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REVIEW ARTICLE

Modeling Sustainability Standards and Evaluation Systems in High-Rise Buildings: Systematic Review

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ABSTRACT

This review highlights the importance of sustainability in the construction sector, focusing on residential and high-rise buildings. It aims to provide a framework for evaluating the environmental, social, and economic impact of these buildings and propose design options that enhance energy efficiency and reduce resource consumption. Using bibliometric and content analysis methods, the research identifies and quantifies relevant studies on sustainability in high-rise residential buildings and extracts key sustainable practices and principles for a comprehensive comparison of different sustainability assessment systems. Key findings indicate that implementing sustainable standards in residential towers significantly enhances energy efficiency, reduces harmful emissions, and promotes effective waste management. A case study of a tower in Basilea City demonstrated that these standards can lead to substantial energy consumption reductions through optimized design alternatives. The study concludes that integrating sustainability criteria into residential tower design and construction is essential for achieving long-term environmental, social, and economic benefits, emphasizing the need to adopt internationally recognized sustainability assessment systems.

Keywords: Sustainability ▪ Green buildings ▪ Sustainable design ▪ Sustainability assessment systems ▪ Sustainable practices

1. INTRODUCTION

High-rise buildings in Syria face significant challenges related to the application of sustainability standards and systems, as there are no specific criteria for modeling these systems [1]. Additionally, there is a lack of interest in applying sustainable design standards and a deficiency in studying the efficiency of buildings in energy and resource use, especially given the current conditions of power outages and limited local resources. This research aims to review the standards and systems for evaluating sustainability in high-rise buildings and how to utilize them in designing sustainable residential environments [2]. By identifying and defining the criteria used to achieve sustainable towers and highlighting the importance of using Building Information Modeling (BIM) [3] in modeling and applying these standards, the research seeks to provide conclusions and recommendations that contribute to constructing sustainable buildings and towers that meet the needs of people in the Syrian community.

The research problem lies in the absence of clear standards for sustainability systems, particularly in high-rise buildings in Syria, and the lack of modeling for these standards [4]. Additionally, there is a lack of interest in applying sustainable design standards and a weak emphasis on studying the efficiency of buildings in using energy and resources, which is crucial given the ongoing power outages and scarcity of local resources. This research aims to review the standards and systems for evaluating sustainability in high-rise buildings and how they can be utilized in designing sustainable residential environments. By identifying and defining the standards used to achieve sustainable towers and highlighting the importance of using BIM in modeling and applying these standards, the research seeks to provide conclusions and recommendations that contribute to constructing sustainable buildings and towers that meet the needs of people in the Syrian community.

The research questions include: What are the standards followed for evaluating residential towers? What are the sustainable practices in the field of evaluating high-rise buildings? How can BIM contribute to achieving a sustainable building? And how can sustainable practices be modeled? The research aims to identify and define the standards used to achieve a sustainable tower, determine the methods, tools, and BIM software for modeling these standards, model the standards for evaluating the sustainable tower, and highlight the importance of BIM in achieving a sustainable tower.

The research hypotheses include the existence of globally recognized standards and principles for evaluating the sustainability of residential towers, studying how to apply these standards to evaluate the sustainability of high-rise buildings in Syria, and focusing on presenting a comprehensive methodology to achieve sustainable towers.

2. LITERATURE REVIEW

2.1 Sustainability

The word "sustainability" is derived from the Latin word "sustiner," and dictionaries provide ten meanings, the most important of which are "maintain," "support," and "endure." Since the 1980s, sustainability has been increasingly used to mean human sustainability on Earth [5]. This concept has been widely included in definitions as part of sustainable development [6]. The Brundtland Commission of the United Nations defined it on March 20, 1987, as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Another definition of sustainability is "prolonging the productive life of a building to contribute to saving energy, money, and materials" [7], according to Sir Bernard Feilden, one of the architects in the United Kingdom. Yet another definition is "designing and constructing buildings using methods and materials from sources that do not harm the health of the environment or related entities, ensuring the well-being of the building's occupants, construction workers, the public, and future generations."

2.2 Sustainability in Buildings

Sustainability in high-rise buildings plays a crucial role in addressing the environmental, economic, and social challenges we face today [8]. Its importance is highlighted in the following areas:

- **Improving resource efficiency:** Sustainable buildings help reduce energy and water consumption through advanced technologies and systems [9], leading to lower operational costs and the conservation of resources for future generations.
- **Reducing environmental impact:** By using sustainable building materials, effectively managing waste, and reducing harmful emissions, sustainable buildings contribute to environmental preservation and pollution reduction.
- **Enhancing quality of life:** Improving indoor air quality and providing comfortable and healthy living environments enhances the well-being and overall health of occupants.
- **Supporting the local economy:** Utilizing local materials and sustainable construction techniques boosts the local economy and creates new job opportunities.
- **Enhancing community resilience and sustainability:** Sustainable buildings contribute to communities that can adapt to climatic and economic changes through designs that consider local climatic conditions and available resources.
- **Compliance with global standards:** Applying internationally recognized sustainability standards enhances a project's reputation and increases its chances of receiving international support and funding.

2.3 Sustainable Practices

Sustainable practices in green building design play a vital role in achieving environmental, economic, and social sustainability. The key practices relevant to this research are:

- **Passive design:** Utilizing architectural design features to harness natural energy sources such as sunlight and natural ventilation for heating and cooling, thereby reducing reliance on artificial systems.
- **Thermal insulation:** Implementing thermal insulation techniques to minimize heat loss and gain, thereby reducing energy consumption associated with heating and cooling systems.
- **Site selection:** Carefully choosing building sites to minimize negative environmental impact, such as avoiding construction in environmentally sensitive or flood-prone areas.
- **Green spaces:** Creating green spaces on roofs and walls, and landscaping surrounding areas to improve air quality and mitigate urban heat-island effects.
- **Renewable energy use:** Integrating renewable energy systems such as solar panels and wind energy to generate a portion of the building's energy needs, contributing to lower carbon emissions and reliance on sustainable energy sources.
- **Water management:** Employing rainwater harvesting systems and installing greywater recycling facilities to reduce water consumption and promote water reuse.
- **Sustainable materials:** Using recyclable building materials and reducing the use of environmentally harmful materials.
- **Enhancing comfort and health:** Improving indoor air quality, ensuring good ventilation, and using low-emission materials to maintain occupant health and comfort.

3. METHODOLOGY

3.1 Bibliometric Data Collection

Data collection begins from major academic databases such as Scopus, Web of Science, and Google Scholar by identifying keywords related to the research topic, such as "sustainable buildings," "Building Information Modeling (BIM)," and "sustainability in construction" [10]. The data is then filtered by specifying a particular time range (e.g., the last ten years) to obtain recent data and by selecting reliable sources, focusing on recognized journals and publishers in the field [11]. Citation data is analyzed using Publish or Perish to determine the most cited research and extract information on the number of citations for each study or author. The number of published articles per year is then analyzed to understand temporal trends and focus on the years with the highest number of publications [12].

3.2 Content Analysis Data Collection

The process begins by collecting data through surveys to gather information from individuals or institutions concerned with the studied subject, such as property developers, employers, or local residents. Next, the data is carefully examined to understand the information presented in each category and sustainable practice, searching for patterns and variations in the displayed numbers. The data is then categorized into groups such as sustainable practices at the urban-design level, sustainable energy, water conservation, and solid-waste management.

Patterns and trends evident in the data are analyzed, followed by comparisons between different categories, aiming to understand the reasons behind variations in the figures. Finally, conclusions are drawn from the data to assess whether certain sustainable practices are more or less emphasized compared with previous studies. An attempt is made to interpret the reasons for these differences, such as a localized focus on specific practices or implementation challenges in certain contexts.

3.3 Data Analysis

3.3.1 Bibliometric Analysis

Table 1. The most cited researchers in previous studies

Cites	Authors
16	E. Graham, G. Warren-Myers
14	L. M. Tucker
7	F. K. B. Abdul Khadir, N. C. Yee, H. B. Takaijudin, et al.
6	H. Kwon
5	K. Hlad

Table 1 presents data on citations and authors in the research field. E. Graham and G. Warren-Myers have received 16 citations for their research contributions, indicating the impact of their work in the academic community. L. M. Tucker has 14 citations, reflecting the significance of his research contributions. The group consisting of F. K. B. Abdul Khadir, N. C. Yee, H. B. Takaijudin, and others has received seven citations collectively. H. Kwon has six citations, while K. Hlad has five.

Table 2. The most productive researchers

A. Count	Authors
11	E. Graham, G. Warren-Myers
8	L. M. Tucker
5	F. K. B. Abdul Khadir, N. C. Yee, H. B. Takaijudin, et al.
4	H. Kwon
3	K. Hlad

Table 2 illustrates the number of studies authored by each group of researchers, reflecting the quantity of research conducted by each group and providing an indication of each group's contribution to the academic field.

Table 3. Top publishers

Cites	Publisher
16	Elsevier
14	Bloomsbury Publishing USA
7	mdpi.com
6	search.proquest.com
5	University of Florida

Table 3 provides a breakdown of citations received by various publishers, reflecting the extent to which their research papers or articles have been referenced in academic literature. Elsevier garnered 16 citations, indicating widespread referencing of its publications. Bloomsbury Publishing USA received 14 citations, underscoring the dissemination and recognition of its research within the academic community. MDPI obtained seven citations, ProQuest received six, and the University of Florida received five.

Table 4. Key referenced studies

Cites	Title	Year
16	Investigating the efficacy of a professional education program in promoting sustainable residential construction practices in Australia	2019
14	Designing sustainable residential and commercial interiors: applying concepts and practices	2014
7	Evaluation of the Implementation of Sustainable Stormwater Management Practices for Landed Residential Areas: A Case Study in Malaysia	2023
6	Worker safety and health in labor practices in sustainable residential buildings	2013
5	Sustainable Practices in Residential Projects	2009

Table 4 presents the number of citations each article has garnered alongside its publication year, reflecting the impact of these studies in academic and research literature. "Investigating the efficacy of a professional education program in promoting sustainable residential construction practices in Australia" (2019) received 16 citations, underscoring its significant influence on literature concerning professional education and sustainable practices in Australian residential construction. "Designing sustainable residential and commercial interiors: applying concepts and practices" (2014) received 14 citations, highlighting its importance in sustainable interior design. "Evaluation of the Implementation of Sustainable Stormwater Management Practices for Landed Residential Areas: A Case Study in Malaysia" (2023) received seven citations, indicating its impact on sustainable stormwater management. "Worker safety and health in labor practices in sustainable residential buildings” (2013) received six citations, while “Sustainable Practices in Residential Projects”(2009) received five. The bar chart in Figure 1 depicts the annual number of pub-lished articles from 2007 to 2023.

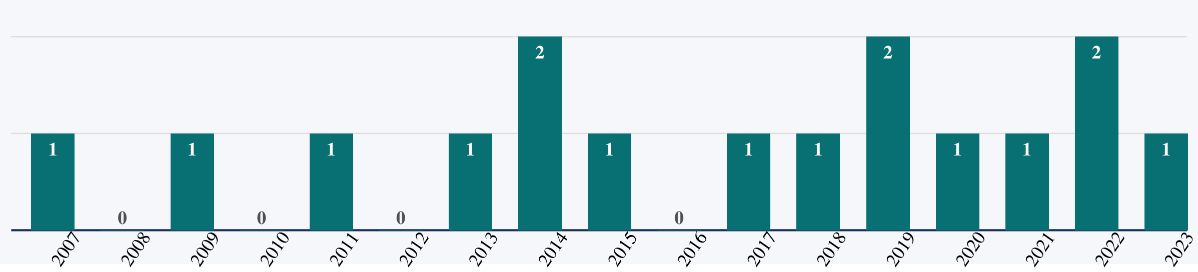

Figure 1. Articles count per year.

Notably, the years 2014, 2019, and 2022 stand out with two articles published each. Conversely, there were no publications in several years, while in most other years the publication rate remained consistent at one article annually. These data highlight fluctuations in annual article publication, with distinct peaks observed in certain years.

Table 5. Number of times each sustainable practice was identified

Count	Sustainable Practice
15	1. Use local and sustainable materials
14	2. Design buildings to be integrated with the natural environment
5	3. Provide green spaces and public parks
4	4. Plan for a sustainable transport network
8	5. Install solar energy systems
5	6. Improve energy efficiency in buildings
4	7. Use highly energy-efficient devices
2	8. Apply intelligent energy-management systems
5	9. Install rainwater collection systems
4	10. Use high-efficiency water fittings
3	11. Recycle greywater
2	12. Use water-saving landscape design
5	13. Implement waste sorting and recycling programs
4	14. Develop waste recycling plants
2	15. Encourage waste reduction at the source
1	16. Use waste-to-energy technology

3.3.2 Content Analysis

Table 5 displays the number of times each sustainable practice has been applied. The numbers indicate the frequency of each practice, providing insight into how common and widely used each practice is in the field of sustainability. For example, the use of local and sustainable materials was identified 15 times, making it the most common practice.

Table 6. Sustainable practices across four different levels

Category	Definition	Detailed Practices	Number
Sustainable practices at the urban-design level	Integrating environmental and social considerations in the planning and development of residential areas, aimed at improving quality of life and reducing environmental impact.	1. Use local and sustainable materials	15
		2. Design buildings to integrate with the natural environment	14
		3. Provide green spaces and public parks	5
		4. Plan for a sustainable transportation network	4
Sustainable practices at the sustainable-energy level	Reducing non-renewable energy consumption and promoting the use of renewable energy sources.	1. Install solar-energy systems	8
		2. Improve energy efficiency in buildings	5
		3. Use high-efficiency energy-consuming devices	4
		4. Implement smart energy-management systems	2
Sustainable practices at the water-conservation level	Reducing water consumption and efficiently reusing water to conserve water resources.	1. Install rainwater-harvesting systems	5
		2. Use high-efficiency water fixtures	4
		3. Recycle greywater	2
		4. Design water-efficient landscapes	2
Sustainable practices at the solid-waste-management level	Reducing waste generation and promoting recycling and reuse.	1. Implement waste sorting and recycling programs	5
		2. Develop recycling stations	4
		3. Promote waste reduction at the source	2
		4. Use waste-to-energy technologies	1

Table 6 presents details of sustainable practices across four levels: urban design, sustainable energy, water conservation, and solid-waste management. It includes a definition for each category, the detailed practices associated with it, and the number of times each practice has been applied.

4. DISCUSSION

4.1 Discrepancies from Previous Studies

Sustainable practices at the energy level were deemed most crucial in Syria due to current issues with power outages and energy deficiencies [13]. Sustainable practices at the urban-design level ranked second in importance, with sustainability experts in Syria prioritizing green spaces and public parks, followed by the use of local and sustainable materials [14]. Sustainable practices in solid-waste management were dominated by the importance of waste recycling, given its absence in Syria. Sustainable water-conservation practices ranked lowest in importance due to inadequate infrastructure in Syria regarding water conservation.

4.2 Limitations

Defining the scope of studies in a literature review presents potential challenges [15]. The chosen specialization might inadvertently omit significant studies or methodologies. Additionally, limitations in accessing relevant sources and resources could hinder the study, complicating efforts to gather supporting articles or original studies. Constraints in the time and effort allocated to the review may limit its depth and currency. Finally, difficulties in analyzing data from selected studies could potentially compromise the accuracy and validity of the review's conclusions.

5. CONCLUSIONS

5.1 Summary of Key Findings

Based on the analysis of the provided data [16, 17], it is evident that there is increasing interest in applying sustainable practices in various areas related to residential construction. The focus on using local and sustainable materials, designing buildings integrated with the natural environment, improving energy efficiency, conserving water, and managing solid waste indicates serious efforts to promote sustainability in residential buildings. These findings reflect the importance of adopting these practices to achieve sustainable buildings that meet the needs of the community while preserving the environment and resources.

5.2 Concluding Remarks

The use of BIM technologies should be enhanced at all stages of the design and implementation of high-rise buildings to ensure the efficient integration of sustainable practices [18]. BIM can improve collaboration among different teams, facilitating the comprehensive application of sustainability standards. Research findings indicate that adopting sustainable practices in the design and implementation of high-rise buildings is not only an environmental necessity but also an economic and social opportunity [19].

The use of BIM technologies plays a pivotal role in achieving these practices efficiently and effectively. By enhancing collaboration among all stakeholders and providing accurate and comprehensive information, BIM can contribute to improving building quality and increasing efficiency in the use of energy and resources. Additionally, enhancing education and training and developing supportive policies can significantly contribute to the transformation toward building sustainable cities that provide a healthy and comfortable environment for residents. The entire community, including governments, developers, and users, must collaborate to achieve this common goal and secure a sustainable future for generations to come [20, 21, 22, 23, 24, 25].

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