# UNDERSTANDING THE IMPEDIMENTS TO THE ADOPTION OF SUSTAINABLE CONSTRUCTION TECHNOLOGIES IN DEVELOPING COUNTRIES

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## ABSTRACT

*Sustainable construction technologies have recently acquired more attention in the construction industry. However, their adoption has faced different barriers. This study aimed to identify and rank the impediments to sustainable construction technologies in developing countries. A systematic literature review (SLR) method was employed. After screening using inclusion/exclusion criteria, 22 publications were selected for further analysis. Afterwards, ten major impediments were explored with a thematic analysis method. Therefore, the finding of this study reveals that developing countries could enhance the implementation of sustainable technologies and alleviate environmental consequences, boost economic growth, and promote inclusive development by designing and implementing corresponding strategies that could tackle the identified impediments.*

**Keywords:** Sustainability, Construction Technology, Developing Countries, Systematic Literature Review, Impediments.

## 1. INTRODUCTION

Sustainable construction technology is gaining global priority due to rising environmental issues. Wang, Chong and Liu, (2021) compliment that sustainable construction technology reduces carbon emissions, protects natural resources, and improves living standards. Even though that is the case implementing sustainable construction technologies in developing countries requires overcoming several obstacles to achieve a more sustainable built environment. (Ahn et al., 2023).

The report of the 2022 Global Status for Buildings and Construction United Nations (2022) shows that despite increased investment and global efforts to reduce energy intensity, the sector's total energy consumption and carbon dioxide emissions increased in 2021. Furthermore, the report stipulates that Europe's construction sector expenditure varies due to the pandemic economic recovery, with Italy, the UK, Hungary, and France experiencing significant increases. Australia, Canada, South Africa, and the US have seen modest increases. On the contrary, some economies struggle with construction, while Sub-Saharan Africa and Asia are expected to experience the majority of future building construction growth. Emerging economies, including South Asia, Southeast Asia, and Africa, have experienced a decline in new building construction activities due to the pandemic, limited public investment, and a significant slowdown in energy efficiency investment (United Nations, 2022).

Similarly, a lack of knowledge and education on sustainable construction technologies in developing nations hinders their full appreciation and understanding of their benefits (Ahn et al., 2023). On the contrary, traditional construction methods remain prevalent, hindering the adoption of sustainable technologies by governments, builders, and developers due to a lack of necessary knowledge and awareness. (Mahmud et al., 2023).

Furthermore, the high initial cost of green construction technologies, coupled with budgetary constraints and limited resources in developing countries, poses a significant obstacle to sustainable building practices (Shukra, Zhou and Wang, 2021). Therefore, this leads to less sustainable and high long-term environmental impacts.

Additionally, Kaliappan, Hamid and Madar, (2023) divulge that the lack of supportive rules and regulations in developing countries is a substantial barrier to sustainable construction methods. Additionally, the construction industry struggles to adopt sustainable practices due to sloppy enforcement of environmental regulations and a lack of clear standards in developing countries (Yuan et al., 2023).

Moreover, poor countries struggle to implement sustainable construction technologies due to weak infrastructure and limited resources. Therefore, developing countries lack renewable energy, sustainable materials, reliable energy, water, and waste management systems, making it difficult to incorporate sustainable practices. (Keskin, Salman and Ozorhon, 2021). Limited access to reliable infrastructure, such as electricity, water, and waste management systems, hinders the adoption and integration of sustainable construction technologies in developing countries. (Altuwaim, AlTasan and Almohsen, 2023).

Lastly, developing countries face challenges in implementing sustainable construction technologies due to a lack of awareness, high costs, inadequate policies, and infrastructural limitations. Addressing these requires education, training, financial support, and supportive policies. (Agenbag and Amoah, 2021). Therefore, the study is significant because it offers a detailed analysis of the specific challenges and constraints that developing countries face in adopting sustainable construction technologies. This understanding is crucial for tailoring solutions that are contextually relevant and effective.

## 2. THEORETICAL FOUNDATION

The implementation of sustainable construction technologies in developing countries is crucial to achieve environmental sustainability and reduce the carbon footprint of the construction industry. However, there are several impediments to the successful adoption of sustainable construction technologies in these countries. The following theories support this study:

Institutional theory suggests that the institutional framework in developing countries may hinder the adoption of sustainable construction technologies.(Mundkur and Venkatesh, 2009). The theory sheds light on how a lack of policies, financial incentives, and institutional capacity in developing countries can hinder the adoption of sustainable construction techniques.(Oti-Sarpong et al., 2022).

Another research theory that underpins the impediments to the implementation of sustainable construction technologies in developing countries is the socio-cultural theory(Rahmatirad, 2020a). The theory highlights those social and cultural factors significantly influence attitudes and behaviours towards sustainable construction technologies, particularly in developing countries where traditional practices and materials may resist change (Hartley, 2009). Rahmatirad, 2020b). indicates that stakeholders, including legislators, developers, and construction experts, may underestimate the benefits of sustainable construction technology, necessitating increased awareness, education, and capacity-building efforts.

Additionally, resource dependency theory provides information on impediments to implementing sustainable construction technologies in developing countries (Hillman, Withers and Collins, 2009). According to (Hillman, Withers and Collins, 2009) the availability and access to resources, including materials, technology, and skilled labour, can significantly impact the adoption of sustainable construction practices. Developing countries may face resource constraints that limit their ability to invest in sustainable construction technologies, such as a lack of access to renewable energy sources, sustainable building materials, and advanced construction methods (Ozturk, 2021). Consequently, (Jiang et al., 2023) emphasize that there is a need for innovation, knowledge transfer, and capacity building to overcome resource constraints and encourage investment in sustainable construction technologies.

Lastly, research theories such as institutional, socio-cultural, and resource dependence theories highlight barriers to sustainable construction in developing countries. Addressing these and promoting policies,

awareness, and resource access can help overcome these challenges and promote a sustainable construction industry.

## 3. RESEARCH METHODOLOGY

The study is exploratory, qualitative research type. A systematic literature review (SLR) was preferred to address the research objective. A systematic literature review involves comprehensive searches of relevant studies on the subject of study (Saunders, Lewis & Thornhill, 2016). In contrast to traditional reviews; SLR employs a transparent, scientific, and replicable procedure that involves a thorough assessment of the literature based on the analysis of previous studies (Mase, 2020).

The authors applied the preferred reporting items for systematic reviews and meta-analyses (PRISMA 2020) method to conduct the SLR (Matthew J et al., 2021). The data were acquired from Scopus, and Web of Science databases. The review covered prior on prior studies published in high-impact factor journals. The query strings used for the search were the keywords: ("Impediments" or "obstacles" or "challenges" or "barriers") and ("sustainability" or "environment") and ("construction technology").

Regarding the exclusion criteria, the authors discarded: duplicate articles; and articles written in other than English language. Book chapters and book reviews were also excluded. The filtering involved screening relevant articles based on the following inclusion criteria: Studies done in the context of developing countries were included. Studies on social sciences; engineering; decision sciences; business, management, and accounting were encompassed. Studies conducted from 2000-2023 were covered in the study. The procedure followed for the article selection is presented in Figure 1.

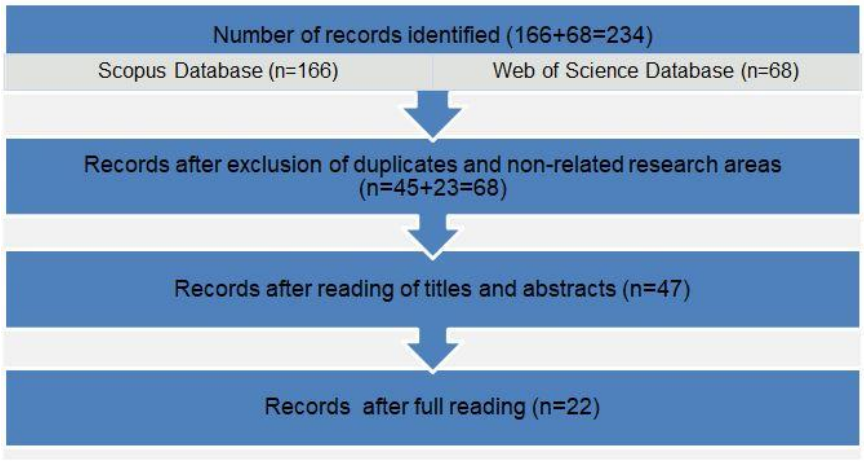



**FIGURE 1**
**FLOW CHART FOR IDENTIFICATION OF INCLUDED ARTICLES FOR SYNTHESIS**

Twenty-two articles were selected for data extraction after screening with the inclusion/exclusion criteria explained in the previous sections (Figure 1).

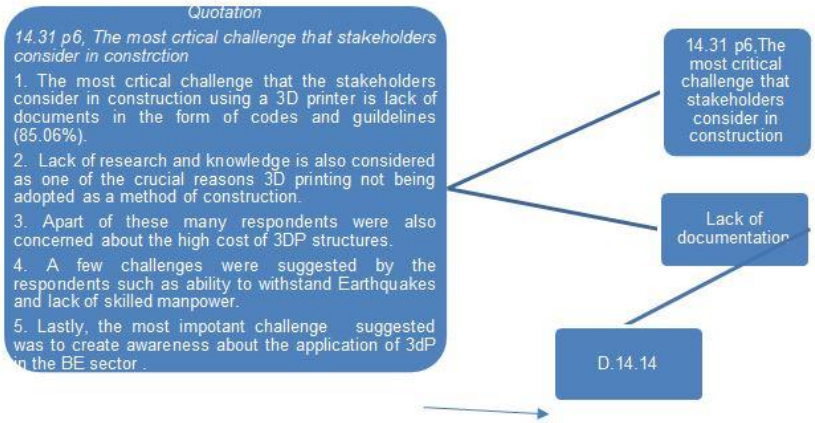
## 4. RESULTS

The screened articles were analysed with thematic analysis using Atlas.ti23 software. Queries like word tree, text searching, word cloud, and node modelling were applied to analyze the data.

To understand the underlying concepts of the articles, initially, a word cloud was generated. Figure 2 depicts the word cloud generated from the screened articles. This helped to overview the different concepts of the publications in a single sight.


**FIGURE 2**
**WORD CLOUD SOURCE: ATLAS.TI OUTPUT**

Then codes were initially generated from different quotations extracted from the screened articles. Figure 3 illustrates a sample coding procedure.




*Source: ATLAS.ti output*

**FIGURE 3**
**SAMPLE CODING/ PARTIAL TO FIT THE PAGE**

With a similar approach, 225 codes were established. Subsequently, 28 meaningful code groups (impediments to the adoption of sustainable construction technologies in developing countries) were then categorized.

Among the identified impediments, the top ten with higher frequency and percentage of mentions in the screened articles were identified. These ten major impediments and their corresponding references are illustrated in Table 1. The data in Table 1 originated from a code-occurrence table generated using Atlas.ti23 software.

| No | Impediment | Reference numbers, $f$: the frequency of the impediments referred to in the documents | | | | | | | | | | | | | | | | | | | | | $f$ | Rank |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | |
| 1 | Lack of adaptability and flexibility | * | | * | * | * | * | * | * | | * | * | * | * | | * | * | | * | * | * | * | | 17 | 5 |
| 2 | Incremental cost | * | * | * | * | * | | * | * | * | * | * | | * | * | * | * | * | * | * | | * | * | 19 | 1 |
| 3 | Gaps in policy and regulations | * | | * | * | * | | * | * | * | | * | * | * | | * | * | * | * | * | | * | * | 17 | 3 |
| 4 | Innovation and creativity deficits | | * | * | * | * | * | * | * | | | * | * | * | * | * | * | * | * | * | | * | * | 18 | 2 |
| 5 | Lack of cooperation in the industry chain | * | * | | | * | * | * | * | * | * | * | * | * | * | | | * | * | * | * | * | | 17 | 4 |
| 6 | Inadequate government support | * | * | * | * | * | | * | | * | | * | * | * | | | | * | | * | | * | | 14 | 6 |
| 7 | Resource constraints | | | | | * | * | | * | * | * | * | * | * | | * | | * | * | | * | * | | 13 | 9 |
| 8 | knowledge and Information gaps | | * | * | | * | | | * | * | * | * | * | * | * | | | * | * | * | | * | | 14 | 7 |
| 9 | Economic viability | * | * | * | * | * | | * | * | | | * | * | | | | * | | | * | * | * | | 13 | 8 |
| 10 | Scepticism and lack of trust | | | * | | * | * | * | * | * | | * | * | * | * | | | * | * | | | * | | 13 | 10 |

*Source: Atlas Ti Calculations*

**FIGURE4**
**IDENTIFIED MAJOR IMPEDIMENTS TO THE ADOPTION OF SUSTAINABLE CONSTRUCTION TECHNOLOGIES IN DEVELOPING COUNTRIES**

Mean, Standard Deviation, and Mean Error of the Dataset

The commonly used indicator of central tendency is the mean Zikmund et al. (2009). The mean frequency of occurrence of this data set is 16.5. The average distance between each data point and the dataset mean is referred to as the standard deviation. It could be calculated using the formula:

$$S = \sqrt{S^2} = \sqrt{\frac{\sum\left(X_i - \overline{X}\right)^2}{n-1}}$$

For this data set, the standard deviation is 2.86. According to Zikmund et al. (2009), the standard error mean is the standard deviation of sampling and is calculated using the formula:

$$S_{\overline{X}} = \frac{S}{\sqrt{n}}$$

The standard error mean of this data set is 0.905.

## 5. DISCUSSION

This study with a systematic literature review and thematic analysis was able to identify the ten major Impediments to the adoption of sustainable construction technologies in developing countries. Next, the identified ten major impediments are discussed.

***Incremental cost***

Sustainable construction technologies require investments in innovative materials, specialized equipment, and advanced construction techniques, all of which tend to come at a premium or "extra costs" compared to conventional construction (Anjum, Misbah & Nanyam, 2017; Wang, Chong & Liu, 2021). The high initial investment may not be proportional to the immediate benefits accrued by the technologies (Saka & Chan, 2020).

The incremental cost of prefabricated buildings and 3D-printed structures could serve as an apt example. A BIM (Building Information Modelling) )-assisted cost calculation was done to study the incremental cost composition of the whole construction stage of prefabricated buildings in comparison with traditional buildings (Qi et al., 2018). The incremental cost for the prefabricated buildings based on a sample case study done, accounts for 43.7% of the total construction cost. This incorporated material, labour, machinery, and other costs(Qi et al., 2018).

3D printing holds a promise for revolutionizing construction by offering faster, more efficient, and potentially more sustainable building methods. However, the initial investment required for the technology is considerable. This includes expenses for acquiring 3D printers, purchasing specialized materials compatible with the printing process, and investing in training for personnel to operate the equipment effectively (Anjum, Misbah & Nanyam, 2017). Getting access to affordable financing options or incentives to offset the additional costs incurred to implement sustainable construction technologies in developing countries is challenging (Anjum, Misbah & Nanyam, 2017).

***Innovation and creativity deficits***

The lack of innovation in the construction industry when compared to other industries has drawn criticism (Ahmed et al., 2023; Wang, Xu & Liu, 2023). Innovation enables the improvement of competitiveness of construction firms and contributes to environmental sustainability in the construction industry. The studies on construction innovation are still in their embryonic stage, as research on theories and practices is based on the body of knowledge of other industries. But the number of construction innovation-related studies has significantly increased in recent years (Wang, Xu & Liu, 2023).

The irreversibility of the time course and the asymmetry in geographical space (e.g., resource conditions) and social space (e.g., policy, law, and culture) of construction activities result in a more complex industry. Due to this, innovation in construction has been deemed complex, nonlinear, and dynamic.

The design and implementation of sustainable construction technologies require novel ideas, methods, and approaches(Firoozi & Firoozi, 2023). The technology of smart highways is a good example of this. Future trends for smart highways include interactive lights, glowing lines, electric priority lanes, piezo-electric energy roads, intelligent (networked) highways, and illumination traffic signs/bollards. These innovations contribute to improving safety, enhance accessibility and mobility, and reduce congestion and emissions (Sazali & Firdaus, 2019).

Developing nations have faced challenges in their effort to innovate and customise sustainable solutions to local contexts due to a lack of skilled professionals and technical experience as well as limited funding for research and development (Wang, Xu & Liu, 2023).

***Gaps in policy and regulations***

Policy-making efforts and regulatory considerations enable to avoid the unnecessary conditions and environments that hinder the adoption of sustainable construction technologies (Firoozi & Firoozi, 2023). Developing countries seem to lag in the formulation and adoption of workable and effective policies and regulations for improvements in the practice of sustainable construction (Babalola & Harinarain, 2024).

Clear policy statements backed with regulatory provisions chart the road to the successful adoption of sustainable construction technologies. This includes specific and minimum required policies that should be formulated and implemented (Babalola & Harinarain, 2024).

***Lack of cooperation in the industry chain***

The adoption of sustainable construction technology requires multiparty participation, and deep cooperation among partners(Sazali & Firdaus, 2019; Ayalp, 2020). During the design, manufacturing and construction stages of sustainable construction technologies, different inputs are required from multiple stakeholders. The decisions made in these stages affect the roles of project participants throughout the construction life cycle. For this, effective coordination among the parties involved is critical(Yuan et al., 2020; Ayalp, 2020). Governments must play a leading role in developing policies and regulations related to the practice of sustainable construction technologies (Babalola & Harinarain, 2024).

***Lack of adaptability and flexibility***

The absence of adaptability and flexibility features is identified as one of the barriers to sustainable construction technologies(Garg & Chhikara, 2020). An illustrative example of this is the differentiating feature of 3D & 4D printing technologies. The new features of 4D printing, smart design, and customization, have opened an array of transformative possibilities that supersede the capabilities of 3D printing. This includes the ability to adapt to environmental conditions and the ability to self-assemble and transform over time(Firoozi & Firoozi, 2023). Sustainable technologies being introduced in the construction industry need to have a feature that can adapt to the dynamic and complex nature of construction projects and the environment.

***Inadequate government support***

Governments not only make policies and regulations, but also need to provide financial initiatives, establish capacity-building initiatives, and take the leadership to motivate the adoption of sustainable construction technologies (Yas & Jaafer, 2020; Paul & Seth, 2017). The limitation of funds for research and development by the government also hinders the development and promotion of sustainable technologies in the construction industry(Geng, Huang, Li & Zhang, 2023).

***Knowledge and information gaps***

Creating awareness about sustainable construction technologies in the construction industry is a fundamental challenge (Anjum, Misbah & Nanyam, 2017). Professional associations with their members and other industry stakeholders must be on board to further the necessary developments and turnarounds needed in the industry on this aspect. There is a need to inculcate an attitudinal change among construction industry stakeholders(Firoozi & Firoozi, 2023). Well-designed training programs and initiatives for construction industry professionals and leaders are instrumental in pushing forward the adoption of sustainable construction technologies.

***Economic viability***

The initial cost of sustainable technologies is mostly higher than the traditional construction ones, creating a disincentive for investors and other stakeholders to adopt (Geng et al., 2023). Also, the missing economies of scale due to small-batch productions of sustainable technologies contribute to higher costs than the traditional ones (Geng et al., 2023).

The benefits of sustainable construction technologies are not usually harvested in the early days. It is therefore crucial to demonstrate the long-term benefits and cost savings associated with sustainable construction technologies, such as reduced maintenance costs, improved structural performance, and increased lifespan to investors, end-users, and other stakeholders (Firoozi & Firoozi, 2023).

***Resource constraint***

The prevalent conventional construction technologies mostly depend on non-renewable resources imposing grave challenges to the environment (Chettri et al., 2021). Developing countries face more resource constraints, including shortages of sustainable materials, energy, water, and skilled labour in the case of sustainable construction technologies. This limits their economic feasibility and scalability (Ahmed et al., 2023).

***Scepticism and lack of trust***

Scepticism towards new technologies and a history of failed projects lead to negative perceptions and mistrust of sustainable construction (Chua et al., 2018). Consultants and other construction stakeholders tend to avert possible project risks expected to arise due to the inclusion of sustainable technologies. Building trust and confidence requires targeted communication and demonstrating pilot and successful benchmark projects (Chua et al., 2018).

The development of appropriate standards and certifications for sustainable construction technologies also enables it to widen its adoption. This would assist in fostering public and industry trust in sustainable technology, thereby accelerating its adoption in the construction industry(Firoozi & Firoozi, 2023).

## 6. CONCLUSION, STUDY CONTRIBUTION AND RECOMMENDATIONS

Through a rigorous systematic literature review coupled with thematic analysis, this study has revealed ten major impediments that hinder the adoption of sustainable construction technologies in developing countries.

### *6.1 Study contributions and recommendations*

The study "Understanding the Impediments to the Adoption of Sustainable Construction Technologies in Developing Countries" likely provides several key contributions to the field of sustainable construction and development. Here are some potential contributions:

#### *6.1.1 Identification of barriers*

The study helps to identify and categorize the specific barriers and impediments that hinder the adoption of sustainable construction technologies in developing countries. This could include economic constraints, lack of technical knowledge, inadequate infrastructure, and regulatory challenges.

#### *6.1.2 Insight into regional challenges*

By focusing on developing countries, the study provides valuable insights into the unique challenges faced in these regions compared to developed countries. This includes understanding the socio-economic, cultural, and political factors that affect the implementation of sustainable practices.

#### *6.1.3 Policy recommendations*

The study may offer policy recommendations tailored to the needs of developing countries. This can help policymakers create more effective strategies and frameworks to support the adoption of sustainable technologies.

#### *6.1.4 Practical solutions and strategies*

It could propose practical solutions and strategies for overcoming the identified barriers. This might involve suggesting ways to improve access to funding, enhance technical training, or develop supportive regulatory environments.

#### *6.1.5 Awareness and education*

The study can raise awareness about the importance of sustainable construction and the benefits it brings, potentially leading to increased efforts in education and training for stakeholders in developing countries.

#### *6.1.6 Framework for future research*

It might provide a framework or a set of guidelines for future research in this area. This can help other researchers build upon the findings and explore new avenues for addressing the challenges.

#### *6.1.7 Encouraging innovation*

By highlighting the challenges, the study can stimulate innovation in sustainable construction technologies and practices tailored to the specific needs of developing countries.

Overall, the study contributes to a deeper understanding of the complex issues surrounding sustainable construction in developing countries and provides a foundation for targeted actions to overcome these challenges.

## 7. CONCLUSION OF THE STUDY

The impediments are not only barriers to efforts to sustain the environment but also perpetuate socio-economic disparities. The construction industry stakeholders in developing countries could get insights into designing and implementing multifaceted strategies for addressing the identified obstacles. To overcome these obstacles and progress towards a more resilient and sustainable construction industry, stakeholders involved in the construction value chain need to demonstrate a continuous commitment and collaborative effort. The study plays a crucial role in achieving environmental sustainability goals. Implementing the outcome of this study can lead to the development of innovative solutions that promote sustainable practices in the construction industry.

## 8. DECLARATIONS

### *Author contributions*

### *The following statements should be used*

Conceptualization, Sayeed Aboobakr Milanzi.; methodology, Henock Asfaw Hailu; software, Sayeed Aboobakr Milanzi; validation, Sayeed Aboobakr Milanzi.; formal analysis, Henock Asfaw Hailu; investigation Sayeed Aboobakr Milanzi; resources, Henock Asfaw Hailu; data curation, Henock Asfaw Hailu.; writing-original draft preparation, Sayeed Aboobakr Milanzi.; writing—review and editing, Henock Asfaw Hailu and Sayeed Aboobakr Milanzi; visualization, Henock Asfaw Hailu; supervision, Henock Asfaw Hailu; project administration, Henock Asfaw Hailu.; funding acquisition, None. All authors have read and agreed to the published version of the manuscript.

### *Data availability statement*

Data sharing not applicable: No new data were created or analyzed in this study. Data sharing is not applicable to this article.

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## 10. DECLARATION OF COMPETING INTEREST

The author declares that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

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