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Environmental Protection in the Construction Industry for Achieving Sustainable Development

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ABSTRACT

The construction industry is one of the primary sectors of the global economy, playing a crucial role in providing housing and public infrastructure. With the increasing global population and the growing demand for more construction, the construction industry plays a greater role in the development and advancement of societies. However, this industry also bears serious environmental responsibilities and must consider environmental protection methods in its activities to reduce negative impacts on the environment and promote sustainable development. Given this issue, environmental protection in the construction industry has received significant attention. This protection includes the optimal use of natural resources, building materials, and increasing energy efficiency. This study will address the methods and challenges related to environmental protection in the construction industry for achieving sustainable development. The findings emphasize the importance of environmental protection in promoting sustainable and socially focused development in the construction industry. Furthermore, it discusses the impact of environmental protection on policymakers, urban planners, and other stakeholders involved in sustainable development in the construction industry. Overall, this study presents references and solutions for environmental protection in the construction industry to achieve sustainable development.

1. Introduction

The term sustainable development can be described as [1] improving the quality of life, which leads to allowing people to live in a healthy environment and results in enhancing social, economic, and environmental conditions for current and future generations. Since the World Commission on Environment and Development (WCED), sustainable development and its multiple dimensions are modern concepts that have become the focus in most countries. The primary reason for attention to the policies of this development is the limited resources and unlimited human needs and demands. In various countries and regions worldwide, urban sustainable development approaches and strategies are one of [2] the important topics and top priorities in their planning. Achieving urban sustainable development requires the deployment of diverse tools, inclinations, and forces that constitute the urban system, assessing the range of sustainable development issues in the form of public and private policies that require managerial functions and emphasizing the importance [3] of government institutions. Government institutions should act as a means to create coordination and balance between different forces and should themselves reasonably have power to promote sustainable urban development.

Sustainable development has attracted significant attention in all countries and [2] a report was published advocating for a unified environmental development strategy and also made a declaration describing sustainable development as a turning point for meeting current needs without compromising the ability of future generations. Saatchi [3] believed that sustainable development will be the great challenge of the 21st century.

Improving the social, economic, and environmental indicators of sustainable development directs attention towards the construction industry, which is a growing sector globally and a very active industry in developed and developing countries [4-6]. In 2015, the European Commission stated that 11.8 million workers are directly employed in this sector, making it the largest industrial employer in Europe, accounting for 7% of total employment and 28% of industrial employment in the European Union-15. In 2003, we invested approximately 910 billion euros in the construction industry, which constitutes 10% of gross domestic product and 51.2% of the capital stock of the European Union-15 [7]. On the environmental front, this sector is responsible for high energy consumption, solid waste production, global greenhouse gas emissions, indoor and outdoor pollution, environmental damage, and resource depletion [8-10].

In order to overcome the growing concern today regarding the reduction of resources and attention to environmental considerations in developed and developing countries, a life cycle assessment can be applied for decision-making in improving sustainability in the construction industry. The aim of this research is to examine environmental protection in the life cycle of the construction sector, analyze the current situation, and highlight the key challenges related to life cycle assessment and the construction industry. In the first stage, this article presents details of the life cycle assessment and its methodology based on the international standard ISO 14040. In the second stage, the article systematically reviews and evaluates various methods of using life cycle assessment for the components and the entire process of construction. This study attempts to highlight the main strengths of life cycle assessment in the construction sector. In summary, it can be stated that life cycle assessment is essential for sustainability and improvement in the construction sector. For industrial activities, the application of life cycle assessment should not only meet consumer demand for environmentally friendly products but also understand the need to increase efficiency and compete in green construction markets. Therefore, this article looks at the broad international acceptance of life cycle assessment as a tool for improving environmental processes and establishing goals to prevent adverse environmental effects, thus improving people's quality of life and allowing them to live in a healthy environment.

Following this discussion, an overview of the perceived benefits and limitations of life cycle assessment is presented, and ultimately, an outlook on the challenges and prospects for future research in the field of life cycle assessment and obtaining its results will be provided.

2. Life Cycle Assessment

Life cycle assessment is a method for assessing the environmental burden of processes and products (goods and services) throughout their entire life cycle, from cradle to grave [11-15]. Since 1990, it has been used as an important tool for assessing buildings in the construction sector, initially defining the goal and scope, including determining the objectives, stakeholders, and system boundaries. The next stage involves creating a life cycle inventory, which includes collecting data for each unit process related to all energy and material inputs and outputs, as well as all information related to air, water, and land emissions. This stage involves calculating the material and energy inputs and outputs of a building system. The third stage is impact assessment, which evaluates the potential environmental impacts and estimates the resources used in the system model. This stage includes three mandatory elements: selecting impact categories, classifying life cycle assessment results, and category indicators for modeling (characterization). The classification of life cycle assessment results involves mentioning emissions, wastes, and resource uses, for example, CO2 and CH4, CO for impact category selection. The transformed life cycle assessment results into a single indicator result, which summarizes the final result of the mandatory life cycle assessment part. Normalization, grouping, weighting, and additional life cycle data quality analysis are optional steps. In a life cycle review, there are essentially two methods: midpoint methods (mean points) and endpoint methods (end points) [16]. The midpoint approach includes environmental effects related to climate change, acidification, eutrophication, creation of photochemical ozone, and human toxicity, which can be assessed using methods based on CML (2003), EDIP 2003, and IMPACT 2003+. The endpoint approach divides flows into different environmental issues, and the impact of each issue causes damage to humans, organisms, the natural environment, and resources. Economic indicators 99 and IMPACT 2002+ are methods used in the endpoint approach.

Finally, the last stage of ISO 14040 is interpretation. This stage identifies significant issues, evaluates findings to draw conclusions, and prepares recommendations. The final report of the last stage aims to complete the stages according to ISO 14040.

Based on the methodology, various tools have been developed and made available for environmental protection assessments. Classifying these tools has been done at three levels. Level 3 is called "whole-building assessment," which includes methods such as BREEAM in the UK, LEED in the United States, and SEDA in Australia.

Level 2 is designated as "whole-building design decision-making or support decision-making tools" and includes LISA (Australia), Ecoquantum (NL), Envest in Britain, ATHENA in Canada, and BEE (FIN).

3. Building Materials

This research provides a review of the application of life cycle assessment in the construction industry, which focuses on two different methods: life cycle assessment for building materials and component compositions, and the entire construction process. Therefore, this article reviews the method of life cycle assessment in determining unit applications. 25 case studies were analyzed, with 60% of them using life cycle assessment for building components and 40% for the construction process [17].

3-1- Building Materials and Their Compositions

Some studies explicitly focused on life cycle assessment of building components have been conducted over the past seven years [18]. The studies on life cycle assessment are not entirely comparable, and there are differences in the final product. Additionally, most studies do not consider costs aside from those indicating the shadow price [19]. However, new methods that include information on environmental impacts and renewable energy in building materials are essential for sustainable development. In pursuit of this goal, the European Commission has officially and voluntarily released the Integrated Product Policy (IPP). This policy focuses on identifying products with environmental potential in the construction sector, concentrating on the entire product life cycle. Essentially, it consists of three stages: products with environmental impacts (EIPRO), products for environmental improvements (IMPRO), and policy implications. The strategies used in implementation.

3-1-1- Life Cycle Assessment for Residential Architecture

Analyzing the importance of knowing which stage in the life cycle has a greater environmental impact, whether there is a similarity between environmental effects and energy consumption, and whether there is a difference in the environment regarding the impact on construction choices. Considering a 50-year occupancy phase for housing, this study demonstrated that the largest environmental impact occurs during the usage phase. Furthermore, 70-90% of environmental impacts arise during this phase. Almost 85% and 15% of energy consumption occur during the occupancy and production stages, respectively. The LCA SBI tool was used for building environmental impacts.

A brief study on environmental impact assessment of the life cycle of a residential building, conducted by Peuportier [20], compared three types of houses with different specifications located in France. The functional unit was one square meter for living. Sensitivity analysis was carried out based on alternative construction materials (wood vs. concrete blocks), heating energy type (gas vs. electricity), and transportation distance of wood. The EQUER tool is used for building environmental impacts.

For this reason, the energy required for air conditioning is very high during the operational phase due to the climatic conditions, and it is heavily dependent on the behavioral pattern of citizens and directly related to building materials, considering the fact that buildings provide a healthy indoor environment for employees. [21]. Additionally, it is observed that both have similar effects, but sensitivity analysis has been performed in different situations, and other considerations such as quality of life, thermal performance, and climate have been studied for the entire building life cycle. Another study was conducted by Jian et al. [22], which analyzed the environmental impacts of urban development by calculating the CO2 emissions during construction, maintenance, and operation of buildings and facilities. Data was collected to complete a case study in the Hyogo region of Japan. Proposed measures for CO2 reduction and simulation of reduction included limiting the use of commercial land in suburban areas, converting non-wooden houses to houses with minimal wood storage, and increasing open spaces such as parks and green spaces.

3-1-2- Commercial construction

There is a significant amount of descriptive work in the area of commercial structures, although the first efforts have been made in recent years, the research conducted so far is limited in relation to complete office buildings. A study by Scheuer et al. was conducted [22]. This study revealed that nearly 60 building materials were identified in the analysis phase. These results showed that the embodied energy in the building materials, which includes activities for designing, constructing, and renovating a building, totals 51,106 megajoules over the building's lifespan. The operational phase accounts for 97.7% of the embodied energy; the energy needed for demolition, deconstruction, and transportation was 0.2%. The following environmental impacts were studied in the operational phase: global warming (4.93%), depletion potential (5.89%), acidification (89.5%), ozone depletion potential (9.82%), and solid waste production (61.9%). The results of this study indicated that the operational phase has higher environmental impacts compared to other stages of the building's lifecycle. Data was obtained from Simapro, Franklin Associates, DEAMTM, and the Swiss Agency for the Environment, Forests, and Landscape.

3-1-3- Engineering Construction

In the case of highway construction, Birgisdottir and colleagues [23] compared two scenarios with natural materials versus different types of materials. The LCA method in the ROAD-RES tool, used for road construction and waste disposal, was evaluated. Environmental impacts such as global warming, acidification, and biological toxicity were analyzed. Marvoo and colleagues [24] have conducted a similar study on environmental impacts, which can be observed in both studies as a strategy to minimize environmental burdens, resource consumption, and practical strategies such as recycling and reusing building materials.

Reviewing the studies shows that the entire lifecycle of a building is not a statistical process [25], because the performance and different engineering characteristics of buildings vary. For example, construction techniques, architectural styles, and different climatic and behavioral conditions such as house size and culture differ in different countries. Additionally, diversity in each design can impact the environment throughout all stages of a building's lifecycle. Furthermore, in this paper, the selected indicators are based on performance units. The performance unit is focused on materials and components of construction on a final product, while for the entire construction, considering a dwelling, building, or area based on square meters of space available in the region, it is analyzed.

Lastly, each scenario is very specific to the industry. For example, construction and building projects have complex processes and require different assumptions during construction, whereas in construction and building materials, processes are based on a single product and final product.

Life Cycle Assessment (LCA) of BMC is conducted to compare the used products, new products, and help make better environmental decisions and policies to address environmental issues. Fifth, most of the LCA information is obtained from architects, engineers, drafters, specialized engineers, suppliers, and interviews, while the life cycle assessment for BMCC is based on industrial processes. Figure 1 depicts the life cycle of both scenarios. The stages of the building lifecycle include raw materials, construction, use and maintenance, and waste disposal, or demolition (cradle to grave). Building materials include processes such as production, use, and final demolition.

4. Advantages and limitations of perceived life cycle assessment

The present study has addressed the discussion of the advantages and limitations of life cycle assessment, although it is not claimed to be comprehensive, and the past seven years have shown evolutionary progress in life cycle assessment in the construction sector. It has been demonstrated how methods for BMCC and WPC exist based on scientific evidence. It has been shown that using life cycle assessment for evaluating building materials and assessing the entire construction process and using sensitivity analysis for innovative cost and data breakdown is not new. However, most life cycle assessment analyses focus on evaluating sustainability indicators. These findings indicate that life cycle assessment for BMCC and WPC certainly demonstrates an innovative approach that enhances sustainability in the construction sector throughout all stages of the building lifecycle. It has also been observed that more than 90% to 95% of case studies focused on evaluating environmental impacts and aiding decision-making in the construction sector. The selection of significant impact categories is among the loads that are usually analyzed. More environmental loads such as global warming potential (GWP), acidification, and energy consumption have been identified. However, other environmental impacts such as inefficient land use, water scarcity, air pollution, traffic congestion, ecological system severity, energy consumption, and waste management were also evaluated.

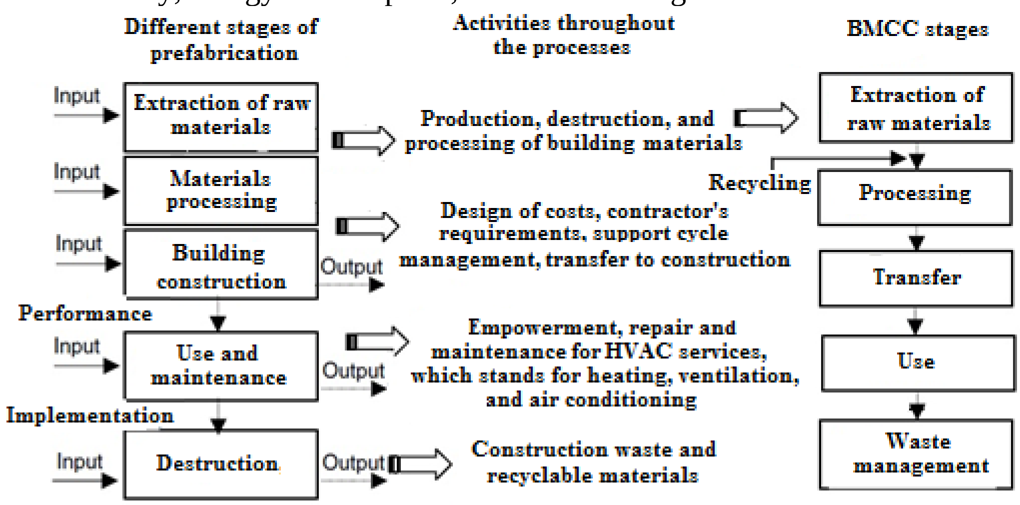

Figure 1: Building Lifecycle

Generally, the present study indicates that most life cycle assessment studies focus on energy consumption. The results have shown that the United States produces the highest amount of CO2 emissions and has the highest per capita energy consumption. However, considering the high economic and industrial levels in China, undoubtedly this Asian giant will surpass the United States in future years in CO2 emissions. Runming et al. [26] have found in their study that the construction sector in China currently accounts for 23% of China's total energy consumption, and it is predicted that this figure will increase to one third by 2010. Therefore, reducing environmental impacts in the construction sector is of great importance for achieving sustainable development. For example, construction using natural materials that have less environmental impact, green materials, and the use of renewable energies to reduce environmental and energy burdens can contribute to promoting sustainable development. Based on these reflections, there are currently two examples worldwide that can consider the best practices in practical programs by integrating material and energy principles to reduce construction costs: European housing projects [27] and buildings with net-zero emissions worldwide.

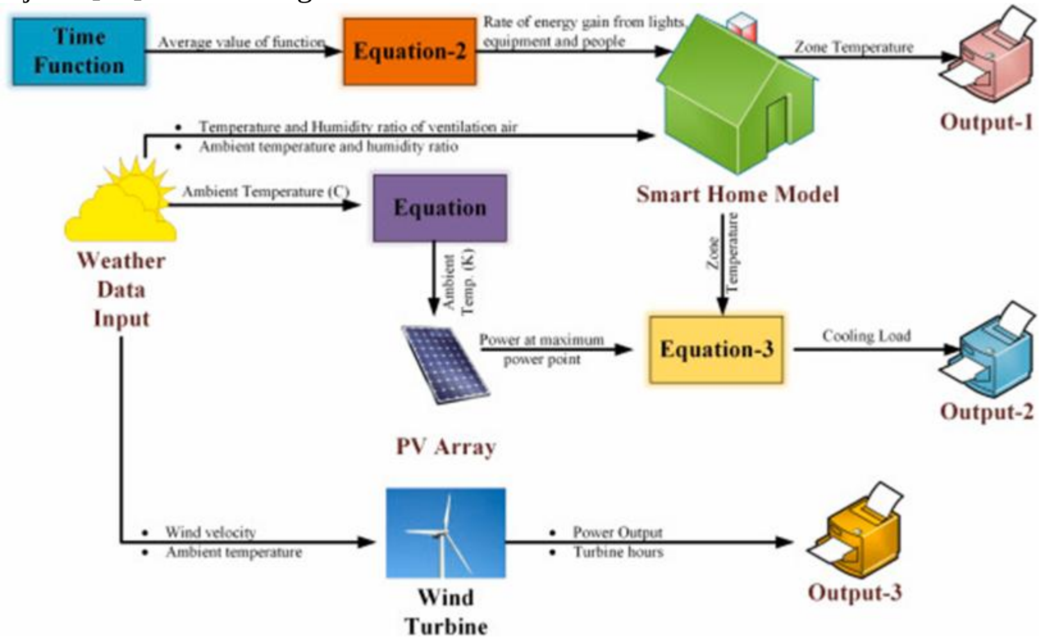

Figure 2: Achieving energy efficiency in buildings towards net zero.

5. Challenges of Achieving Sustainability

An examination of the available resources has proven that some studies published in the context of sustainability have focused on the complete life cycle assessment of the building life cycle. Adalberth et al. [28] conducted a study to evaluate the life cycle sustainability of four houses in Sweden. Peuportier [29] compared three types of houses with different specifications located in France. While previous studies have addressed the various environmental considerations and energy consumption of residential buildings in Europe and Latin America, there has been a lack of comparative studies in developing countries.

Therefore, the use of life cycle assessment in the construction sector is undoubtedly vital in achieving sustainable development goals. Curran [30] stated that the most appropriate method for comprehensive assessment is a systematic examination of the life cycle (material production, construction/processes, use, maintenance, refurbishment, and end-of-life treatment) and the chain of environmental impacts of products, processes, and services. Consequently, life cycle assessment requires the promotion of the best practical methods for assessment, decomposition, and analysis, as well as for preventing environmental impacts and implementing geological engineering techniques for buildings.

Ultimately, promoting and enhancing sustainable construction principles in developed and developing countries is crucial for sustainable development.

6. Conclusion

In the present study, the main strengths of the latest life cycle assessment towards environmental sustainability have been demonstrated. Life cycle assessment is recognized as an innovative method that improves sustainability in the construction industry throughout all life stages. It can be gathered from the conducted studies that there is a large number of life cycle assessment studies that focus on a specific part of the building life cycle, and only a few of them address the entire lifespan of a building. Although most case studies on life cycle assessment have been conducted in developed countries in Europe and the United States, there are few comparable studies in developing countries.

Therefore, sustainability indicators in design, construction, operations, and demolition need to be developed and used for environmental goals and energy considerations worldwide. Based on the conducted review, it can be concluded that environmental protection in the construction industry is vital and essential. By implementing environmental protection methods, this industry can contribute to sustainable development and reduce negative impacts on the environment.Some effective solutions for environmental protection in the construction industry include optimizing the use of natural resources, reducing air and water pollution, waste management, and increasing energy efficiency. These measures, in addition to protecting the environment, can help the construction industry improve its performance. Therefore, paying attention to environmental issues in construction activities is a necessary and obligatory step for sustainable development and responsiveness to the needs of society.

For this reason, because tropical areas have higher environmental loads and require more energy for air conditioning, domestic hot water, lighting, and entry into the atmosphere. The contribution made in the operational phase in buildings in tropical regions is not very significant due to low energy. Proper evaluation of the energy required for air conditioning systems depends on climatic conditions and behavioral patterns of citizens, as clearly demonstrated. Ultimately, governments and environmental organizations must enforce building codes and other environmental policies to improve sustainability in the construction sector. Other stakeholders also need to make a serious effort and commitment. Hence, to create environmental, social, and economic indicators, full participation in the construction industry is necessary to bring stability and promote the use of sustainable construction methods in both developing and developed regions.

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