%  |
| 5 | 0.08| 0.07| 0.03| 0.02| 0.05| 4.99%  |

Table 5. Sample of Analytical Hierarchy Process Consistency Index and Consistency Ratio Calculations Matrix.

|   | 1   | 2   | 3   | 4   | 5   | SUM   | SUM/Weight |
|---|-----|-----|-----|-----|-----|-------|------------|
| 1 | 0.36| 0.58| 0.40| 0.39| 0.25| 1.99  | 5.30       |
| 2 | 0.18| 0.29| 0.61| 0.39| 0.20| 1.67  | 5.78       |
| 3 | 0.18| 0.10| 0.20| 0.39| 0.25| 1.12  | 5.55       |
| 4 | 0.09| 0.07| 0.05| 0.10| 0.20| 0.51  | 5.19       |
| 5 | 0.07| 0.07| 0.04| 0.02| 0.05| 0.26  | 5.20       |

Table 6. Sample of the geometric mean of all participants calculations matrix.

| Item Description | 1   | 2   | 3   | 4   | 5   |
|------------------|-----|-----|-----|-----|-----|
| 1                | 1.00| 1.23| 2.17| 2.90| 3.40|
| 2                | 0.81| 1.00| 2.17| 3.50| 3.52|
| 3                | 0.46| 0.46| 1.00| 3.07| 4.04|
| 4                | 0.34| 0.29| 0.33| 1.00| 4.01|
| 5                | 0.29| 0.28| 0.25| 0.25| 1.00|
| Sum              | 2.91| 3.26| 5.91| 10.72| 15.97|

The comparison-paired matrix of the geometric mean was put through the same steps to get the final weights and to check the consistency of the answers.
4.6. NU Case Study

The newly established green building rating system was applied to the NU building located in Giza, Egypt, as a case study. Accordingly, data were collected concerning the university through interviews conducted individually, with certain people in the university responding to questions regarding monthly electricity and water bills, solid waste and rainwater management, number of motion sensor switches and timers used, type of light bulbs used, programmable thermostats installed or not, and number of Heating, Ventilation, and Air Conditioning (HVAC) systems. The NU building was assessed using the newly established rating system and LEED for maintenance and renovations, where it was weighted based on participant responses.

5. Results and Discussions

5.1. Newly Proposed Rating System for Existing Buildings

The lowest percentage of the research topics covered in the papers related to the field of green buildings in Egypt involved use of the AHP. Therefore, the present study employed the AHP to the results of the questionnaire. A checklist was then produced and classified into seven main categories, each containing several subcategories, which have their own calculated weight (Table 7). The checklist for rating systems for existing buildings resulting from the AHP analysis is shown in Table 7. The criteria with the highest weights of all subcategories are Disposal in the Waste Management category followed by Wastewater Reuse in the Water Efficiency category and Sustainable Purchasing Policy in the Materials and Resources category. The highest weight in each category is considered a mandatory credit, while the others are considered optional credits, except for the Innovation and Added Value category, which was considered as extra points. For the Innovation and Added Value category, there were no values for the subcategory as there was only one item in which there were no other items to be compared with in the questionnaire.

The results are very satisfying as one of the main challenges in Egypt is waste management and water issues and should encourage researchers to focus more effort on green building rating system research in Egypt. In particular, this should support the introduction of new rating systems for both new and existing buildings, depending on the type of each building. However, the criteria with the lowest weights is Energy-efficient HVAC Systems, falling under the Energy Efficiency category. This might be explained by the fact that the present study focuses mainly on the existing building, where it is difficult to replace already existing systems with energy efficient ones due to costs, but methods should be examined to improve the energy efficiency. As a step towards promoting more efficient usage of energy, the Egyptian government prepared a national plan for energy efficiency [21], while the Supreme Energy Council of Energy supports efforts to encourage new projects to use renewable energy technology, specifically wind and solar, and enhance hydro energy efficiency. The present research encourages developing countries to adopt green building practices and guidelines as a step towards implementing the green building concept.

The decision-making tool AHP was used to choose the most vital criteria and sub criteria to establish a new rating system and achieve the desired sustainability. This tool permits the decision maker to judge how well an alternative can succeed to meet overall sustainability goals. Moreover, it can draw the decision maker’s attention to various fields where the chosen alternative can be exchanged for a better one that achieves all sustainability goals. The AHP tool is based on the opinion of different professionals in the sustainability field through a questionnaire.
Table 7. Proposed green building checklist for rating system in Egypt.

| Rating System for Existing Buildings | Checklist | Points |
|-------------------------------------|-----------|--------|
| **Sustainable Sites (SS)**          | Building Exterior and Hardscape Management Plan | 0.286  |
|                                     | Alternative Transportation Program            | 0.264  |
|                                     | Site Development                               | 0.181  |
|                                     | Storm/Rainwater Design—Quantity and Quality Control | 0.122 |
|                                     | Heat Island Effect—Green Space, Hardscape, and Building | 0.094 |
|                                     | Exterior Light Pollution Reduction             | 0.054  |
| **Energy and Atmosphere (EA)**      | Building Operating Plan                        | 0.177  |
|                                     | Fundamental Refrigerant Management             | 0.153  |
|                                     | Minimum Energy Performance                     | 0.151  |
|                                     | Existing Building Commissioning—Investigation and Analysis | 0.139 |
|                                     | Existing Building Commissioning—Implementation| 0.102  |
|                                     | Existing Building Commissioning—Ongoing Commissioning | 0.089 |
|                                     | Performance Management—Building Automation System | 0.066 |
|                                     | Performance Management—System level metering   | 0.052  |
|                                     | Renewable Energy Sources                       | 0.044  |
|                                     | Energy-efficient HVAC Systems                  | 0.03   |
| **Water Efficiency (WE)**           | Wastewater Reuse                               | 0.313  |
|                                     | Water Efficient Landscaping                    | 0.289  |
|                                     | Water Efficient Fixtures                       | 0.203  |
|                                     | Metering and Leak Detection System             | 0.071  |
| **Materials & Resources (MR)**      | Sustainable Purchasing Policy                  | 0.291  |
|                                     | Renewable Materials and Materials Manufactured using Renewable Energy | 0.209 |
|                                     | Reduction of Overall Material Use              | 0.205  |
|                                     | Alternative Building Prefabricated Elements    | 0.143  |
|                                     | Environment—Friendly, Sound, and Thermal Insulation Materials | 0.092 |
|                                     | Regionally Procured Materials and Products      | 0.059  |
| **Indoor Environmental Quality (IEQ)** | Green Cleaning Policy                          | 0.211  |
|                                     | Minimum Indoor Air Quality Performance         | 0.198  |
|                                     | Indoor Air Quality Best Management Practices    | 0.146  |
|                                     | Light Pollution Reduction                      | 0.145  |
|                                     | Enhance Ventilation Performance                | 0.114  |
|                                     | Thermal Comfort                               | 0.085  |
|                                     | Visual Comfort                                | 0.059  |
|                                     | Acoustic Comfort                              | 0.042  |
| **Waste Management**                | Disposal                                      | 0.384  |
|                                     | Spaces for Collecting and Sorting of Waste     | 0.276  |
|                                     | Contract with Specialized Company in Waste Removal | 0.155 |
|                                     | Recycling Wastes Onsite/Offsite                | 0.116  |
|                                     | Storage and Collection of Recyclables          | 0.069  |
| **Innovation and Added Value (IN)** | Innovation and Added Value                     |        |
5.2. Evaluation of NU Using the Proposed Rating System for Existing Buildings and LEED for Maintenance and Renovations

The NU building was evaluated using the newly proposed and LEED rating systems in order to compare their results and show how each assesses the sustainability of the building and how the environmental change may affect the evaluation results. The collected data about the building are as follows:

- The selected building undergoes a daily electric reading.
- There are no readings for water consumption.
- Concerning waste management, there is no recycling for waste, but there is a specialized company that collects the waste.
- Though waste is not recycled, consumed maintenance materials are recycled and reused.
- There is no plan for collecting rainwater and reusing it, but there are manholes in the roof to drain the rainwater in desert areas.
- The university has a building management system (Figure 3) that controls the HVAC systems, generators, and lighting.
- There are 134 fan coils and 64 splits. There are also about 250 sensors for heating, smoking, and control modules.
- All bathrooms have sensors, and the building has begun using LED bulbs.
- Solar lighting is being used for the landscaping.
- There are 18 ventilation systems.

![Figure 3. Samples of the building management systems in the Nile University building.](image)

5.2.1. Evaluation of LEED for Existing Buildings (Maintenance and Renovations)

The results of the NU building evaluation using the LEED rating system for existing buildings are shown in Table 8. Most of the prerequisites were not achieved according to LEED for the existing buildings checklist, except for tobacco smoke control. Furthermore, no innovation or added value was achieved.

5.2.2. Proposed Green Building Rating System Evaluation

Table 9 shows the results of the NU building evaluation using the newly proposed rating system. The results consist of the same categories as those of LEED for existing buildings, but the subcategories differ, and there is a new Waste Management category. Additionally, the checklist does not include regional priority credits.
Table 8. Evaluation of Nile University building using Leadership in Energy and Environmental Design (LEED) for existing buildings.

| LEED 2009 for Existing Buildings: Operations & Maintenance | Sustainable Sites | 100% |
|-----------------------------------------------------------|-------------------|------|
| Credit 1 LEED Certified Design and Construction           | 0                 | 15   |
| Credit 2 Building Exterior and Hardscape Management Plan  | 3                 | 4    |
| Credit 3 Integrated Pest Management, Erosion Control, and Landscape Management Plan | 3 | 4 |
| Credit 4 Alternative Commuting Transportation              | 29                | 58   |
| Credit 5 Site Development—Protect or Restore Open Habitat | 3                 | 4    |
| Credit 6 Stormwater Quantity Control                       | 3                 | 4    |
| Credit 7.1 Heat Island Reduction—Non-Roof                  | 1                 | 4    |
| Credit 7.2 Heat Island Reduction—Roof                       | 0                 | 4    |
| Credit 8 Light Pollution Reduction                         | 2                 | 4    |

**Energy and Atmosphere**

| Credit 1 Optimize Energy Efficiency Performance | 0 | 51 |
| Credit 2.1 Existing Building Commissioning—Investigation and Analysis | 0 | 6 |
| Credit 2.2 Existing Building Commissioning—Implementation | 1 | 6 |
| Credit 2.3 Existing Building Commissioning—Ongoing Commissioning | 5 | 6 |
| Credit 3.1 Performance Measurement—Building Automation System | 3 | 6 |
| Credit 3.2 Performance Measurement—System-Level Metering | 3 | 6 |
| Credit 4 On-site and Off-site Renewable Energy            | 0 | 17 |
| Credit 5 Enhanced Refrigerant Management                  | 0 | 3 |
| Credit 6 Emissions Reduction Reporting                     | 0 | 3 |

**Water Efficiency**

| Credit 1 Water Performance Measurement                     | 0 | 14 |
| Credit 2 Additional Indoor Plumbing Fixture and Fitting Efficiency | 0 | 36 |
| Credit 3 Water Efficient Landscaping                        | 25 | 36 |
| Credit 4 Cooling Tower Water Management                      | 0 | 14 |

**Materials and Resources**

| Credit 1 Sustainable Purchasing—Ongoing Consumables       | 0 | 10 |
| Credit 2 Sustainable Purchasing—Durable Goods             | 0 | 20 |
| Credit 3 Sustainable Purchasing—Facility Alterations and Additions | 0 | 10 |
| Credit 4 Sustainable Purchasing—Reduced Mercury in Lamps  | 1 | 10 |
| Credit 5 Sustainable Purchasing—Food                       | 0 | 10 |
| Credit 6 Solid Waste Management—Waste Stream Audit        | 0 | 10 |
| Credit 7 Solid Waste Management—Ongoing Consumables       | 0 | 10 |
| Credit 8 Solid Waste Management—Durable Goods             | 0 | 10 |
| Credit 9 Solid Waste Management—Facility Alterations and Additions | 0 | 10 |
Table 8. Cont.

| Prereq 1 | Minimum indoor air quality IAQ Performance not achieved |
| Prereq 2 | Environmental Tobacco Smoke (ETS) Control achieved |
| Prereq 3 | Green Cleaning Policy not achieved |
| Credit 1.1 | Indoor Air Quality Best Management Practices—Indoor Air Quality Management Program 0 7 |
| Credit 1.2 | Indoor Air Quality Best Management Practices—Outdoor Air Delivery Monitoring 0 7 |
| Credit 1.3 | Indoor Air Quality Best Management Practices—Increased Ventilation 5 7 |
| Credit 1.4 | Indoor Air Quality Best Management Practices—Reduce Particulates in Air Distribution 0 7 |
| Credit 1.5 | Indoor Air Quality Best Management Practices—Facility Alterations and Additions 0 7 |
| Credit 2.1 | Occupant Comfort—Occupant Survey 1 7 |
| Credit 2.2 | Controllability of Systems—Lighting 3 7 |
| Credit 2.3 | Occupant Comfort—Thermal Comfort Monitoring 1 7 |
| Credit 2.4 | Daylight and Views 5 7 |
| Credit 3.1 | Green Cleaning—High Performance Cleaning Program 0 7 |
| Credit 3.2 | Green Cleaning—Custodial Effectiveness Assessment 0 7 |
| Credit 3.3 | Green Cleaning—Purchase of Sustainable Cleaning Products and Materials 0 7 |
| Credit 3.4 | Green Cleaning—Sustainable Cleaning Equipment 0 7 |
| Credit 3.5 | Green Cleaning—Indoor Chemical and Pollutant Source Control 0 7 |
| Credit 3.6 | Green Cleaning—Indoor Integrated Pest Management 0 7 |

Innovation in Operations 0 100

| Credit 1.1 | Innovation in Operations: Specific Title 0 17 |
| Credit 1.2 | Innovation in Operations: Specific Title 0 17 |
| Credit 1.3 | Innovation in Operations: Specific Title 0 17 |
| Credit 1.4 | Innovation in Operations: Specific Title 0 17 |
| Credit 2 | LEED Accredited Professional 0 17 |
| Credit 3 | Documenting Sustainable Building Cost Impacts 0 17 |

Regional Priority Credits 0 100

| Credit 1.1 | Regional Priority: Specific Credit 0 25 |
| Credit 1.2 | Regional Priority: Specific Credit 0 25 |
| Credit 1.3 | Regional Priority: Specific Credit 0 25 |
| Credit 1.4 | Regional Priority: Specific Credit 0 25 |

Figure 4 summarizes the results of the NU building evaluation using the newly proposed and LEED rating systems. In the Sustainable Sites category, the building achieved 62% with the proposed rating system and 43% with LEED, while the Energy Efficiency category achieved 30% with the proposed rating system and 13% with LEED for existing buildings.

In the Water Efficiency category, the percentages are similar to a great extent, whereas there is a huge difference between the percentages achieved in the Materials and Resources (proposed system, 32%; LEED, 1%) and Indoor Environmental Quality (proposed system, 64%; LEED, 15%) categories. The Waste Management category achieved 54% with the proposed rating system, but could not be evaluated by LEED because the category does not exist. Clearly, each rating system has its own criteria for evaluating the sustainability level of the building, which is based on the cultural and environmental conditions of the country. Based on the resultant percentages in most categories, most of the LEED criteria is not applicable to the nature of Egypt. For instance, the extreme difference in system rating in the Materials and Resources category stems from the fact that most of the LEED items are very expensive if purchased in Egypt and difficult to obtain locally.
Table 9. Evaluation of Nile University building using the proposed rating system for existing buildings.

| Rating System for Existing Buildings | Checklist                                                                 | Sustainable Sites (SS) | 62 | 100% |
|-------------------------------------|---------------------------------------------------------------------------|------------------------|----|------|
| Building Exterior and Hardscape Management Plan | 23 | 29 |
| Alternative Transportation Program | 13 | 26 |
| Site Development | 14 | 18 |
| Storm/Rainwater Design (Quantity and Quality Control) | 6 | 12 |
| Heat Island Effect (Green Space, Hardscape, and Building) | 2 | 9 |
| Exterior Light Pollution Reduction | 3 | 5 |
| Energy & Atmosphere (EA) | 30 | 100% |
| Building Operating Plan | 5 | 18 |
| Fundamental Refrigerant Management | 0 | 15 |
| Minimum Energy Performance | 0 | 15 |
| Existing Building Commissioning (Investigation and Analysis) | 0 | 14 |
| Existing Building Commissioning (Implementation) | 2 | 10 |
| Existing Building Commissioning (Ongoing Commissioning) | 7 | 9 |
| Performance Management (Building Automation System) | 5 | 7 |
| Performance Management (System Level Metering) | 4 | 5 |
| Renewable Energy Sources | 4 | 4 |
| Energy-efficient HVAC Systems | 2 | 3 |
| Water Efficiency (WE) | 20 | 100% |
| Wastewater Reuse | 0 | 31 |
| Water Efficient Landscaping | 20 | 29 |
| Water Efficient Fixtures | 0 | 20 |
| Metering and Leak Detection System | 0 | 7 |
| Materials & Resources (MR) | 32 | 100% |
| Sustainable Purchasing Policy | 3 | 29 |
| Renewable Materials and Materials Manufactured using Renewable Energy | 0 | 21 |
| Reduction of Overall Material Use. | 21 | 21 |
| Alternative Building Prefabricated Elements | 0 | 14 |
| Environment—Friendly, Sound, and Thermal Insulation Materials. | 5 | 9 |
| Regionally Procured Materials and Products. | 3 | 6 |
| Indoor Environmental Quality (IEQ) | 64 | 100% |
| Green Cleaning Policy | 0 | 21 |
| Minimum Indoor Air Quality Performance | 16 | 20 |
| Indoor Air Quality Best Management Practices | 12 | 15 |
| Light Pollution Reduction | 12 | 15 |
| Enhance Ventilation Performance | 9 | 11 |
| Thermal Comfort | 7 | 9 |
| Visual Comfort | 5 | 6 |
| Acoustic Comfort | 3 | 4 |
| Waste Management | 54 | 100% |
| Disposal | 38 | 38 |
| Spaces for Collecting and Sorting of Waste | 0 | 28 |
| Contract with Specialized Company in Waste Removal | 16 | 16 |
| Recycling Wastes Onsite/Offsite | 0 | 12 |
| Storage and Collection of Recyclables | 0 | 7 |
| Innovation and Added Value (IN) | 0 | 100% |
| Innovation and Added Value | 0 | 0 |
6. Conclusions

Green building in Egypt is a major problem facing the construction industry due to increasing concerns associated with climate change and sustainability worldwide. Unfortunately, there is a deficiency of research in the green building field in Egypt and other developing countries, and the present study is lacking several topics that have not been tackled in recent studies, such as policies for green buildings and numerical methods for assessing green ratings. Proposing a new rating system for existing buildings in Egypt will help in solving some of the challenges facing the country. The current AHP analysis results revealed that waste management and water are the main challenges facing Egypt today. In addition, this analysis focuses on exerting more efforts on green building rating systems research in Egypt, with the aim of developing better rating systems for new construction and existing buildings that depend on building types and suits all environmental aspects in Egypt.

The principles of green architecture have not yet been given enough attention, and there are many factors being neglected while designing buildings, such as choosing the appropriate materials and designs to suit the environment. However, when the previously mentioned factors are considered, they are not taken based on scientific methods. Accordingly, human health and comfort are affected by poor indoor environmental quality. The present study integrates the design and environmental impact of the design through setting guidelines and standards to ensure the quality of the building and assessing the impact of the building/construction on the environment. The current study also includes the possibility of converting existing buildings into green ones by (1) reducing the energy consumption, (2) following passive strategies to reduce the energy required for heating or cooling during different seasons, (3) minimizing water usage by using certain types of irrigation, and (4) modifying windows to benefit from solar heat and, at the same time, achieving occupant comfort. Furthermore, the present study will serve as a roadmap for future studies to advance the field of green building research in developing countries, including Egypt, and conduct more related projects, as well as being a step towards analyzing existing buildings and converting them to green and sustainable buildings.

**Author Contributions:** Conceptualization, I.S.F., S.E.-O. and M.A.; methodology, N.H. and I.S.F.; software, N.H.; validation, S.E.-O., M.A. and I.S.F.; formal analysis, S.E.-O. and I.S.F.; investigation, N.H.; resources, N.H., M.A. and I.S.F.; data curation, N.H., M.A. and I.S.F.; writing—original draft preparation, N.H., M.A. and I.S.F.; writing—review and editing, S.E.-O., M.A. and I.S.F.; supervision, S.E.-O. and I.S.F.; project administration, I.S.F.; funding acquisition I.S.F. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.
Conflicts of Interest: The authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest.

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