Impediments to Building information modelling-Enabled construction waste management in Nigeria

Eze, Emmanuel Chidiebere, Sofolahan, Onyinye, Uzoma, Clementina, Ameyaw, Ernest and Omoboye, Olayinka

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ABSTRACT

Purpose –Building Information modelling (BIM) has the potential to significantly minimise the quantity of construction waste (CW), but its adoption is low in construction waste management (CWM). This study examined the factors impeding the adoption of BIM in CWM efforts at the design and precontract stages from the perspective of construction stakeholders in Nigeria.

Design/methodology/approach – The study was informed by a post-positivism philosophical stance, which involved using the structured questionnaire as a quantitative research design tool for data collection via snowball sampling technique. The data garnered from construction experts were analysed using Cronbach's alpha test, normalities test, Frequency, Percentage, Kendall's coefficient of concordance and Chi-square tests, Analysis of variance (ANOVA), and exploratory factors analysis (EFA)

Findings – The study concluded that the awareness of BIM potential for CWM is high, but the adoption in waste management (WM) is low. The factor analysis reduced the twenty assessed factors into four key clusters of impediments to BIM adoption in CWM: (1) knowledge and resistance barriers, (2) support and interest barriers, (3) interoperability and experts' factors, and (4) economic barriers. These factors are critical impediments to BIM-enabled CWM at the design and precontract stage, and there was no significant statistical difference in their rating by the construction stakeholders in Nigeria.

Originality/value – Studies on the impediments to BIM adoption in CWM efforts, primarily at the design and precontract stages in emerging countries are scarce. This sought to fill this literature gap by establishing the critical impediments that should be overcome to improve BIM use in CWM.

Keywords: BIM, impediments, construction waste, sustainable construction, waste management, sustainability

1. INTRODUCTION

The architectural, engineering and construction (AEC) industry contributes largely to the proportion of waste that ends up in landfills compared to other industries, and these have a negative environmental impact with the attendant CO_2 emission (Gupta et al., 2022). The high construction waste (CW) generation of the sector cannot be dissociated from the high materials consumption attributes of the sector, and this is largely due to the industry's attempt to match up the ever-growing population demand for housing (Unuigbe et al., 2022). CW has remained a global issue. For instance, a 2019 report by the International Energy Agency (2019) indicates that in 2018, the AEC sector accounted for 36% of global energy consumption and 39% of emissions from energy, processes and activities of the sector. This was corroborated by Vasilca et al. (2021), who state that the usage of natural resources in the industry ranges from 20% to 50%, and it generates 50% of solid waste. Regardless of the level of industrialisation, the CW figures from countries are still high. According to Eurostat (2023), construction accounts for 37.5% of the 2135 million tonnes of waste generated in the

EU. In 2016 alone, 62% of the total waste generated in the UK came from the construction industry (UK Environment Agency, 2021). In 2018, the United States Environmental Protection Agency (US EPA) (2023) reported that in America, construction waste was twice of municipal waste. In Canada, it is 27%, and it ranges between 20%-30% in Australia and 50% in Brazil (Luangcharoenrat et al.,2019), and it stands between 30%-40% in China (Huang et al., 2018). This situation is similar in Nigeria, as the study by Ameh and Itodo (2013) showed that material waste generated from 100 housing units would be enough to build another ten houses. This shows the massive economic and social impact of CW. Based on these, Sharman (2018) regarded the sector as the largest producer of waste. These further indicate the predominance of the linear, non-cyclic project delivery method.

Digital technology such as BIM is one of the technological interventions that have the potential to prevent and minimise the quantity of CW in a project. For example, Won and Cheng (2017) reported that BIM reduces the effects of wasteful activities and processes across the project lifecycle. Hannan et al. (2015) found that BIM reduced waste by about 2% and can also prevent up to 4.3% to 15.2% of waste (Won et al., 2016). Recent study in Bangladesh revealed that the BIM-based approach can reduce CW by 44% (Hasan et al., 2022). Despite BIM's potential for waste reduction, its adoption for waste management in construction is still low. Although the adoption level of BIM is higher in advanced construction markets, it is low in emerging countries like Nigeria (Awodele et al., 2023). This has contributed to the high quantity of waste generated in the major cities of Abuja, Lagos, and others, as well as persistent cost and time overruns, loss of profits, and safety issues. Akinade et al. (2018) posit that waste management tools adopted in construction still need BIM functionality. The design and precontract stages have been identified as where the fight against waste and its negative impacts should begin (Liu et al., 2011; Mohammed et al., 2022). This is because the waste generated during the construction phase results from the hidden waste vectors from the design documentation and preconstruction phases (Luangcharoenrat et al., 2019).

Unseen errors in designs at the precontract stage contribute significantly to waste and rework and other non-value-adding events at the construction stage. Rework and waste have been identified to emerge from mistakes, errors, and omissions in design and contract documents (Umoren et al., 2019). The inefficiencies and deficiencies in designs and other contract documents from the precontract stages are what incubate the many problems that manifest during construction. These have been blamed for the poor project performance records of construction projects in Nigeria, and the reason why the Nigerian construction industry (NCI) is highly criticised as delays, cost overruns, time overruns, safety issues, high waste, and Rework, among other problems, are still predominant (Eze et al., 2022).

These problems can be curbed through BIM adoption and implementation (Umoren et al., 2019). Won and Cheng (2017) state that BIM has the capabilities to effectively manage waste as it can be used to estimate waste generation and develop an integrated waste management system. BIM use by the design teams can reduce the need for Rework and the associated wastes (Tanko et al., 2022). Amongst the suggestions to minimise the intensiveness of waste in the construction industry is dealing with waste from the design stages and using BIM to enforce compliance with waste management (Ajayi et al., 2015). Extant literature revealed that BIM-driven waste management studies are lacking as well, and it is an area that is underexplored, mainly in emerging countries (Nigeria inclusive) (Umoren et al., 2019). Furthermore, there is the absence of studies on the impediments to BIM adoption and implementation for CWM, especially at the design and preconstruction stages in the Nigerian context, hence this study. This study aims to determine the critical factors impeding BIM adoption for CWM in developing countries, with a focus on Nigeria. This study exposes the critical impediments to BIM adoption in CWM so that construction organisations and experts are aware and develop strategies to overcome them for better project performance and sustainability. Government and policymakers will be guided by this study in their policy formulation function. The study will also be helpful to construction management researchers, as it will serve as a basis for future research on the digitalisation of CWM and sustainable built environment.

2. THEORETICAL BACKGROUND

2.1 BIM Adoption and Construction Waste Management

Liu et al. (2011) posit that BIM is a “real-time interactive and collaborative communication system” that can be utilised by project stakeholders to collaboratively minimise waste and attain sustainable construction from the design, construction, and across the lifecycle. Although BIM adoption is higher in developed economies, it has not reached the expectations of the industry’s stakeholders (Ayinla & Adamu, 2018). Government support and policies in countries like Singapore, the UK, the USA, Denmark, and Canada, among others, are responsible for the high BIM adoption level of BIM in mature nations (Awodele et al., 2023). However, in Africa and the Middle East, the lack of government support and guidelines for technology uptake, among other factors, have been blamed for the low adoption of BIM technology (Lam et al., 2017).

The design and preconstruction stages have been blamed for the high waste generated in construction projects (Osmani et al., 2008; Nagapan et al., 2011). Wastes are non-value-adding and account for the high records of construction time and cost overruns, and design decisions are responsible for one-third of CW (Osmani et al., 2008). Eze et al. (2021) reported that construction wastes impact project schedules, project budgets, and contractors' profits and lead to disputes and claims. Saidu et al. (2017) found that 96.88% of the causes of materials waste at the preconstruction stages of a project are equally responsible for causing cost overruns in projects. Undiscovered and hidden design issues at the preconstruction stages of building projects can cause unprecedented contractual problems during construction. This makes design and precontract waste causal factors devastating to the success of construction projects. The use of BIM technologies by design team experts has the potential to prevent and/or reduce these factors (Mohammed et al., 2022) and thus minimise CW associated with designs. BIM use in Quantity take-off and cost estimation, clash detection through 3D functionality and site utilisation planning are the major areas in BIM applications that can be useful at the early stages of construction projects to mitigate waste (Tanko et al., 2022). Minimisation of errors and mistakes that could lead to design changes at the later stages of the construction projects, improved clash detection and communication and coordination among multiple parties, were among the prominent benefits of BIM (Okereke et al., 2021). These functions help to curtail potential issues that could lead to waste generation during construction. Therefore, mitigating this design and precontracting waste vectors are essential if the volume of waste generation in construction must be drastically reduced. It is also a sustainable approach to adopting BIM technologies for waste management (WM).

2.2 Impediments to BIM adoption in CWM

BIM aids the representation of a built asset in a digital format. This feature makes it impracticable for BIM to manipulate information that would enable the making of a well-thought decision on CWM and, thus, relies on information and algorithms (Lu et al., 2017). The quantities of waste associated with a particular design option can be determined, and appropriate decisions can be made, but the capability of BIM to perform this function is dependent on the quality of the information provided in materials or components specification. Therefore, designers and contractors must provide clear materials/component details and specifications to be able to minimise waste during the construction stage. The potential of BIM for design waste reduction has been highlighted in extant studies (Liu et al.,2015), but a specific method is yet to be developed. Therefore, the lack of a clearly defined approach for utilising BIM for construction and demolition waste reduction is a factor impacting full deployment for CWM (Salgin et al., 2017).

Poor coordination, collaboration and communication among the designed team members impact the effective use of BIM. BIM improves design reviews through shared 3D models, which helps to improve collaboration, coordination, and communication among the design team and reduce design issues related to clashes of components and materials (Liu et al., 2015). The lack of adequate support from governments through regulations and policies governing waste reduction has also been highlighted. The legal framework encourages consideration of the environmental impact of construction activities. Insufficient legal backing has hampered waste minimisation practices due to poor policies to enforce the use of technologies to improve CWM (Yuan et al., 2011; Zhou et al., 2019). Legal issues are among the critical unresolved barriers to BIM adoption in China, and this has led to an appreciable volume of waste generation in construction projects. Legal issues were also corroborated by Doan et al. (2021) in New Zealand, as it was perceived to be among the most perceived barriers to BIM adoption in construction and, by extension, affecting WM efforts of construction stakeholders. The lack of government regulations is one of the critical barriers to the mandatory use of BIM and the lean concept in waste minimisation efforts in the construction industry (Evans & Farell, 2021)

Waste reduction efforts are expensive (Yuan et al., 2011), and they even worsen when construction firms comply with various environmental regulations and guidelines. Therefore, there is a lack of incentive to invest in such endeavours. Investment in BIM is equally high, especially in software and hardware, and even in the cost of training. Most contractors and clients are not ready to invest a large amount of money in such an investment. BIM adoption in the Australian construction sector, according to (Hosseini et al., 2016), is hindered by the high cost of BIM implementation and training cost. The same high investment issues were confirmed by (Ismail et al., 2017; Evans & Farell, 2021), and these have impacted collaborative efforts and design simulations at the precontract stage. The non-identification and removal of waste factors in design at the precontract stages mean high waste during construction. The cost of securing licenses, training and running BIM is high, and this discourages BIM use in CWM.

The lack of demand from clients is another factor hindering the adoption of BIM for CWM. Demand for BIM has an impact on the investment decision of consultants and contractors in BIM, and the non-availability or even poor demand or requirement of such from clients is a factor that has been reported to impact BIM adoption in construction (Hall et al., 2022), particularly for WM. Clients play a critical role in both the project and environmental performance of their projects. Demand and willingness to pay for BIM in CWM will encourage industry stakeholders to invest more in BIM. McAuley et al. (2017) study revealed that lack of client interest, standard tools and protocols, data ownership, inadequate expertise, and training issues are the barriers to BIM adoption in Ireland. In addition, the absence of an experienced BIM team and the lack of mentorship to champion the course of BIM are the main barriers to BIM adoption (Almuntaser et al., 2018). This is corroborated by Umoren et al. (2019) and Hyarat et al. (2022), who found that one of the major inhibitors to BIM adoption in CWM is the unavailability of trained professionals and awareness issues. A focus on training local professionals and wider publicity among industry players will help improve BIM usage in construction projects, particularly for WM.

A total of 20 factors were selected from related literature and modified to reflect how they limit BIM adoption for waste minimisation efforts at the design and preconstruction stages in construction-based organisations (Table I). These factors are referred to as the impediments to BIM-driven waste management (IBWM) at the design and preconstruction stages.

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3. RESEARCH METHODOLOGY

3.1 Research Design and Factors Identification

This study adopted a post-positivism research philosophy, which informed the utilisation of quantitative research techniques to gather relevant data using a questionnaire. This technique allows for a deductive approach to interpreting statistical data as well as quantifying and generalising research findings (Culka, 2018). The questionnaire is suitable for this study because of its capability to cover large audiences at shorter durations. It can also be adopted remotely to gather data from audiences separated by space and time. The questionnaire was designed using information from the literature review.

3.2 Questionnaire design, sampling and data collection

The questionnaire is a widely used data collection instrument whose use is not limited to any specific industry or field of study. It is well utilised in construction management research as evident in studies on BIM and other digital technologies applications in construction, as well as in waste management (WM) studies (Umoren et al., 2019). Hence, the questionnaire was used in this study to investigate the various factors limiting BIM-enabled CWM at the design and preconstruction phase in Nigeria since it provides quantifiable data over a relatively shorter time (Tan, 2011). The questionnaire was designed to have three sections. The first section gathered data on the respondents' background, and the second section gathered data on the level of awareness of BIM benefits in CWM and their level of adoption in WM. The final section garnered data on the factors impeding BIM-driven WM. The targeted construction participants (Architects, Builders, Engineers, and Quantity Surveyors) from construction-based organisations, who are construction experts with BIM knowledge and experience in CWM, were required to rate identified factors according to their level of criticality in limiting BIM usage in CWM on a 5-point scale, using 1=not critical, 2 critical, neutral, 4 critical and 5=very critical.

Recruitment of the participants that took part in the study was guided by some sample selection criteria such as (1) they must have at least five years of industry experience, (2) they must at the time of the survey be or have been engaged on construction project(s) in study areas. These are in addition to having knowledge of BIM and experience in CWM. It is most likely that respondents with at least five years' experience have gained appreciable practice knowledge in CWM, BIM and construction in general, thus, would give an intelligible response based on sound industry experience (Aghimien et al., 2024) and have high willingness to participate in an online survey (Padayachee, 2016). These sample selection criteria were clearly stated in the questionnaire so that data were collected from qualified participants from the study areas (Abuja and Lagos) only. Abuja and Lagos are the two main metropolitan cities with the highest numerical strength regarding active construction projects/sites, construction firms and professionals in Nigeria (Eze et al., 2022), and thus, have a high level of construction waste generation in the country. Since there is no specific database for construction experts in the study areas who met these criteria for a firm sample population and size to be established, a non-probabilistic snowball sampling technique was chosen for the study.

The snowball sampling method is respondent-driven, as it is based on referrals and can increase the sample size (Heckathorn, 2011). This sampling method is suitable when time and cost are of the essence in reaching difficult-to-access groups (Naderifar et al., 2017) with homogenous features as defined by the selection criteria. The study leveraged electronic means to administer the questionnaire to the respondents after the initial set of participants were identified via a preliminary survey. The electronic means of the survey is eco-friendly as it eliminates hardcopy paper questionnaires. Electronic means of survey (i.e., use of Google Forms) makes data collection less cumbersome and data analysis easy since SPSS, Microsoft Excel, etc., used for data analysis are spreadsheet-based. The intelligibility and clarity of the questions in the questionnaire were determined through a pilot study amongst the subject-areas-knowledgeable experts, six from the industry and four from academia. This is in line with (Fellows & Liu, 2008), who advocated for the survey of a small sample to determine the clarity, relevance and correctness of the items contained in a research instrument. This measure was taken to ensure that more reliable, acceptable and generalisable results and findings are obtained.

3.3Adopted Data Analysis Methods

3.3.1 Data screening, Reliability and Normality tests

At the end of the survey period, 216 construction professionals from clients, consultants and contractors' organisations took part in the survey. Initial screening of the gathered data showed that 37 respondents answered "No" to the question: *Do you have practical knowledge of BIM usage and experience in construction waste management*? Furthermore, 13 incomplete responses were found in the dataset. The responses of 37 unqualified respondents and 13 incomplete responses were discarded. The researchers did not make any item compulsory, and this could be the reason for the incomplete responses obtained. This screening exercise brought down the total response to 166, and this number was deemed fit and formed the basis for the analyses and results reported in this study. The 166 responses are higher than what was obtained in related technology and sustainability studies that used questionnaires, snowball sampling and electronic surveys. For instance, 105 responses were obtained and used by (Awodele et al., 2023), and Aghimien et al. (2022) utilised 134 for analysis. The data reliability was measured using Cronbach's alpha coefficient test, and an alpha value of 0.903 was obtained (for the impediments to BIM-driven CWM, which is well above the 0.70 cut-off suggested (Pallant, 2005). Thus, indicating a very high reliability of the data obtained. Next was the normality test, which used skewness and kurtosis values. The satisfactory range of values for skewness is -2 to 2, and it is -7 to 7 for Kurtosis (Hair et al., 2010). Based on the values obtained, the normality of the gathered data was confirmed.

3.3.2. Descriptive analysis: Frequency and percentage were used to analyse the background information of the respondents, as well as the level of awareness and adoption of BIM in CWM.

3.3.3. Agreement analysis: Kendall's coefficient of concordance or (Kendall's W) and Chi-square (X^2) were used to confirm the relationship in the pattern of ranking of the variables within groups. Analysis of variance (ANOVA) - This was used to determine if there is a statistically significant difference between the various professional groups (client, consultants, and contractor organisations) regarding the impediments to BIM adoption in CWM.

3.3.4 Exploratory factors analysis (EFA): The EFA was used to reduce the impediments into a manageable proportion, and prior to the EFA, the factorability and adequacy evaluation was carried out on the data.

4. RESULTS AND DISCUSSION

4.1 Background details of respondents

The analysis of the respondents' background data showed that 47% of the respondents are engaged by contracting firms, followed by consulting firms (32%), and lastly, clients' organisations (21%). In terms of professional distribution, 40% are Engineers, followed by Architects 32%, then Quantity Surveyors 15%, and builders 13%. This shows an uneven but fair distribution of BIM-knowledgeable and WM-experienced experts. The work experience of the participants showed that they had gained adequate experience to provide information to aid this study. This is premised on the average years of experience obtained of 14 years. However, the breakdown revealed that 37% of them had spent between 11-15 years in the industry, 30% had 16-20 years of experience, 23% had 5-10 years of experience, and 10% had an experience of 21 years and more. Furthermore, the participants had a satisfactory level of education to understand the questions. This is based on their academic profiles; 53% hold a bachelor's degree, 31% have a master's degree, 11% have an HND, and 5% have a PhD.

4.2 Awareness and adoption levels of BIM adoption in CWM

The results on the level of awareness of the benefits of BIM to CWM show that the respondents are very much aware of the benefits of BIM in waste management. This is premised on the proportion (i.e., 58.43%) of them who indicated a 'very high' awareness level, followed by 28.92%, which indicated that they have a 'high' awareness level and 12.65% whose awareness level is moderate. None of the participants indicated low or very low awareness. This further confirms the very high significance of BIM's adoption contribution to waste minimisation in construction projects. Regarding the level of adoption of BIM in CWM, the results show that BIM adoption by construction organisations is low. This is based on the proportion of the respondents who indicated 'very low' and 'low', which are 12.65% and 46.99% respectively. These make up 59.64% of the respondents. There are, however, signs of growing adoption of BIM as 6.02% indicated a 'very high' adoption level, 8.43% indicate high adoption and an appreciable number (25.90%) of them have moderately considered BIM in minimising waste at design and precontract stages (Figure 1).

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4.3 Agreement analysis and Factor analysis of the Impediments to BIM-driven CWM

The outcomes of the ANOVA, Kendall's W test and Factor analysis of the data on the impediments to BIM-driven construction waste management at the design and precontract stage are displayed in Table II.

4.3.1 Agreement analysis

The ANOVA test results (column 9, Table II) showed that 13(65.0%) of the assessed factors have their p-value≥0.05, indicating that the views of the respondents converged on these variables. It also means that there is no significant statistical difference in the perceptions of the various respondents' groups. However, a statistically significant difference was observed in the way the different respondents' groups (Client, consultant, and contractors) ranked 7(35.0%) of the variables as they have their p-value<0.05. Notwithstanding the results obtained from the ANOVA test, Kendall's W test showed that there is no disagreement among the respondents regarding the significance of the impediments to BIM adoption in CWM. Kendall's W of 0.036 is significant statistically as the p-value =0.000. The calculated X^2 for all the respondents is (124.546), which is higher than the critical X^2 value of (30.144) in the statistical table. This implies a significant degree of agreement among the experts from different organisational groups in ranking the impediments to BIM adoption in CWM. The use of chi-square values of Kendall's test to interpret the relatedness of variables ranking within survey respondents is evident in literature (Aghimien et al., 2024).

4.3.2 Exploratory factor analysis (EFA) of the impediments to BIM-driven CWM

The EFA is preceded by a preliminary evaluation of the adequacy and suitability of the data for factor analysis (FA). The preliminary tests confirmed that the gathered data are suitable for EFA. Justifications: (1) a value of 0.860 was obtained for the Kaiser–Meyer–Olkin (KMO). The KMO value is greater than the cut-off of 0.60 suggested (Hair et al., 2010), (2) Bartlett's test of sphericity (BTS) is statistically significant with a chi-square = 1378.814 at a degree of freedom =190, and (3) the average communalities for the assessed variable = 0.568, which is greater than the cut-off of 0.50 (Pallant, 2005). Following the confirmation of the factorability of the data, the EFA was conducted utilising principal component analysis (PCA) with a Varimax rotation. Four cluster PCA solutions with eigenvalue >1 based on Kaiser criteria were obtained, and these clusters have all the items loaded and accounted for 56.838% of the total cumulative variance (TCV) and thus surpassed the 50% recommended (Pallant, 2005).

The four clusters were named, and the numbers of items with the factor loadings (FL) are shown in Table II. Furthermore, the component clusters were subjected to a reliability test using the Cronbach alpha coefficient (α) for construct validity confirmation. The results obtained showed that they have good internal consistency and validity.

<INSERT TABLE II>

4.4 Discussion of EFA Results

The PCA results revealed that the first cluster has seven items loaded onto it with an eigenvalue of 7.238 and a total variance explained (TVE) of 36.190%. These seven items with their factor loadings (FL) are IBWM07 (FL=0.755), IBWM02 (FL=0.68), IBWM12 (FL=0.673), IBWM08 (FL=0.66), IBWM14 (FL=0.618), IBWM03 (FL=0.552) and IBWM15 (FL=0.528). A closer examination of the items showed that they are related to knowledge and resistance issues and were consequently named "*knowledge and resistance barriers*". The importance of awareness and education in the diffusion of innovative technologies and methodologies cannot be over-emphasised. Poor awareness of and education on the functionalities and benefits of BIM tools in minimising CW in construction projects is partly why the level of adoption and implementation is low in Nigeria (Umoren et al., 2019). It is also responsible for the resistance to new approaches and why a more significant proportion of the stakeholders still stick to the old, traditional approach to management waste. Resistance to change is one of the most cited reasons for the low digital technology uptake in the construction industry (Ullah et al., 2019). Construction organisations do not have a structured way of minimising waste from the design and precontract stage because waste management predominantly starts at the construction phase. The attempt at initiating waste management at the design and precontract stage presents itself as a change and, characteristically, will face resistance from some design stakeholders. The culture of resistance to BIM adoption in WM reported in this study is consistent with previous studies (Azhar, 2011; Toyin & Mewomo, 2022). The poor attitude of some experts who prefer to work in silos, avoiding collaboration and sharing of knowledge with regards to BIM use in CWM, further strengthen the barriers associated with education and resistance to change. Therefore, poor coordination, collaboration, and communication attitudes of some experts and stakeholders impede BIM use of CWM (Liu et al., 2015; Doan et al., 2021).

Seven factors are equally loaded onto the second cluster, and this cluster has an eigenvalue of 1.609 and accounts for 8.046% of the TVE. The latent features of these factors show they are associated with support and interest from stakeholders; thus, they were named "supports and interest barriers". These factors are IBWM16 (FL=0.743), IBWM11 (FL=0.721), IBWM09 (FL=0.674), IBWM05 (FL=0.663), IBWM13 (FL=0.587), IBWM06 (FL=0.539) and IBWM10 (FL=0.521). Government interventions, support and interest via policies and regulations formulation are critical for the adoption of successful technology and innovative techniques (Chan et al., 2018). Governments of developing countries like Nigeria may have to offer strong support to ensure the adoption of BIM technology in all public projects with a focus on ensuring the sustainability of the environment and society. Management support and interest are also essential in driving waste reduction and cost and time savings initiatives in construction; this is because the design and preconstruction stages are central to the fight against waste and other losses. The lack of management support and interest in CWM will impact investment in BIM and associated items like internet and power supply. Internet is needed to support collaboration and unhindered connectivity among project teams for better productivity and performance. Inconsistent power supply will discourage the use of BIM and internet services and could impact sustainable efforts at minimising waste. The limiting effects of poor government and management support, poor internet connectivity and irregular power supply on BIM adoption in project management activities like WM is well recognised in the literature (Ullah et al., 2019; Hall et al., 2022; Umoren et al., 2019). Support through regulations and guidelines helps to create an environment that enables the implementation of sustainable practices like BIM usage for CWM. Support is also needed as they motivate stakeholders' interest in responsibility for waste management.

The third cluster has these four items loaded onto it - IBWM19 (FL=0.801), IBWM18 (FL=0.678), IBWM04 (FL=0.671) and IBWM17(FL=0.515) and accounted for 6.900% of the TVE with an eigenvalue of 1.380. The items are related to interoperability and experts, and based on this, the cluster was named "*interoperability and experts' barriers*". BIM's lack of interoperability with existing waste management systems/practices could be why (Akinde et al., 2018) suggested that WM tools utilised in construction still require BIM functionality. BIM may need to properly function with other existing or new systems in use by the organisations, which could cause interoperability issues. Further, the BIM concept in CWM requires a proper introduction to the stakeholder, and where this is lacking, BIM may not work well with the existing practices the experts are used to. Interoperability issues and lack of appropriate introduction of BIM have been acknowledged as impediments to digital technology adoption in project management activities (Toyin & Mewomo, 2022; Hall et al., 2022). Experts are critical to driving innovative tools and methodologies like BIM. Waste management (WM) is an area that is critical to project success. Construction organisations do not have a separate department responsible for WM, but the function is integrated as part of the project manager's responsibility. Effective WM is a sustainable approach, but the experts who drive WM and sustainability initiatives are limited. BIM in WM is a novel approach that reduces waste generation and wastes build-up in landfills. This makes BIM-driven CWM a sustainable technique. However, the need for more skilled experts is a general problem for the construction industry, and the lack of technology-ready experts has caused serious drawbacks in technology adoption (Ismail et al., 2017). BIM and sustainability experts are scarce, and this has impacted the adoption of BIM and other emerging technologies in Nigeria. The absence of trained experts and professionals to handle BIM tools for visualisation and simulation of design for possible waste factors identification at the precontract stages is one of the impediments to attaining sustainable CWM, and this is in line with previous studies (Azhar, 2011; Umoren et al., 2019). This lack of BIM experts is further worsened by the length of time it takes to train experts in BIM usage for CWM and sustainability.

The fourth cluster caused 5.702% of the TVE and a total cumulative variance (TCV) of 56.838%. The cluster has an eigenvalue of 1.140 with two items loaded under it, and these items are IBWM01 (FL=0.798) and IBWM20 (FL=0.529), and based on their latent features, were named "*economic factors*" since they are associated with cost and investment returns. Investment in digital technologies (DTs) is high, and this has remained a critical challenge to construction organisations' efforts at adopting technology and sustainable approaches in project management activities such as waste management. The Nigerian construction industry is dominated by small and medium-sized enterprises, which may not have the needed financial resources, thus making financing a severe problem in BIM innovation adoption. This makes BIM adoption in waste management a challenging one. This finding corroborates previous studies that have stressed how the high cost of investment in BIM software, hardware, and training of local manpower, impedes BIM adoption in CWM efforts of construction organisations (Yuan et al., 2011; Umoren et al., 2019; Evans & Farell, 2021). The lack of guarantee of profits from investment in DT is also a contributory economic factor limiting BIM deployment in project management activity like CWM (Ismail et al., 2017).

5. IMPLICATIONS OF THE STUDY

Practical implications: Industry partners, professional bodies, and educational institutions of learning in Nigeria could leverage this study to improve the learning and broadening of construction experts' knowledge regarding the factors responsible for the drawback in innovative methodologies adoption for waste management and minimisation of other losses. This study reinforces the need to be proactive in the early fight against waste and other losses on projects. Waste results in time overrun and cost overrun, and it impacts the satisfaction of the stakeholders as it constitutes a danger to the environment. BIM adoption in design and precontract state will help improve the performance of project baselines and environmental safety. Client satisfaction and the satisfaction of other project stakeholders are other essential values that construction waste reduction via BIM brings. This study will also be valuable to the government and policymakers in their quest to make informed decisions and policies regarding BIM technology adoption in project management.

Theoretical implications- this study utilised factor analysis to identify the profound impediments to BIM-enabled construction waste management on construction projects, particularly at the design and preconstruction stages. This area is underexplored in the NCI. Stakeholders in the industry could utilise these critical impediments to understand the key challenges to the adoption of BIM technology and other innovative methodologies in waste management, which is a crucial project management function. The validity of the construct reflects the reality expressed by the construction experts, and the finding further enriches the theoretical framework on CWM and the critical limiting factors impacting technology diffusion and sustainability targets of the construction industry.

Material implications- As construction projects go through the various life cycle stages, waste is produced in each phase. The pressure of the continuous extraction of materials from nature causes environmental imbalance and disturbances of the ecosystem. BIM and digital technology adoption reduces waste generation, and this means less pressure on natural resources. Mitigating the impediments to BIM-driven CWM reported in this study, would help save materials on construction projects, as well as improve savings in cost and time and client satisfaction.

6. CONCLUSIONS AND RECOMMENDATIONS

This study utilised a structured questionnaire and snowball sampling technique via electronic means to gather relevant data from experts in construction organisations. The gathered data were analysed using both descriptive and inferential statistical tools, and results were obtained upon which a conclusion was drawn. Based on the findings, the awareness level of BIM benefits on CWM is very high among construction organisations in the NCI. However, the actual adoption of BIM in WM at the design and precontract stage of construction projects is low. The cluster of factors impeding the widespread adoption level of BIM in CWM are (1) knowledge and resistance barriers, (2) support and interest barriers, (3) interoperability and experts' factors, and (4) economic barriers.

Construction organisations and professional bodies should be proactive in propagating measures that will improve the awareness and knowledge of the construction stakeholders on the benefits of BIM in WM. This will help minimise resistance and improve acceptance. Government support via enabling policies and regulations will help speed up the uptake of BIM in construction. Incentives and financial grants will help organisations improve interest and propel actions toward BIM adoption for waste reduction and other losses. Adequate financial support is needed from management to improve investment and develop experts to handle BIM tools and apply them to WM. Interoperability assessment should be carried out and confirmed to ensure new techniques work well with existing systems and practices.

The adoption of the non-probabilistic snowball sampling method, the data analysis methods used, the sample size and the geographical boundary of the study are limitations to the generalisation of the study's outcome. These limitations do not void the usefulness of this study in giving insight into the factors that retards the adoption of BIM for improving waste minimisation and sustainability on construction projects in Nigeria and, by extension, other developing countries in Africa and beyond with similar construction market structures. Future studies could identify more variables and use exploratory factor analysis (EFA) and Confirmatory factor analysis (CFA) to determine the connection between the clusters. The geographical limitations should trigger future research in other regions or areas of Nigeria or other emerging nations. This would provide more frameworks for the comparison of outcomes.

References

Aghimien, D., Aigbavboa, C.O., Chan, D.W.M. and Aghimien, E.I. (2024), "Determinants of cloud computing deployment in South African construction organisations using structural equation modelling and machine learning technique", *Engineering, Construction and Architectural Management*, Vol. 31 No. 3, pp. 1037-1060.

Aghimien, D., Ikuabe, M., Aghimien, L.M., Aigbavboa, C., Ngcobo, N. and Yankah, J. (2022), "PLS-SEM assessment of the impediments of robotics and automation deployment for effective construction health and safety", Journal of Facilities Management, Vol. ahead-of-print No. ahead-of-print. https://doi.org/10.1108/JFM-04-2022-0037

Ajayi, S.O., Oyedele, L.O., Bilal, M., Akinade, O.O., Alaka, H.A., Owolabi, H.A., and Kadiri, K.O. (2015), “Waste effectiveness of the construction industry: Understanding the impediments and requisites for improvements”, *Resources, Conservation and Recycling*, Vol. 102, pp.101–112. http://dx.doi.org/10.1016/j.resconrec.2015.06.001

Akinade, O.O., Oyedele, L.O., Ajayi, S.O., Bilal, M., Alaka, H.A., Owolabi, H.A., and Arawomo, O.O. (2018), “Designing out construction waste using BIM technology: Stakeholders' expectations for industry deployment”, *Journal of Cleaner Production*, Vol. 180, pp. 375-385.

Almuntaser, T., Sanni-Anibire, M.O. and Hassanain, M.A. (2018), “Adoption and implementation of BIM – case study of a Saudi Arabian AEC firm”, *International Journal of Managing Projects in Business*, Vol.11 No.3, pp.608-624.

Ameh, O.J. and Itodo, E. D. (2013), “Professionals’ Views of Material Wastage on Construction Sites”, *Organization, Technology and Management in Construction. An International Journal*, Vol.5 No.1, pp.747-757. DOI 10.5592/otmcj.2013.1.11

Awodele, I.A., Mewomo, M.C., and Eze, E.C. (2023), “Inhibitors to the Adoption of Building Information Modelling in Modular Construction: A Case Study of the Nigerian Construction”, *Journal of Construction in Developing Countries*, Vol. 18 No. 2, pp.19-36.

Ayinla, K.O. and Adamu, Z. (2018), "Bridging the digital divide gap in BIM technology adoption", *Engineering, Construction and Architectural Management*, Vol. 25 No. 10, pp. 1398-1416. https://doi.org/10.1108/ECAM-05-2017-0091

Azhar, S. (2011), “Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry”, *Leadership and Management in Engineering*, Vol.11 No.3, pp. 241-252. https://doi.org/10.1061/(ASCE)LM.1943-5630.0000127

Chan, A.P.C., Darko, A., Olanipekun, A.O. and Ameyaw, E.E. (2018), “Critical barriers to green building technologies adoption in developing countries: The case of Ghana”, *Journal of Cleaner Production,* Vol. 172, pp. 1067–1079. Doi: 10.1016/J.JCLEPRO.2017.10.235

Culka, M. (2018), "Quantitative scenario design with Bayesian model averaging: Constructing consistent scenarios for quantitative models exemplified for energy economics", *Energy, Sustainability and Society,* Vol.8 No.1, pp.1–21.

Doan, D.T., GhaffarianHoseini, A., Naismith, N., Ghaffarianhoseini, A., Zhang, T. and Tookey, J. (2021), "Examining critical perspectives on Building Information Modelling (BIM) adoption in New Zealand", Smart *and Sustainable Built Environment,* Vol.10 No.4, pp.594-615. https://doi.org/10.1108/SASBE-04-2020-0043

Eurostat (2023), Waste Statistics: Available at: https://shorturl.at/fhsHS [accessed August 8, 2023].

Evans, M. and Farrell, P. (2021), "Barriers to integrating building information modelling (BIM) and lean construction practices on construction mega-projects: a Delphi study", Benchmarking*: An International Journal*, Vol. 28 No.2, pp.652-669.

Eze, E.C., Aghimien, D.O., Aigbavboa, C.O. and Sofolahan, O. (2022), "Building information modelling adoption for construction waste reduction in the construction industry of a developing country", Engineering*, Construction and Architectural Management*, Vol. ahead-of-print No. ahead-of-print. https://doi.org/10.1108/ECAM-03-2022-0241

Eze, E.C., Awodele, I.A. and Egwunatum, S.I. (2021), "Labour–Specific Factors Influencing the Volume of Construction Waste Generation in The Construction Industry", Journal *of Project Management and Practice,* Vol.1 No.2, pp.1-16.

Fellows, R. R., and Liu, A. (2008), "*Research Methods for Construction*", 3rd Edition. Wiley- Blackwell Science, London.

Hair, J., Black, W., Babin, B. and Anderson, R. (2010), "*Multivariate Data Analysis*: A Global Perspective, In Multivariate Data Analysis: A Global Perspective.

Hall, A.T., Durdyev, S., Koc, K., Ekmekcioglu, O. and Tupenaite, L. (2022), "Multi-criteria analysis of barriers to building information modeling (BIM) adoption for SMEs in New Zealand construction industry", *Engineering, Construction and Architectural Management*, Vol. ahead-of-print No. ahead-of-print. https://doi.org/10.1108/ECAM-03-2022-0215

Hannan, M. Al Mamun, M.A., Hussain, A., Basri, H. and Begum, R.A. (2015), "A review on technologies and their usage in solid waste monitoring and management systems: Issues and challenges", *Waste Management*, Vol.43, pp.509–523.

Hasan, R., Rakib, M.F.H. and Rahman, M (2022), "Quantification of Construction Waste through BIM", *Journal of Technology Management and Business*, Vol.9 No.1, pp.62-77. DOI: 10.30880/jtmb.2022.09.01.007

Heckathorn, D.D. (2011), "Comment: snowball versus respondent-driven sampling", *Sociological Methodology*, Vol.41 No.1, pp.355-366. Doi: 10.1111/j.1467-9531.2011.01244.x.

Hosseini, M. R., Banihashemi, S., Chileshe, N., Namzadi, M. O., Udaeja, C., Rameezdeen, R. and McCuen, T. (2016), "BIM adoption within Australian small and medium-sized enterprises (SMEs): An innovation diffusion model", *Construction Economics and Building*, Vol. 16, No. 3, pp.71-86. DOI: http://dx.doi.org/10.5130/AJCEB.v16i3.5159

Huang, B., Wang, X., Kua, H., Geng, Y., Bleischwitz, R. and Ren, J. (2018), "Construction and demolition waste management in China through the 3R principle", *Resources, Conservation and Recycling,* Vol. 129, pp. 36-44

Hyarat, E., Hyarat, T. and Al Kuisi, M. (2022), "Barriers to the Implementation of Building Information Modeling among Jordanian AEC Companies", *Buildings*, Vol.12 No.150, pp. 1-20. https://doi.org/ 10.3390/buildings12020150

International Energy Agency (2019), "Global Status Report for Buildings and Construction 2019 Paris": International Energy Agency. Available at: https://shorturl.at/dmzGZ [accesed 8 August 2023]

Ismail, N.A.A., Chiozzi, M., and Drogemuller, R. (2017), "An Overview of BIM Uptake in Asian Developing Countries", *Proceedings of the 3rd International Conference on Construction and Building Engineering (ICONBUILD) 2017*; AIP Conference Proceedings, No.1903, pp.1-7. https://doi.org/10.1063/1.5011596

Lam, T. T., Mahdjoubi, L., and Mason, J. (2017), "A framework to assist in the analysis of risks and rewards of adopting BIM for SMEs in the UK", *Journal of Civil Engineering and Management,* Vol. 23 No.6, pp.740-752. https://doi.org/10.3846/13923730.2017.1281840

Liu, Z., Osmani, M., Demian, P. and Baldwin, A. (2015), "A BIM-aided construction waste minimisation framework", *Automation in Construction*, Vol. 59, pp.1-23. https://doi.org/10.1016/j.autcon.2015.07.020

Liu, Z., Osmani, M., Demian, P. and Baldwin, A.N. (2011), "The potential use of BIM to aid construction waste minimalization" In: *Proceedings of the CIB W78-W102 2011: International Conference*, 26th-28th October 2011, Sophia Antipolis, France, paper53.

Lu, W., Webster, C., Chen, K., Zhang, X. and Chen, X. (2017), "Computational building information modelling for construction waste management: moving from rhetoric to reality", *Renewable and Sustainable Energy Reviews*, Vol.68 No.1, pp.587-595.

Luangcharoenrat, C., Intrachooto, S., Peansupap, V., and Sutthinarakorn, W. (2019), "Factors Influencing Construction Waste Generation in Building Construction: 'Thailand's Perspective", *Sustainability,* Vol.11 No. 13, pp.1-17. **https://doi.org/10.3390/su11133638**

McAuley, B., Hore, A. and West, R. (2017), "*Building information modelling in Ireland 2017*", BIM Innovation Capability Programme, CitA Ltd.

Mohammed, M., Shafiq, N., Al-Mekhlafi, A.-B.A., Al-Fakih, A., Zawawi, N.A., Mohamed, A.M., Khallaf, R., Abualrejal, H.M., Shehu, A.A., and Al-Nini, A. (2022), "Beneficial Effects of 3D BIM for Pre-Empting Waste during the Planning and Design Stage of Building and Waste Reduction Strategies", *Sustainability*, Vol.14 No.6, pp.1-22. https://doi.org/10.3390/su14063410

Naderifar, M., Goli, H., and Ghaljaie, F. (2017), "Snowball Sampling: A Purposeful Method of Sampling in Qualitative Research", *Strides Dev Med Education*, Vol. 14 No. 3, pp.1-6. doi: 10.5812/sdme.67670

Nagapan, S., Rahman, I.A. and Asmi, A. (2011), "A review of construction waste cause factor", Conference paper. Conference: *Asian Conference of Real Estate: Sustainable Growth Managing Challenges (ACRE 2011),* At: Thistle Hotel, Johor Bahru.

Okereke, R., Muhammed, U. and Eze, E. (2021), "Potential benefits of implementing building information modelling (BIM) in the Nigerian construction industry", *Journal of Technology Management and Business,* Vol.8 No.2, pp.1-15.

Osmani, M., Glass, J., and Price, A.D.F. (2008), "Architects' perspectives on construction waste reduction by design", *Waste Management*, Vol.28, pp.1147–1158

Padayachee, K. (2016), "Internet-mediated research: Challenges and issues", *South African Computer Journal,* Vol.28 No.2, pp.25–45. doi: 10.18489/sacj.v28i2.376.

Pallant, J. (2005), "*SPSS Survival Manual*": A Step by Step Guide to Data Analysis Using SPSS for Windows (Version 12), 2nd ed., Allen & Unwin, Crows Nest NSW

Saidu, I., Shakantu, W.M., Adamu, A.D. and Anugwo, I.C. (2017), "A bespoke approach for relating material waste to cost overrun in the construction industry", *Journal of Construction Business and Management*, Vol.1 No.1, pp.39-52

Salgın, B., Akgün, A., Coşgun, N. and Agyekum, K. (2017), "Construction Waste Reduction Through BIM-Based Site Management Approach", *International Journal of Engineering Technologies-IJET,* Vol. 3 No.3, pp.135-142.
Sharman, J. (2018), "Construction waste and materials efficiency". Available at: https://shorturl.at/ezJQ4 [accessed 10 August 2023]
Tan, W.C.K. (2011), "*Practical Research Methods",* Pearson Custom, Singapore
Tanko, B.L., Zakka, W.P. and Heng, W.N. (2022), "BIM in the Malaysian construction industry: a scientometric review and case study", *Engineering, Construction and Architectural Management,* Vol. ahead-of-print No. ahead-of-print. https://doi.org/10.1108/ECAM-04-2021-0324
Toyin, J.O. and Mewomo, M.C. (2022), "An investigation of barriers to the application of building information modelling in Nigeria", *Journal of Engineering, Design and Technology,* Vol. ahead-of-print No. ahead-of-print. https://doi.org/10.1108/JEDT-10-2021-0594
UK Environment agency (2021), "Construction and demolition sites - Do you know what's in your waste"? Available at: https://shorturl.at/gwAQZ [accessed 21/08/2023]
Ullah, K., Lill, I. and Witt, E. (2019), "An Overview of BIM Adoption in the Construction Industry: Benefits and Barriers", Lill, I. and Witt, E. (Ed.) *10th Nordic Conference on Construction Economics and Organization (Emerald Reach Proceedings Series, Vol. 2), Emerald Publishing Limited, Leeds,* pp. 297-303. https://doi.org/10.1108/S2516-285320190000002052
Umoren, E.K., Adewuyi, T.O. and Otali, M. (2019), "Application of BIM to construction material waste management: 'stakeholders' perceptions in selected states of south-south, Nigeria", *Journal of Contemporary Research in the Built Environment*, Vol 3 No.2, pp.1-16.
United States Environmental Protection Agency (US EPA) (2023), "Sustainable Management of Construction and Demolition Materials", Available at: https://shorturl.at/gjrs4 [accessed August 8, 2023]
Unuigbe, M., Zulu, S. L. and Johnston, D. (2022), "Challenges to energy transitioning in commercial buildings in the Nigerian built environment – from generator to RETs economy", *Built Environment Project and Asset Management*, Vol.13 No.1, pp.157-171.
Vasilca, I.-S., Nen, M., Chivu, O., Radu, V., Simion, C.-P. and Marinescu, N. (2021), "The Management of Environmental Resources in the Construction Sector: An Empirical Model", *Energies*, Vol.14 No.9, pp.1-19. https://doi.org/10.3390/en14092489.
Won, J. and Cheng, J.C.P. (2017), "Identifying potential opportunities of building information modelling for construction and demolition waste management and minimization", *Automation in Construction*, Vol. 79, pp. 3-18.
Won, J., Cheng, J.C. and Lee, G. (2016), "Quantification of construction waste prevented by BIM-based design validation: Case studies in South Korea", *Waste Management*, Vol.49, pp.170–180.
Yuan, H., Shen, L. and Wang, J. (2011), "Major obstacles to improving the performance of waste management in China's construction industry", Facilities, Vol.29 No.5/6, pp.224–242. https://doi.org/10.1108/02632771111120538
Zhou, Y., Yang, Y. and Yang, J.-B. (2019), "Barriers to BIM implementation strategies in China", *Engineering, Construction and Architectural Management*, Vol. 26 No.3, pp. 554-574. https://doi.org/10.1108/ECAM-04-2018-0158

Table I: Impediments to BIM-driven waste minimisation on construction projects

Code	Impediments	Statements	Sources
IBWM01	High cost of BIM investment (software, hardware, and training of experts)	the high cost of waste reduction investment is further worsened by the high cost of BIM software and hardware	Hyarat et al. (2022); Umoren et al. (2019); Ismail et al. (2017); Hosseini et al. (2016); Hall et al. (2022); Doan et al. (2021); Zhou et al. (2019)
IBWM02	Lack of awareness and education about BIM technology	Poor awareness and education on BIM use for CWM	Umoren et al. (2019); Ullah et al. (2019); Nemati et al. (2020); Toyin and Mewomo (2022); Ismail et al. (2017); Hosseini et al. (2016)
IBWM03	Lack of client requirements and demand	Clients focus on physical/finished assets and not the process, affecting the market for BIM adoption for CWM	Umoren et al. (2019); Ullah et al. (2019); Azhar (2011); Ismail et al. (2017); Hall et al. (2022)
IBWM04	Lack of trained experts and professionals to handle the tools	The lack of BIM experts to handle BIM tools to enable visualisation and simulation of design for possible waste factors identification at the pre-contract stages	Almuntaser et al. (2018); Umoren et al. (2019); Ullah et al. (2019); McAuley et al. (2017); Azhar (2011); Doan et al. (2021)
IBWM05	absence of an enabling environment and sufficient guidelines for BIM implementation	absence of enabling environment and guidelines for BIM implementation in CWM	Hyarat et al. (2022); Umoren et al. (2019)
IBWM06	issues of poor internet connectivity	poor internet connectivity limits collaboration between design experts at the preconstruction stage	Umoren et al. (2019)
IBWM07	resistance to innovation and approaches	Resistance to new methods, techniques, and technologies, leading to poor visualisation of design decisions/options	Umoren et al. (2019); Ullah et al. (2019); Toyin and Mewomo (2022); Azhar (2011); Ismail et al. (2017) Hosseini et al. (2016); Zhou et al. (2019)
IBWM08	Poor collaboration, coordination, and communication	Poor attitudes of some experts to coordination, collaboration, and communication affect BIM use for CWM	Umoren et al. (2019); Doan et al. (2021); Liu et al (2015)
IBWM09	Legal and contractual constraints	lack of the legal and contractual backing to adopt BIM for CWM	Evans and Farell, (2021); Zhou et al. (2019); Doan et al. (2021); Umoren et al. (2019); Ullah et al. (2019); Doan et al. (2021)
IBWM10	Frequent power failure	Erratic and regular power failure discouraging the sustainable use of BIM	Umoren et al. (2019)
IBWM11	Acceptance of BIM from middle & senior management	Poor management support for BIM usage at the design stage to reduce waste factors	Ullah et al. (2019)
IBWM12	the dominance of the traditional construction methods	Overreliance on the ineffective traditional ways of managing waste	Nemati et al. (2020)
IBWM13	lack of attention and interest in BIM	the general lack of interest by stakeholders in using BIM for CWM	Almuntaser et al. (2018); Ullah et al. (2019); Nemati et al. (2020)
IBWM14	lacks mentorship to champion the course of BIM	Absence of BIM for CWM mentorship among construction experts	Almuntaser et al. (2018)
IBWM15	Lack of sufficient evaluation of BIM capability	lack of adequate assessment of BIM capability for CWM	Toyin and Mewomo (2022); Doan et al. (2021)
IBWM16	Lack of government enforcement, regulation, and policies	Weak government support: policies, regulations, and enforcement in the use of BIM to curb CW	Ullah et al. (2019); Hall et al. (2022); Doan et al. (2021)
IBWM17	Length of time required to train BIM users	The lack of sufficient time to train experts on how to use BIM for CWM	Toyin and Mewomo (2022)
IBWM18	inappropriate BIM concept introduction	The BIM concept lacks an appropriate introduction to CWM	Toyin and Mewomo (2022)
IBWM19	interoperability issues	BIM lack of interoperability with the existing system of waste management/practices	Hall et al. (2022);
IBWM20	lack of assurance of return on investment (ROI)	A lack of assurance on the ROI of BIM in CWM	Ismail et al. (2017)

Source: Authors' own creation

Table II: Rotated Component Matrix of the impediments to BIM-enabled CWM

Cluster name	Code	Variables	FL	Eigenvalue	% of Variance	Cumulative %	α	P-value
Cluster 1: Knowledge and resistance barriers	IBMW07	Resistance to new methods, techniques and technologies, leading to poor visualisation of design decisions/options	0.755	7.238	36.190	36.190	0.816	0.164
	IBMW02	Poor awareness and education on BIM use for CWM	0.680					0.638
	IBMW12	Over reliance on the non-effective traditional ways of management waste	0.673					0.002*
	IBMW08	Poor attitudes of some experts to coordination, collaboration and communication affect BIM use of CWM	0.660					0.005*
	IBMW14	Absence of BIM for CWM mentorship among construction experts	0.618					0.062
	IBMW03	Clients focus on physical/finished asset and not the process, affecting the market for BIM adoption for CWM	0.552					0.129
	IBMW15	lack of adequate assessment of BIM capability for CWM	0.528					0.004*
Cluster 2: Supports and interest barriers	IBMW16	Weak government support: policies, regulations and enforcement in the use of BIM to curb CW	0.743	1.6092	8.046	44.236	0.802	0.522
	IBMW11	Poor management support for BIM usage at design stage to reduce waste factors	0.721					0.076
	IBMW09	lack of the legal and contractual backing to adopt BIM for CWM	0.674					0.029*
	IBMW05	absence of enabling environment and guidelines for BIM implementation in CWM	0.663					0.082
	IBMW13	the general lack of interest/motivation by stakeholders in using BIM for CWM	0.587					0.001*
	IBMW06	poor internet connectivity limiting collaboration between design experts at the preconstruction stage	0.539					0.864
	IBMW10	Erratic and regular power failure discouraging the sustainable use of BIM	0.521					0.392
Cluster 3: interoperability and experts' factors	IBMW19	BIM lack of interoperability with existing system of waste management/practices	0.801	1.380	6.8995	51.135	0.719	0.481
	IBMW18	BIM concept lacks appropriate introduction to CWM	0.678					0.717
	IBMW04	The lack of BIM experts to handle BIM tools to enabled visualisation and simulation of design for possible waste factors identification at the pre-contract stages	0.671					0.346
	IBMW17	The lack of sufficient time to train experts on how to use BIM for CWM	0.515					0.015*
Cluster 4: Economic barriers	IBMW01	the high cost of waste reduction investment is further worsened by the high cost of BIM software and hardware	0.798	1.140	5.702	56.838	0.667	0.014*
	IBMW20	A lack of assurance on return on investment (ROI) of BIM in CWM	0.529					0.182
		N	166					
		Kendall's W[a]	0.04					
		calculated X^2	125.0					
		Critical X^2 from Statistical Table	30.10					
		df	19					
		Asymp. Sig.	0.00					

*=P-value≤0.05; FL= factor loading; α=Cronbach alpha coefficient

Source: Authors' own creation

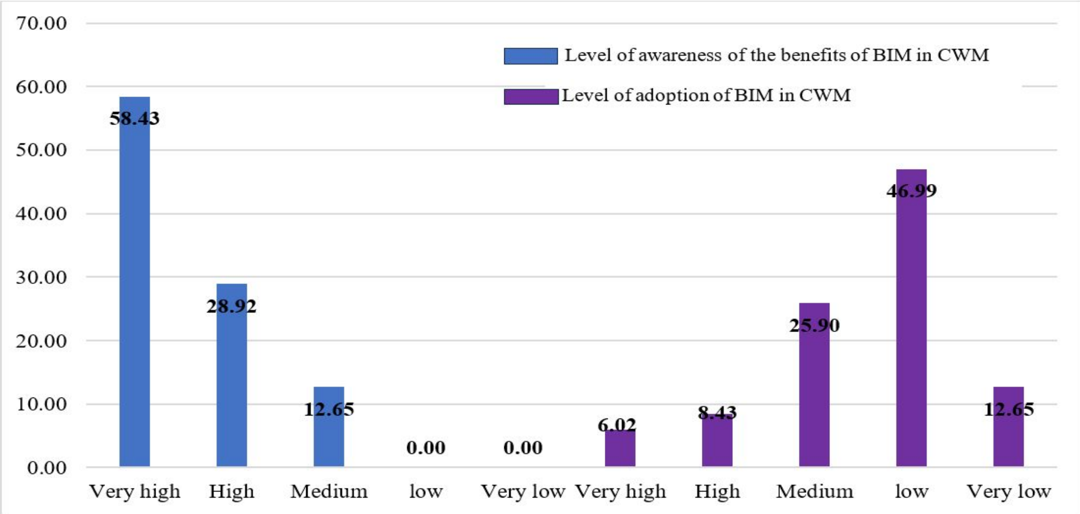

Figure 1: Awareness and adoption levels of BIM adoption in CWM

Source: Authors' own creation

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GUEST EDITORS' COMMENTS AND AUTHORS' RESPONSE

The authors deeply wish to extend thanks to the Guest editors for their observations, comments and suggestions to improve the paper. The paper has now been improved as a result of addressing these positive feedbacks. Each comment has been addressed appropriately (refer below) and manuscript file resubmitted for re-review and consideration for final acceptance (see green coloured texts and sentences) within MS Word.

Once again, thank you.

Guest Editors' Comments to Author	Authors Response to Reviewers/Guest Editors Comments
GUEST EDITOR COMMENTS TO AUTHORS	
1. It is recommended to address the below comments;	All Guest editors comments have been followed to significantly improved the manuscript
1(a). All Tables and Figure are submitted in one Word file (The guideline says: It is OK to keep the Figures (if any) in the main text document if preferred. However, IF submitting separately, all Figures should be in One separate Word Doc (not with Tables) also submitted FOR REVIEW.). Therefore, please separate the figure inserted to the tables file and submit in a separate word file.	Tables and figure now on separate files See attached tables and figure files
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1(c). The manuscript title has a full stop at the end, which we do not usually include for a manuscript title. Please remove the full stop in the title.	Thank you. the 'full stop' in the Title now removed See page 1
1(d). Why have the authors included 'design waste' as a keyword? Instead, it is recommended to use 'construction waste'. Please check and revise, if needed. Otherwise provide reasons for including it.	Thank you. 'Design waste' has been changed as recommended to 'construction waste'

	See page 1
1(e). Section 5 Implication of the study - the heading can be stated as 'Implications of the study' (with an 's' at the end), where the first subheading 'Practical Implication' can also be changed as 'Practical Implications'.	Thank you 's' has been added to Section 5 and the first subheading under section 5, and it now read; 'Implications of the study' And 'Practical Implications' See page 10
1(f). Section 6 also can be Conclusions and Recommendations (instead of Conclusion and Recommendations)	Thank you. Section 6 now reads; Conclusions and Recommendations (not Conclusion and Recommendations) See page 11
2. The present wordcount is 8,815 i.e. text: 7,975 + 280 x 3 (2 Tables + 1 Figure) = 8,815. Since 'Minor Revisions' are needed, and several typos have been pointed out, your word limit remains at 8,850.	Thank you. Manuscript wordcount is still within recommended (i.e.
3. Please submit the required 'Revisions Summary' as a Word File (and classed as a "Supplementary File for Review") – clearly itemising changes done, for easier Re-review, also clearly specifying in page/ line numbers, or by some other means, the exact location of each of the revisions.	Thank you. Means of identification of changes made has been added for easy re-review
4. Please Also remember to download, complete and submit the BEPAM Checklist. See:http://www.emeraldgrouppublishing.com/authors/writing/bepam_checklist.doc	Checklist download, filled and uploaded
5. Please also follow all other Author Requirements/ Guidelines.	Authors requirements/Guideline followed
6. In conclusion, we look forward to an improved submission that will address the above comments and make a significant contribution to knowledge in this domain.	Thank you. The revised submission is improved and makes a significant contribution to knowledge