Barriers to the Successful Adoption of Innovative Building Materials for Sustainable Construction: A Review

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Abstract. The use of sustainable or innovative building materials (IBM) for sustainable construction has brought about many significant advantages to the construction industry. These advantages include increased productivity, environmental protection, efficient use of materials, etc. Despite these advantages, there are still numerous barriers affecting the successful adoption of IBM. However, this paper aims to outline and discuss the barriers influencing IBM and also recommend better ways for IBM adoption. To explore the present issues of barriers to IBM adoption, the study considered published academic journals and thesis to get the most valuable sources of information. Thus, the research findings identified 25 barriers but the 6 (six) most reported barriers were discussed in this paper; and they include lack of awareness and knowledge; lack of local authority and government involvement; poor funding for research and developments, training, and education; lack of clear benefits; lack of qualified staff or practitioners; and lack of building codes and, regulations on innovation. Therefore, identifying these barriers and providing recommendations might help to overcome the barriers to IBM adoption for sustainable construction.

Keywords: Innovative building materials · Sustainable construction · Construction industry · Barriers · Adoption

1 Introduction

According to [1], construction materials can account for up to 40% of the total cost of building projects; and [2] between 50–60% of the project cost. Even as construction activities improve peoples' lives, they also have a significant environmental impact. Construction materials have a huge direct and indirect impact on the global environment, not only because of large energy usage but also for the massive greenhouse gas emissions [3]. The building industry has a substantial environmental influence on the overall environment [4]. They are responsible for a large number of harmful pollutants, accounting for 30% of greenhouse gas emissions induced by their operation, including an additional 18% contributed by material extraction and transportation [5, 6].

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Sustainable construction is achieved when the construction industry employs more recycled, revitalized, and reused materials for construction while utilizing less energy and other natural resources. One of the main objectives of sustainable construction is to create a better-built environment for human lives. To achieve this objective, there is a need to focus more on sustainability techniques. Sustainable or innovative building material is an aspect of sustainable construction. Aside from technology and trends, innovative construction materials contribute to the advancement of construction innovation. Materials used for construction should be selected based on the project's specifications and suitability. According to [7] the latest advanced materials have the potential to change the way we create and retrofit buildings and they provide value by enhancing the performance and functionality of the building.

This paper focuses on the barriers affecting the successful adoption of IBM. This was achieved through the following questions:

1. What are the barriers that affect the successful adoption of IBM in construction?
2. What are the recommendations to the top barriers affecting IBM adoption?

Studying the concept and benefits of IBM and how they can act as barriers to IBM adoption, addresses a specific research gap through:

1. Collecting barriers of IBM by literature review from academic journals.
2. Identifying and discussing how the top barriers significantly influence the adoption of IBM by using a qualitative approach.
3. Providing recommendations to the top barriers.

The paper is structured as follows; The concepts of Sustainable Construction (SC) and Innovative Building Materials (IBM) are briefly described in the next section, followed by the research methodology. The section after the methodology covers research findings and discussion. Finally, conclusions and recommendations are presented.

In light of environmental impact, global warming, high usage of resources, waste generation, and pollution, technologies designed to promote sustainability are receiving special attention due to their importance in achieving 17 United Nations Sustainable Development Goals [8] with special emphasis on Goal 11 (sustainable cities and communities) and Goal 9 (fostering innovation). Therefore, the way the building sector could contribute to the creation of sustainable cities and communities is by the successful implementation of innovative building materials to ensure sustainable construction and safety for all.

2 Literature Review

2.1 Understanding Sustainable Construction

Langston and Ding [9] regarded sustainable construction as part of sustainable development that encompasses design, tendering process, site planning and organization, selection of materials, material recycling, and waste reduction. Sustainable construction is the process of creating a structure that is environmentally friendly and resource-efficient throughout its life. To improve performance, reduce the project's environmental problems, waste minimization, and be more environmentally friendly, sustainability in construction entails following appropriate practices in terms of selecting and sourcing material, construction methodologies, and design principles [10]. The goal of sustainability is to prevent depletion of energy, raw materials, and water, as well as deterioration of the environment caused during the life cycle of the facilities and infrastructure [11] (Fig. 1).

Sustainable Construction			
ENVIRONMENT	ECONOMIC	SOCIAL AND HUMAN	FUNCTIONAL
* Natural resources * Bio-diversity * Tolerance of nature * Environmental loads	* Market demand * Life cycle economy * Future values * Construction process and management	* Social stability * Built environment * Transport, health, aesthetics and cultural aspects	* Meeting needs * Indoor environment quality * Durability * Technical performance

Fig. 1. Four components of sustainable construction [12]

2.2 Understanding Innovative Building Materials (IBM)

IBM is one of the aspects of the modern method of construction, others include innovative building technology and innovative project finance, and these construction methods are connected to sustainability. Innovative building materials are also known as sustainable building materials. Sustainable materials according to [13] are materials that are economically and thermally sustainable, and environmentally friendly, thereby requiring lesser energy than conventional materials and also low harmful emissions such as Carbon (iv) oxide emissions and renewable resources are used. According to [14] based on the material life cycle, three distinct groups of criteria are used to assess the sustainability of building materials. Also, the presence of one or more of these characteristics in building materials is guaranteed to be environmentally friendly.

(1) **In Pre-Building Phase** (Manufacture): Pollution prevention, waste reduction, recycled content, embodied energy of a material, natural materials
(2) **In Building Phase** (Use): Construction waste minimization, locally produced building materials, energy efficiency, water conservation, non or less-toxic materials, renewable energy systems, and longer life materials
(3) **In Post-Building Phase** (Disposal): Reusability, recyclability, and biodegradability

Also, according to the study carried out by [16] about 150 innovative building materials were analysed from various design considerations which include physical properties, physical performance, environmental properties, installation, and maintenance factors (Fig. 2).

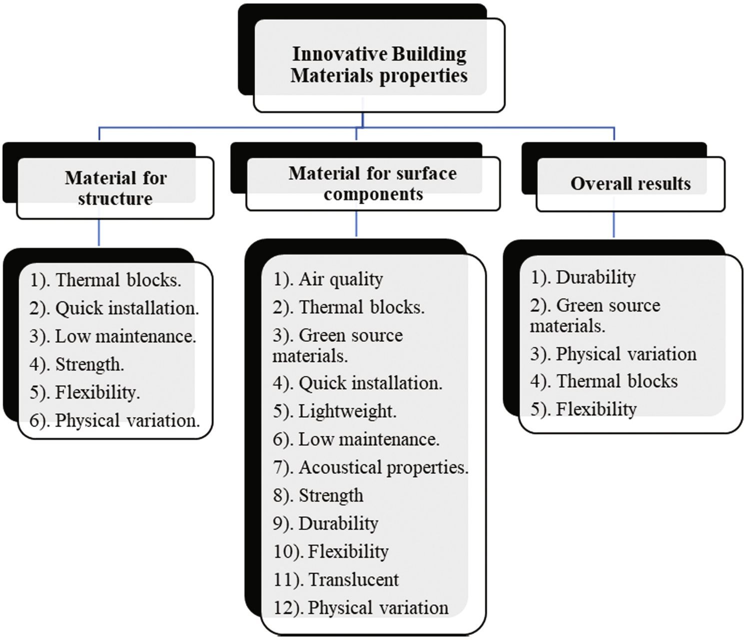

Fig. 2. The properties of innovative building materials [15]

Examples of IBM include 3D printed ceramics, 3D printing, aluminum foam, laminated wood, pollution-absorbing concrete, bio-receptive concrete, bamboo reinforced concrete, bricks made from pollutants, superplasticizers, and plaited microbial cellulose [16].

The benefits of IBM however go beyond cost savings, they should include reusing materials, lower environmental effects, thermally effective, adoption of renewable resources, economically sustainable, and low harmful emissions. The fundamental aims of sustainable or green construction according to [17] are to reduce environmental impact, improve end-user health and wellbeing, and provide a corresponding return on client investment. This study adds to [18] conclusions that the most essential benefits of IBM-designed buildings are low lifecycle costs, lower energy consumption, improved occupant health and comfort, overall productivity increase, and environmental protection. One of the primary benefits of using IBM in construction, according to [19] is a reduction in operating expenses, a rise in asset value and profitability, an improvement in occupant health and comfort, and an increase in staff productivity and satisfaction. The selection of IBM according to [20] is encouraged by toxic emissions reduction, carbon emissions reduction, employment creation, and, skill improvement opportunities for people. [21] affirms that the improvement in the quality of construction products, efficiency, and safety of the construction process is one of the most important ways towards achieving sustainable construction.

3 Research Methodology

The study adopted an exploratory approach using literature as its primary technique. To explore the present issues of barriers or challenges to IBM adoption, the study considered published academic journals and thesis to get the most valuable sources of information. To retrieve relevant papers for this study, a systematic literature search was conducted using the Scopus and web of science search engines. The search keywords used include 'barriers', 'innovative building materials', 'sustainable building materials', 'sustainable construction' 'construction innovation', and 'sustainable development'. The initial search was limited to articles published from 2000 to 2022. The IBM barriers reported in the relevant articles were critically reviewed, presented, and discussed in the next section of the paper and finally recommendations and conclusions were made.

4 Research Findings and Discussions

Through the review of the related papers considered in this study, a total of 25 barriers were identified as shown in table 1 along with their codes. In addition, the IBM barriers identified from the literature were ranked according to the number of times the barrier was reported by the papers. Therefore, Table 1 shows the several barriers that affect the successful adoption of IBM, but the six most reported barriers are B1, B2, B3, B4, B5, and B6. Showing that these are the major barriers hindering IBM adoption for sustainable construction.

This paper discusses only the top six barriers to IBM adoption.

B1: **Lack of awareness and knowledge**: It is vital to raise public awareness by providing adequate information and prioritizing education first since this promotes long-term behavior and this can also serve as a driver of IBM. Lack of information as a result of poor education and inaccurate research on IBM not only makes attaining good IBM knowledge difficult but also reduces the public awareness of IBM. Based on previous studies, lack of awareness and knowledge of IBM has become the top global barrier to the implementation of IBM. According to research conducted by [25, 28, 29], lack of awareness and understanding among people and developers influences the adoption of innovative construction materials. Most design and construction professionals lack awareness and education on the potential benefits of building innovative building technologies as the most significant barriers to the growth of green construction in Malaysia [32] and in Burkina Faso [28].

B2: Lack of local authority and government involvement: From this review, lack of local authority and government involvement has shown to be the second-ranked barrier to IBM adoption in this paper. This government-related barrier was identified in various

Table 1. IBM barriers identified from previous research

Code	Barriers	References
B1	Lack of awareness and knowledge	[22, 24–26, 28–31]
B2	Lack of local authority and government involvement	[22, 26–31]
B3	Poor funding for research and developments, training, and education	[24–26, 28–31]
B4	Lack of clear benefits	[24, 26–28, 30, 31]
B5	Lack of qualified staff or practitioners	[25, 26, 28–31]
B6	Lack of building codes and, regulations on innovation	[26–28, 30, 31]
B7	Inappropriate regulations/standards	[22, 24, 26, 27, 29]
B8	Cost & economic viability	[22, 24, 28, 29]
B9	Lack of public interest and buyers' demand	[22, 29–31]
B10	Lack of availability of green/ sustainable building materials on the market	[22, 23, 28, 29]
B11	Lack of end-user involvement and knowledge	[24–26, 28]
B12	Poor technical knowhow	[24, 25, 27, 28]
B13	Fragmented nature of construction	[24–27]
B14	Poor coordination and communication among project participants	[25, 27, 30, 31]
B15	Lack of top management commitment	[22, 25, 29]
B16	Unwillingness to change	[25–27]
B17	Learning/training period	[22, 28, 29]
B18	Temporary nature of construction (one-off construction industry)	[24, 25, 27]
B19	The perception that the industry is doing well without it	[24, 26]
B20	Lack of green/innovative building databases and access to information venues	[28, 32]
B21	Project delivery method	[27, 28]
B22	Lack of exemplar demonstration projects	[23]
B23	Poor innovation motivators in an organization	[25]
B24	Lack of sustainability measurement tools	[23]
B25	Associating sustainable concepts with luxury living	[22]

literature considered for this study [22, 26–28, 30–32]. The study conducted by [29] also noted a lack of implementation and enforcement of the law by local authorities and the government as a barrier that affects the practice of sustainability in the building industry in Nigeria.

B3: Poor funding for research and developments, training, and education: Inadequate funding for research and developments, training, and education (from the government) is ranked third among the top six IBM barriers identified in the literature. There is lack of a long-term financing foundation for the national research and development (R&D) center. Adequate funding for training and education from the government is important for promoting IBM adoption. In essence, adequate training serves as a driver that makes people adopt and incorporate IBM for their building projects. Despite the importance of research and developments in encouraging IBM adoption among the public and stakeholders, studies have shown that they are still lacking in many countries thereby affecting IBM adoption [24–26, 28, 30] and [31]. Active research activities foster innovation but require adequate funding. Therefore, inadequate research funding is a barrier to innovation.

B4: Lack of clear benefits: One of the commonly perceived barriers is people's lack of awareness of the need for IBM as well as their lack of understanding of its numerous benefits and also lack of database and available information on IBM [26, 28, 30, 31]. The results indicate that the lack of clear benefits hinders the widespread adoption of IBM. However, this finding has several implications for both governments, the public, and other stakeholders.

B5: Lack of qualified staff or practitioners: The lack of qualified workers with the appropriate technical experience needed to properly handle or install innovative building materials is a rank fifth among the top 6 IBM barriers identified in the literature review. Innovation demands some level of expertise without which innovation may be hampered [24]. Highly qualified professionals are essential for the inception and management of innovation. However, this has an impact on the level of innovation of a team.

B6: Lack of building codes and regulations on innovation: From our review, lack of IBM codes and regulations has been identified as the sixth most reported barrier. These barriers were identified in various research papers [26–28, 30, 31]. Mandatory IBM codes and regulations are lacking, which hinders individuals from adopting IBM; thus, the development of codes and standards would be beneficial in facilitating IBM adoption.

5 Conclusion and Recommendations

A systematic review of literature on barriers to IBM adoption was conducted for this paper. Scopus and web of science search engines were used to collect relevant academic journal articles reviewed in this study.

From the first objective of reviewing the literature on IBM barriers, it was found that there are numerous barriers affecting IBM adoption but the top 6 barriers in the paper such as lack of awareness and knowledge; lack of local authority and government involvement; poor funding for research and developments, training and education; lack of clear benefits; lack of qualified staff or practitioners; and lack of building codes and, regulations on innovation; implying that these 6 (six) barriers are the major barriers hindering the adoption of IBM in the global construction community. The second objective was to recommend measures to overcome the barriers to IBM adoption for sustainable construction.

As a result, potential options derived from the literature are presented in this section to address each of the top six barriers outlined above.

The first recommendation is that the government, construction industry associations, and all the stakeholders involved in the development of innovative building materials and technologies should adopt a strong collaborative system. This is to facilitate the successful adoption of IBM in developing and developed countries.

The most frequently stated barrier to IBM adoption in the literature, according to this review, is a lack of awareness and knowledge (which is due to poor funding for research and developments, training, and education), which leads to lack of understanding and public awareness about IBM, demonstrating the importance of information in IBM implementation. [28] suggested that government should provide funds for research for innovative materials and technologies to gain a comprehensive understanding of their characteristics, benefits, and disadvantages, as well as where the IBM should be applied. Also, the government could incorporate innovative design in education and into existing education systems, as well as increase the amount of formal innovative design education programs. [28] That is, this also allows for the implementation of training in the use of green or innovative materials for all stakeholders (such as architects, engineers, technicians, and masons) by including this training in the educational curriculum of schools and vocational programs.

This study has contributed to the knowledge of barriers affecting IBM adoption by identifying the most reported barriers in this literature. The findings are essential because they provide information on primary barriers to IBM implementation, leading to the proper understanding of what hinders the successful adoption of IBM from a global perspective. This study has been able to contribute to the global construction community as it has revealed the top six barriers to IBM adoption and provided recommendations that improve sustainable construction. It is expected that when the barriers are tackled, stakeholders would be eager to increase the level of adoption of innovative or sustainable features instead of conventional features in future construction projects. Also, the checklist of IBM barriers and references provided in this study can be relevant to scholars for further empirical studies on IBM barriers in different locations.

Limitation of the study

The scope of the research was limited to academic journals and thesis to get valuable information on the barriers or challenges of IBM adoption for sustainable construction.

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References

1. Andrade, J.J., Possan, E., Squiavon, J.Z., Ortolan, T.L.: Evaluation of mechanical properties and carbonation of mortars produced with construction and demolition waste. Constr. Build. Mater. **161**, 70–83 (2018)

2. Safa, M., Shahi, A., Haas, C.T., Hipel, K.W.: Supplier Selection Process in An Integrated Construction Materials Management Model. Autom. Constr. **48**(1), 64–73 (2014)
3. Schmidt, W., et al.: Innovation potentials for construction materials with a specific focus on the challenges in Africa. RILEM Tech. Lett. **5**, 63–74 (2020)
4. Yu, C.: (2008). Environmentally sustainable acoustics in urban residential areas. Ph.D. dissertation. University of Sheffield, UK: School of Architecture (2008)
5. Yudelson, J.: The green building revolution. Island Press, Washington, D.C. (2008)
6. Venkatarama, R.B.V., Jagadish, K.S.: Embodied energy of common and alternative building materials and technologies. Energy Buildings **35**(2), 129–137 (2003)
7. Delgado, J.M. P.Q., Cerný, R., Barbosa de Lima, A.G., Guimarães, A.S.: Advances in building technologies and construction materials. Hindawi Publishing Corporation, 1–3 (2015)
8. United Nations Department of Global Communications. (2020). Sustainable Development Goals, Guidelines for the use of the SDG logo including the colour wheel and 17 Icons. United Nations Department of Global Communications
9. Langston, C.A., Ding, G.K.C.: Sustainable practices in the built environment (Eds.). Oxford: Butterworth-Heinemann (2001)
10. Abolore, A.A.: Comparative study of environmental sustainability in building construction in Nigeria and Malaysia. J. Emerg. Trends Econ. Manag. Sci. **3**(6), 951–961 (2013)
11. Das, B.B., Neithalath, N. (eds.): Sustainable Construction and Building Materials. LNCE, vol. 25. Springer, Singapore (2019). https://doi.org/10.1007/978-981-13-3317-0
12. CIB (International Council for research and innovation in Building and construction). Agenda 21 on sustainable construction. Association of Research in Construction Management, 2, 49 (2011)
13. Umar, U.A., Khamidi, M.F., Tukur, H.: Sustainable building material for green building construction, conservation, and refurbishing. Management in Construction Research Association Micra) Postgraduate Conference vol 1(August), 2–7 (2016)
14. Badr, S.S. (2013). Research Methods Building Materials and Techniques applied to achieve Sustainability
15. Mandala, A. (2019). The improvements of building materials innovation: a review for the future architecture concept. Advances in Engineering Research, 156
16. Bamigboye, G.O., Davies, I., Nwanko, C., Michaels, T., Adeyemi, G., Ozuor, O.: Innovation in construction materials-a review. In: IOP conference series: materials science and engineering, 640, 1–11 (2019)
17. Raouf, A.M., Al-Ghamdi, S.G.: Managerial practitioners perspectives on quality performance of green-building projects. Buildings **10**(71), 1–23 (2020)
18. Darko, A., Chan, A.P.C., Owusu, E.K., Antwi-Afari, M.F. (2018). Benefits of green building: a literature review. In: The Construction, Building and Real Estate Research Conference of the Royal Institution of Chartered Surveyors (RICS COBRA), 23–24 April 2018, RICS HQ, London, UK
19. Simpeh, E.K., Smallwood, J.J.: Analysis of the benefits of green building in South Africa. J. Constr. Project Manage. Innov. **8**(2), 1829–1851 (2018)
20. Patil, K.M., Patil, M.S.: Sustainable construction materials and technology in context with sustainable development. Int. J. Eng. Res. Technol. **10**(1), 112–117 (2017)
21. Plessis, C. (2002). Agenda 21 for sustainable construction in developing countries. Pretoria: CSIR Building and Construction Technology
22. Abidin, N.Z.: Investigating the awareness and application of sustainable construction concepts by Malaysian developers. Habitat Int. **34**(4), 421–426 (2010)
23. Dzokoto, S.D., Dadzie, J.: Consultants perspectives. In Laryea, S.A. (ed.) Barriers to Sustainable Construction in the Ghanaian Construction Industry, pp. 223–234. Accra, Ghana: Procs 5th West Africa Built Environment Research (WABER) Conference (2013)

24. Owolabi, J.D., Faleye, D., Eshofonie, E.E., Tunji-Olayeni, P.F., Afolabi, A.O.: Barriers and drivers of innovation in the nigerian construction industry. Int. J. Mech. Eng. Technol. (IJMET) **10**(2), 334–339 (2019)
25. Eze, E.C., Sofolahan, O., Adegboyega, A.A., Saidu, K.J.: Factors limiting the full-scale adoption of process and product innovation in the Nigerian construction industry. SEISENSE J. Manage. **2**(3), 67–81 (2019)
26. Ozorhon, B., Abbott, C., Aouad, G., Powell, J. (2010). Innovation in construction: a project life cycle approach. Salford Centre for Research and Innovation
27. Gambatese, J.A., Hallowell, M.: Enabling and measuring innovation in the construction industry. Constr. Manag. Econ. **29**(6), 553–567 (2011)
28. Nikyema, G.A., Blouin, V.Y.: Barriers to the adoption of green building materials and technologies in developing countries: the case of Burkina Faso. IOP Conf. Series Earth Environ. Sci. **410**, 1–11 (2020)
29. Abisuga, A.O., Oyekanmi, O.O.: Organizational factors affecting the usage of sustainable building materials in the Nigerian construction industry. J. Emerg. Trends Econ. Manage. Sci. (JETEMS) **5**(2), 113–119 (2014)
30. Hwang, B.G., Tan, J.S.: Green building project management: obstacles and solutions for sustainable development. Sustain. Dev. **20**(5), 335–349 (2012)
31. Hwang, B.G., Ng, W.J.: Project management knowledge and skills for green construction: overcoming challenges. Int. J. Project Manage. **31**(2), 272–284 (2013)
32. Esa, M.R., Marhani, M.A., Yaman, R., Noor, A., Rashid, H.A.: Obstacles in implementing green building projects in Malaysia. Aust. J. Basic Appl. Sci. **5**(12), 1806–1812 (2011)