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Smart Technology Integration: SHM and BIM for Preventing Building Collapses

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Abstract

Building collapse is arguably one of the most devastating disasters faced by many African countries. Nigeria has experienced a number of building collapses that have posed serious threat to human life and properties. As such, this alarming trend calls for innovative and sustainable solutions to safeguard the built environment. This paper examines how Structural Health Monitoring (SHM) and Building Information Modeling (BIM) can be integrated as a remedy for such disasters. The data from 175 respondents including construction professionals, policy makers and other stakeholders were collected through internet-based questionnaires. Descriptive statistics were used to analyse the data, and the results showed trends in people's perceptions and awareness of various technologies. To investigate the variations in perceptions among the different stakeholder groups, an ANOVA single factor test was also performed. According to the data, 45.14 percent of respondents said that building collapses in Nigeria occur frequently and that poor construction techniques are the main reason for these failures. Additionally, the fact that 75.43% and 69.71% of them had never utilised SHM and BIM, respectively, before suggests that they have little understanding of the two technologies. However, 85.14% of respondents were sufficiently certain that integrating these technologies would lower the number of building failures since it would be feasible to identify structural issues sooner and make better constructions. Therefore, capacity building programs, better collaboration between government and industry and supportive regulations should be put in place in order to promote SHM and BIM adoption.

Keywords: Building Collapse, Structural Health Monitoring (SHM), Building Information Modeling (BIM), Building Safety, Nigeria.

Introduction

Sustainable cities and communities are known as the 11th goal of the 17 sustainable development goals (SDGs). It makes cities and human settlements inclusive, safe, resilient and sustainable with the proper construction of residential, commercial and industrial buildings. In recent years, the problem of building collapses has taken an alarming and troubling turn in Nigeria, culminating in great loss of lives, economic losses, and erosion of confidence, trust, and belief in the construction industry. These incidents are mostly associated with workmanship, use of inferior materials, poor supervision and enforcement of building codes. Buildings are designed to carry and transfer both dead and live loads to their foundations safely and without excessive deformation, however certain circumstances including bad design, poor construction methods, little or no supervision, foundation failure, excess loading, not adhering to design, and a combination of these or other causes may lead to building failure and collapse (Franklin et al., 2022).

The construction sector is one of the few if not the only who has sustained a lot of casualties as well as damages within building project collapse (BPC) in any part of the earth. History has shown surveys such as those done by Skinbniewski (2014), Mwangi (2016) and Boateng (2020) and more that the industry has the highest cases of accidents. The third world countries experience the greatest impact. As such, it may have had problems of social vulnerability in the wake of the tragedies (Massazza et al., 2019). The sheer destructiveness resultant of BPC demonstrates that developing construction industries put wives and mothers at risk (Boateng, 2020). Building collapse may affect developed countries too but not as frequent as it is for developed nations. In June 2021, a balcony of a house which had been in existence for 40 years came down in Miami, United States of America (Lu et al, 2021).

Structural failure refers to the loss of load carrying capacity of a structural component or structure itself, this failure in many cases renders the building unsafe for habitation or continuation of construction activities and could eventually lead to collapse, damage to property and loss of lives (Chiemezie and Krzystof, 2021). This failure can be attributed to many factors including design error, faulty construction, excessive settlement, foundation failure, overloading, inadequate steel reinforcement, poor concrete mix design, lack of maintenance, etc. A failure could be in the form of building over use beyond its design capacity, breakdown of building services leading to underground seepages, construction materials weakness overtime, maintenance negligence and flood (Olabosipo et al, 2010). Therefore, maintaining structural safety over the course of a structure's lifetime requires the detection of structural degradation. Nonetheless, it is critical to keep an eye on the deterioration's frequency, location, and extent from the standpoints of performance and safety (Sivasuriyan et al, 2021).

Literature Review

According to Lu et al. (2021), unintended loading may cause a building to gradually collapse. A design with sufficient load redistribution capacity after the initial localised failure was proposed by the authors. Several studies have claimed that building collapses occur more frequently in poor nations, including Boateng (2019), Windapo and Rotimi (2012), and Okeke et al. (2020). Boateng (2020) states that building collapse results in losses of assets and lives as well as both temporary and permanent disabilities. Awoyera et al. (2021) report

that throughout the past ten years, man-made factors have accounted for 87.5% of building collapses in Nigeria, while natural conditions have contributed the least. But the growing number of incidents should act as a wake-up call and a cautionary tale for all parties involved in the building sector.
As noted by Mohammed (2017), building failure around the world has been attributed to two major factors, which are both natural and engineered. Natural events entail Environmental catastrophes such as earthquakes, flood, tsunami, soil liquefaction etc, and when these events strikes they are referred to events as in man-made disasters, negligence however, in testing soils, safety in structural design, poor quality materials used, unskilled personnel used, and lack of control over work carried out are all reasons which fall into the category of the manufactured phenomena.
Ayedun et al. (2012) identifies that the frequency of occurrence has become a major source of concern to the all Nigerians, from government officials, regulatory agencies, professionals and relevant stakeholders to the unskilled labour in the building industry, as the magnitude of the incidents are becoming very unprecedented. Despite all the efforts by many researches in the field of engineering, the incidence is still regularly occurring which have brought brought to question whether these stakeholders have critically examined the reasons for building failure and the roles they can play or the strategies they can articulate that would help mitigate the issue.
Adebowale et al. (2016) in their study identified that the effects of building collapse are usually in the form of economic and social implications which include: Loss of human life, Loss of materials, Loss of capital investments, Physical damage and psychological trauma. Chendo and Obi (2015) identified the following as the consequences of building collapse in Nigeria and they include: loss of life property and huge sum of capital, loss of reputation and integrity leading to psychological trauma, Loss of new commissions and contracts, Withdrawal of practicing licenses and Loss of materials and capital investments.
explores the factors influencing minimal building failures in Rivers State, Nigeria, a region known for its exceptionally low rate of structural failures. The study identifies several critical factors behind this achievement, including strict legal frameworks, premium building materials, skilled labor, successful community collaboration, favorable environmental conditions, and technological integration. The findings emphasize the importance of upholding strict building regulations and norms to maintain high construction standards. Regular inspections and compliance checks ensure adherence to defined safety protocols, significantly reducing the likelihood of structural problems.
In a developing country like Nigeria, the review of literature and aanecdotal evidence reveal that between 1974 and 2019, which is 45 years, over 221 incidences of collapsed buildings have been reported in her major towns and cities leading to several fatalities. In fact, within the last four years, Nigeria has recorded over 56 cases of building collapse (M. Yakub, 2019). There is no state in Nigeria, without at least one incident of building collapse in the past ten years (O.A Oyedele, 2018). Available records also show that between 1971 and 2016, 1,455

fatalities were recorded in 175 collapse cases (F.C omenihu, 2016). Many studies, such as Okeke et al. (2020), Falana and Ipindola (2020) and Mrabure and Awhefeada (2021) have researched this area and proffered suggestions to prevent future occurrence.

According to (Francis et al, 2020), The Nigeria Construction and Infrastructure Summit Group estimates that the country loses between 2.03tn and 3.05tn annually to infrastructure deficit from building failure because the magnitude of overall damage to the initial cause is usually out of proportion due to progressive collapse. Resulting from these, research efforts have been focused on identifying the various factors that contribute to the burgeoning cases of collapsed buildings in this country through physical observations and or sample collection of debris from building collapse sites and oral interviews of eye witnesses or residents within the vicinities.

Within 7 months (from January, 2024 to July, 2024), the Council for Regulation of Engineering in Nigeria (COREN) recorded 22 building collapses in Nigeria with Lagos accounting for 27.27%, Abuja and Anambra 18.18% each, Ekiti and Plateau followed with 9.09% and Kano, Taraba and Niger States accounted for 4.55% each. This was made known by the president of COREN in a conference held in Abuja on the 17th July, 2024. Table 1. shows some of the occurrences of building collapse in Nigeria within 7 months.

Table 1: Recent Building Collapse in Nigeria

S/N	Location	Types of Building	Year	Suspected Cause(s)	Lives Lost
1.	Plateau	School building	2024	Poor construction practice	22
2.	Abuja	2-Story residential building	2024	Faulty design and workmanship	-
3.	Lagos	4-Story residential building	2024	Excessive loading, substandard materials	-
4.	Anambra	3-Story building	2024	Aging building	6
5.	Niger	3-Story building	2024	Structural failure	-

Source: *Online news of recent building collapses in Nigeria.*

Many researchers investigate the causes of building collapse in Nigeria, while some focus on mitigation procedures to address this prevalent issue. However, this study evaluates the role of technology on assessment of existing buildings in an attempt to prevent structural failure of the building. It focuses on examining the current state of Structural Health Monitoring (SHM) and Building Information Modeling (BIM) adoption, and investigates the potential benefits of integrating these approaches through a desk study.

Nuhu et al (2021) defined SHM as a process of detecting damages to engineering structures. Structural Health Monitoring (SHM) deals with the use of various types of sensors and data analysis techniques for monitoring the actual condition of a building in real time. These systems will be able to carry out tasks such as detecting any anomalies on structures, assessing what type of repairs needs to be done as well being able to predict when that structure might fail hence necessitating prompt maintenance. This approach ranges from visual inspection, unmanned aerial vehicle (UAV) based inspection, 3D-Reconstruction and machine learning detection strategies.

Maintenance schedules and repair strategies can be informed by SHM data. Therefore, maintenance efforts will be enhanced to focus on their repair need and thus lead to more precise and effective repairs that take care of issues on time and prevent the complete collapse of the structure. This means, during construction, SHM is employed to ascertain that the materials used in building and construction practices comply with the necessary specifications. Cawley (2018) claims that there hasn't been much industry use of this massive research project on structural health monitoring. Thus, the purpose of this review is to close the knowledge gap between certain SHM techniques proposed by researchers and those found in the literature, evaluate their applicability in real-world settings to ascertain their efficacy, talk about their accessibility, and offer recommendations for reducing the risk of building collapse in Nigeria. Visual inspection is a widely practiced structural health monitoring technique in Nigeria. While it is a crucial first step for non-destructive examination of buildings, it is not a comprehensive solution on its own. In Nigeria, visual inspection has been instrumental in assessing the current conditions of buildings and determining the necessary testing for structural health monitoring. (Ibrahim et al, 2020; Osuji et al, 2020; Thomas and Ede, 2019).

On the other hand, Building Information Modeling (BIM) refers to the detailed creation of 3D forms or representations with the inclusion of various aspects related to building designs and infrastructural works. It contains information on all aspects of the construction including its geometry, the spatial relations between objects, its location on the map, e.t.c. This approach makes it possible to develop exact 3D designs for buildings taking into consideration their structural composition, not just their outside appearance as is often the case when architects work with traditional modeling tools like AutoCAD. Thus, by creating such models' engineers who use them can conduct thorough analyses focusing at such aspects as possibility structural failures occurring in certain parts or weaknesses.

Building Information Modeling makes it easy for anyone who is involved in constructing or keeping up a structure to get to all details concerning structures of a building. This helps to avoid instances of making would be fatal errors during construction such as wrong specifications of building materials or even design changes which could lead to total collapse when someone is going about his/her normal routine within that premises by ensuring that there is a central resource place with every bit of information regarding the whole construction process on such buildings. In addition, BIM includes life cycle management (LCM). This means that all possible descriptions about a given building should always be available at every time such as energy consumption, greenhouse gas emissions or materials used in construction. In other words, through BIM it is also possible to continuously update the information about a given building.

Saka et al. (2020) suggest that transitional dynamics with respect to the integrated use of technology in the construction industry seem to be very slow and not up to the desired pace. They added that even developed nations as well as developing ones are still facing the challenge of BIM adoption. Benedict et al. (2024) examines the barriers to the implementation of Building Information Modeling (BIM), which is typical in developed countries, in construction projects in Nigeria, a developing nation. BIM has been essential in the architecture, engineering, and construction space, reducing the overall cost of projects, maximizing efficiency, and lowering the delivery time. Nevertheless, these changes have proved difficult and the industry has been slow to respond to changes. The focus of this study is to determine the TISM model in understanding these barriers. The results from the TISM analysis indicate that the absence of skilled personnel in the use of BIM tools possesses the highest driving power and lowest dependence power showing its significance towards the implementation of BIM. The results further indicate that lack of information about BIM system and unwillingness to change play important role in the implementation of BIM technology in the construction projects.

Xu et al. (2023) delved into the application of SHM and BIM for the purposes of large scale bridge infrastructure monitoring in the US. They reported that the use of real time SHM data and BIM models allowed better understanding of the structural performance which in turn promoted predictive maintenance and lowered the maintenance repair costs. A study by Afolayan et al. (2023) in Ghana showed that while BIM is being increasingly adopted for construction design, integrating SHM remains a challenge due to limited technical expertise and financial constraints. However, the study emphasizes the potential for SHM-BIM integration to address building collapse issues, much like in Nigeria.

This major problem could be solved which is promising but not widely studied by integrating Structural Health Monitoring (SHM) with Building Information Modeling (BIM). Through the use of SHM's real time data on structural performance and BIM's detailed digital description of building information, there could be an active system that prevents as well as anticipates rather than reaction after identifying the most probably points for failure. In the Nigerian context the combined use of SHM and BIM in averting building collapses is a field that has received scant research despite potential gains from the same. The shortfall necessitates a profound study that propose a means of integrating these technologies in an attempt to address these prevalent issues of building collapse in the country.

The phenomenon of building crashes has taken a disturbing turn in Nigeria, claiming lives and properties as well as economic impact. No matter how hard the authorities try to implement building regulations, one of the reasons why such misfortunes keep happening is the ineffective controlling and maintaining existing building structures. Although every construction sector in the world has modernized with the implementation of SHM systems and tools, Building Information Modeling, and even other advanced auxiliary technologies, the application of these technologies in the construction environment in Nigeria is still very old fashioned.

The precise challenge that this research targets is that SHM and BIM technologies are not well harnessed to curb building collapses in Nigeria. However, while the, literature highlights the advantages of applying SHM is for its ability to provide updated data, and BIM to render a model more functional and efficient, these technologies have not been well utilized in practice in Nigeria. This study will seek to fill that gap by exploring the applicability of SHM and BIM Systems towards the reduction of building collapses and enhancing construction safety in Nigeria. In this way, through the perspectives of the stakeholders, this research will perform both roles and prepare all the construction professionals and the authorities concerned towards the use of these technologies together with the recommendations that will be given. To achieve this goal, the study pursued the following objectives:

1. Assess the current state of SHM and BIM adoption in the Nigerian construction industry.
2. Identify the challenges and barriers hindering the adoption of SHM and BIM technologies.
3. Evaluate the potential benefits of SHM and BIM integration in preventing building collapses.
4. Develop actionable recommendations for policymakers and construction professionals to foster the implementation of SHM and BIM technologies.

Methodology

This study investigates the integration of structural health monitoring (SHM) and building information modeling (BIM) to mitigate building collapse in Nigeria. The methodology adopted involved quantitative and qualitative approaches through the administration of a structured questionnaire. This method sought to receive first-hand views from major stakeholders within the Nigerian construction industry on Structural Health Monitoring (SHM) and Building Information Modeling (BIM) for collapse mitigation. Data was collected using internet-based forms, which were designed through Google Forms then sent out for broader outreach among different respondents from across the various regions in Nigeria.

The target population for this study were constructors, policy makers and the general public. Engineers, architects and construction managers made up the constructors who provides expert opinion regarding technicalities and practicalities related to incorporation of such technologies into current practices in Nigerian construction sector. The evaluation of these technologies, as well as their adoption to mitigate cases of building collapse, greatly relied on this group.

Additional to construction professionals, other respondents tended to be the enforcers of regulation concerning SHM and BIM technologies. With including the policy makers, the objective of this investigation was to be able to consider the building safety policies and the legislation instituted in Nigeria. That was to help find the differences and recommendation for policy changes where necessary for effective implementation of the policies. An increasing number of individuals were also solicited for their views regardless of their knowledge of construction, including building users. Their feedback was important for exploring the issue of lay understanding of building security and familiarity with SHM and BIM technologies. This aided in addressing the safety perception of the public and also described the need for advanced systems if at all there were safety measures.

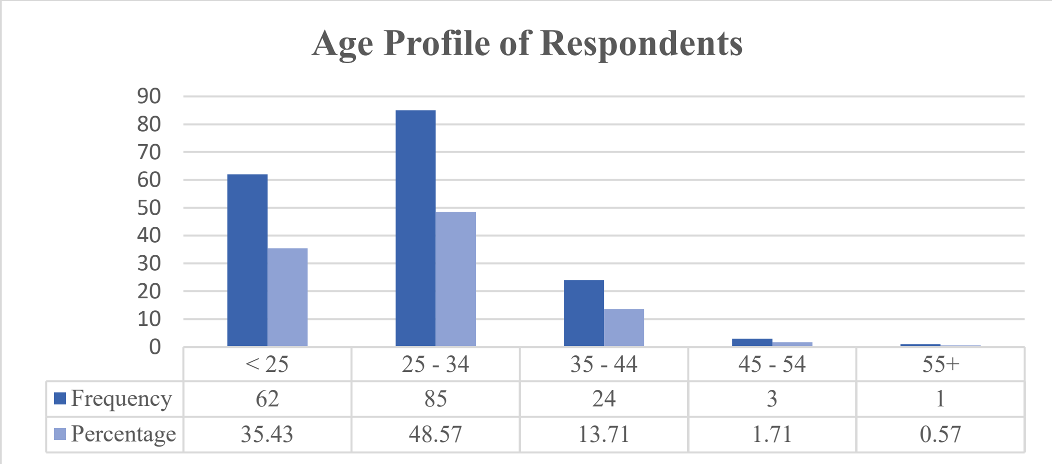
Statistical evaluation of the data proceeded by using both non-parametric and parametric methods in the statistical package. Descriptive techniques such as frequencies and percentages were used to present quantitative data that had been captured through the four survey instruments. Such analysis assisted in making conclusions relative to the demographics of the respondents, their awareness concerning SHM/BIM, and perceptions on the usefulness of these technologies in combating unwanted building collapses. In order to analyze the relationship between different variables specifically, an ANOVA (Analysis of Variance) single factor test was utilized. This exploit was designed to assess the means between several populations (construction professional, policy makers and the general public) at a variance of their views towards the perception of SHM and BIM with the aim of testing the hypothesis that they have the same mean. The ANOVA validated if the variations in the opinions of the members of the above mentioned four groups were simply out of randomness or were due to the true diversity in their attitudes as per their professions or connection with the construction industry.

Result and Discussion

1. Demographic Information of Respondents

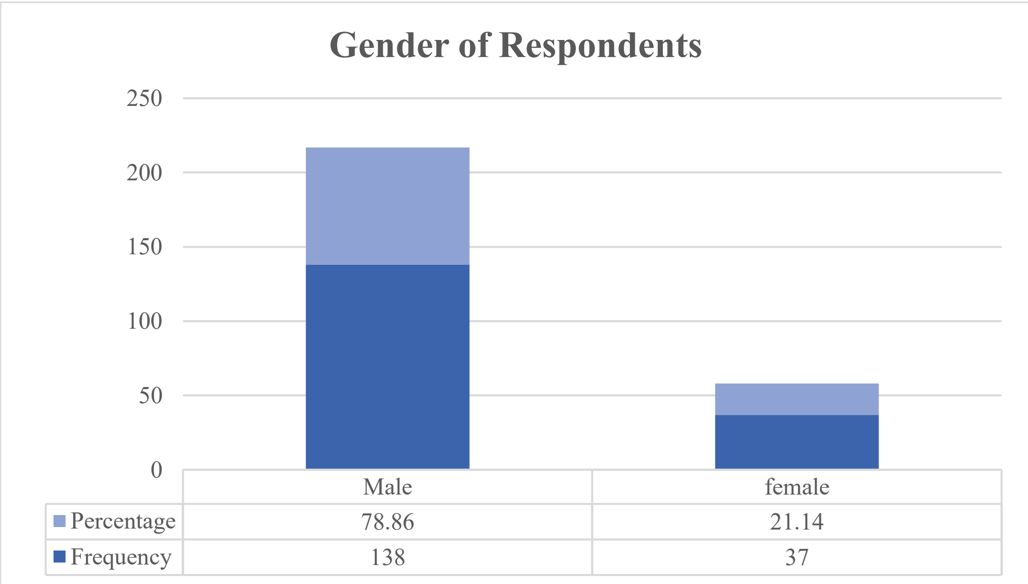
Out of 175 respondents, 138 are male and 37 are female indicating a strong male predominance (78.86) as shown in Fig. 1. The gender imbalance may reflect on current workforce distribution in Nigerian construction and policy-making related sectors where males have traditionally dominated technical and engineering fields. Fig. 2 shows that the majority of the respondents (49%) fall within the 25-34 age group indicating that they are likely to be young professionals or individuals at early or mid stages of their career which is an important demographic for adopting new technologies like Structural Health Monitoring (SHM) and Building Information Modeling (BIM).

With regard to occupation as shown in Fig. 3, the largest percentage (58.86%) are civil servants while 28% are construction practitioners, 4% IT practitioners and 9.14% students. This high proportion of civil servants demonstrates how such individuals play a critical role in designing strategies aimed at addressing building collapses as part of the policy implementation plan. Additionally, it also provides people directly involved with construction processes with practical insights due to presence of construction practitioners (28%).



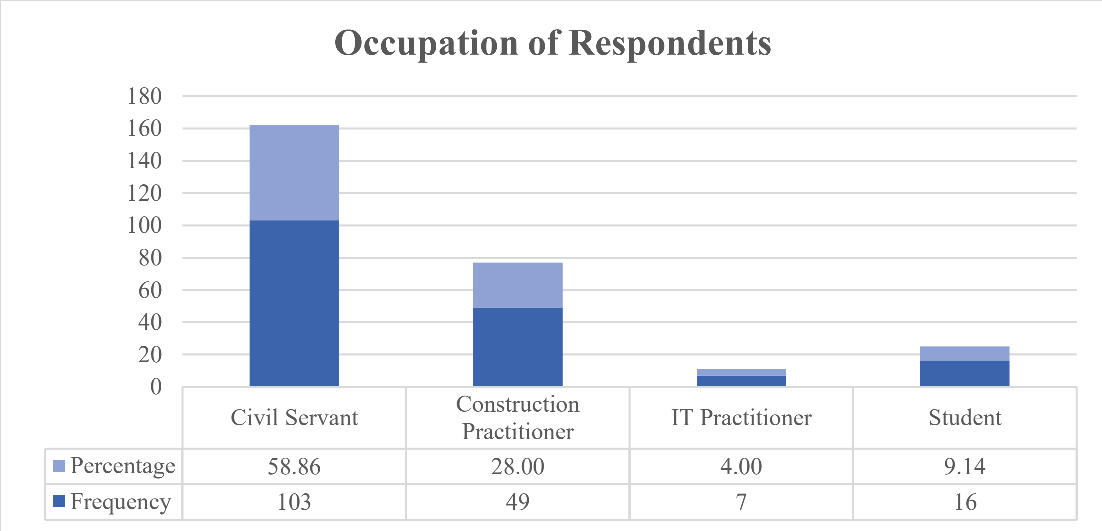
Source: *Authors Electronic based survey, 2024.*

Figure 1. Age Profile of Respondents



Source: *Authors Electronic based survey, 2024.*

Figure 2. Gender of Respondents



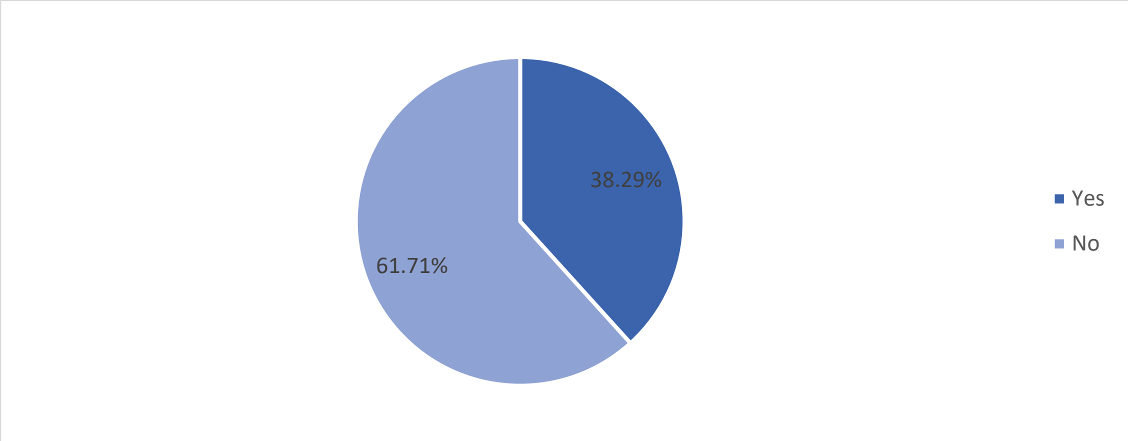
Source: *Authors Electronic based survey, 2024.*

Figure 3. Occupation of Respondents

2. *Current State of Building Collapse in Nigeria*

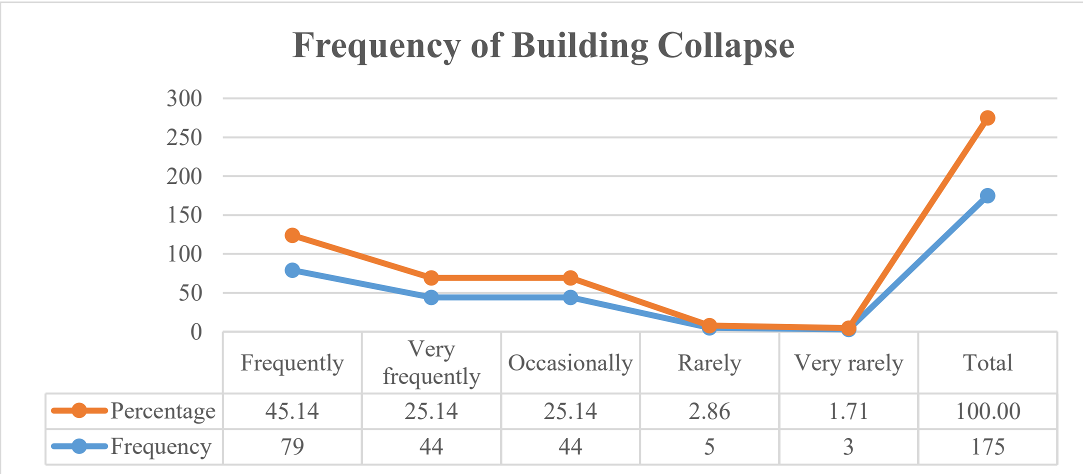
Among the 175 respondents, 61.71% did not witness nor were involved in any building collapses while 38.29% had experienced one as shown in Fig. 4. This distribution shows that while many of the respondents have not experienced a building collapse but were able to provide perceived response on the current state of building collapse in Nigeria, some of them (38.29%) have done so before, thus depicting how common and potentially risky structural failures can be in certain locations or contexts. Therefore, these statistics demonstrate the need for raising issues about safety in constructions as well as setting up effective means for monitoring so that such cases may be avoided.

Fig. 5 shows the response on the frequency of building collapse which indicates a concerning trend with a large share of people seeing building collapse as being common. Out of 175 people who were asked, 45.14 % responded that there are frequent cases of collapse whereas an additional 25.14 % said they happen very often. Hence, this indicates that about 70 % of the people questioned often witnesses or are aware that they may end up facing such problems in residential houses. On the other hand, 25.14 % believed that collapses occur occasionally indicating that even though this issue is common, for some respondents it might not be so regular. Very few respondents (2.86% and 1.71%) think buildings should be classified under rare or very rare cases respectively. This finding emphasizes on how serious an issue it is for Nigeria and as such requires some urgent actions like integrating Structural Health Monitoring (SHM) with Building Information Modeling (BIM).



Source: *Authors Electronic based survey, 2024.*

Figure 4. The distribution of Respondents based on building collapse experience



Source: *Authors Electronic based survey, 2024.*

Figure 5. Response on Frequency of Building Collapse

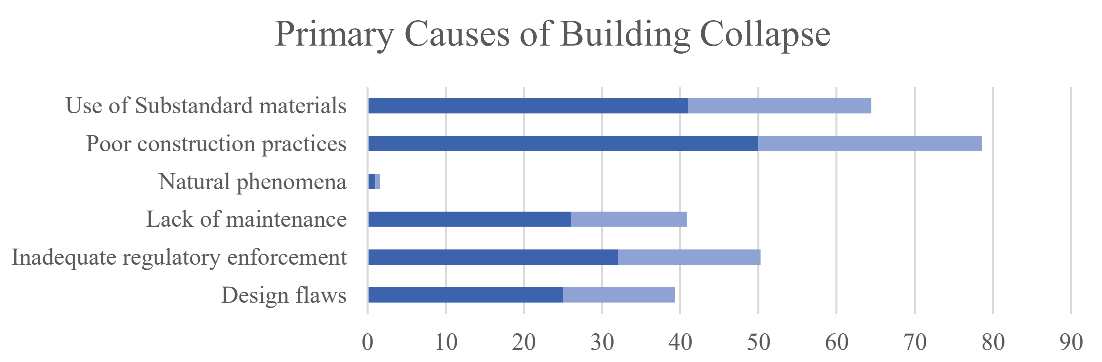
As depicted in Fig. 6, the respondents acknowledged certain primary causes of building collapse. The data also indicates that in Nigeria, research and most likely empirical evidence suggests 35.73% construction practices approach is the main cause of building collapse. This is a result of the high prevalence of improper construction practices which could include; among other things, unskilled labor, poor hygrometric conditioning during curing among others. In addition, poor quality materials is also an issue for (23.43%) as this again reiterates the weak structures put up using substandard components that are not fit for purpose. Therefore, in conclusion, these two variables tend to reveal the level of the quality of the raw materials and also the construction techniques employed in Nigeria and Basically these contribute to a lot of collapse incidences.

According to 18.29% respondents, lack of effective implementation of policies which is another factor considered has also been significant; therefore, there is also a concern regarding the need for better controls and building regulations so that dangerous buildings are not put up or left standing. Besides, design flaws (14.29%) and insufficient care (14.86%) also contribute significantly which indicates that not every first plan considers the final strength of a building while some buildings are left to the states of deterioration. Damaging events like floods or earthquakes are estimated to be the most insignificant risk factor by taking part of (0.57%).

Table 2 contains ANOVA and regression analysis results based on the investigation of the main causes of the building collapse. It can be deducted from the analyzed data that the level of significance of F-statistic is enormous at 1.66e+32 while the F statistic itself is not statistically significant at 6.03e-33. This implies that it can adequately account for the changes seen in the dependent variable. The regression sum of square (523.10) suggests that the majority of the variance is explained by the model while its residual sum of squares (6.31e-30).

3. *Perceived Benefits and Challenges of SHM-BIM Integration*

Integrating Structural Health Monitoring (SHM) with Building Information Modeling (BIM) provides transformative potential for improving safety in buildings, maintenance, and construction practices in Nigeria. Continuous monitoring of structural conditions is facilitated through SHM while detailed digital models for managing building data are provided by BIM. These technologies can help prevent building collapses, streamline inspections, and improve overall infrastructure management.



	Design flaws	Inadequate regulatory enforcement	Lack of maintenance	Natural phenomena	Poor construction practices	Use of Substandard materials
Frequency	25	32	26	1	50	41
Percentage	14.29	18.29	14.86	0.57	28.57	23.43

Source: *Authors Electronic based survey, 2024.*

Figure 6. Response on Primary Causes of Building Collapse in Nigeria

Table 2: Primary Causes of Building Collapse Analysis

	df	SS	MS	F	Significance	F
Regression		1	451.2653061	451.2653061	6.86456E+31	3.8775E-48
Residual		3	1.97215E-29	6.57384E-30		
Total		4	451.2653061			

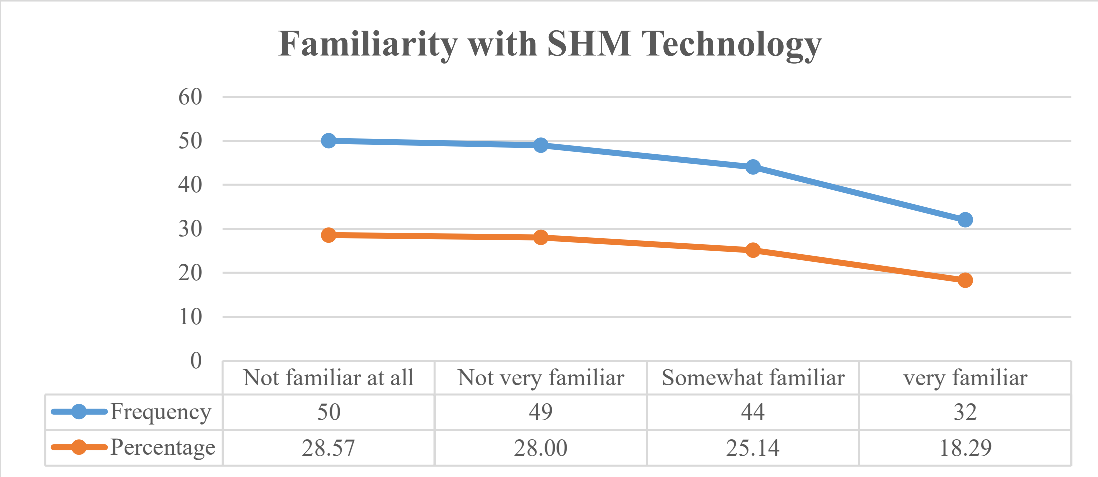
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%
Intercept	0	2.36556E-15	0	1	-7.52825E-15	7.52825E-15
25	0.571428571	6.89693E-17	8.28526E+15		3.8775E-48	0.571428571
	0.571428571					

Source: *Authors Electronic based survey, 2024.*

Figures 7 and 8 depict that there is minimal knowledge regarding both SHM and BIM since the level of familiarity of the respondents is very low. In case of SHM, over half of the people have little awareness of the technology as 28.57% just selected the option "Not Familiar at all" while 28% indicates "Not very familiar". Similarly in case of BIM also, 23.43% were "Not familiar at all" while 28% were "Not very familiar". 35.43% were "Somewhat familiar" with BIM, these so further corroborates that there is a still a growing awareness of these technologies to harness their full potential where 18.29% was deemed "Very familiar" with SHM which makes us determine that development of knowledge would lead to increased abilities in this regard.

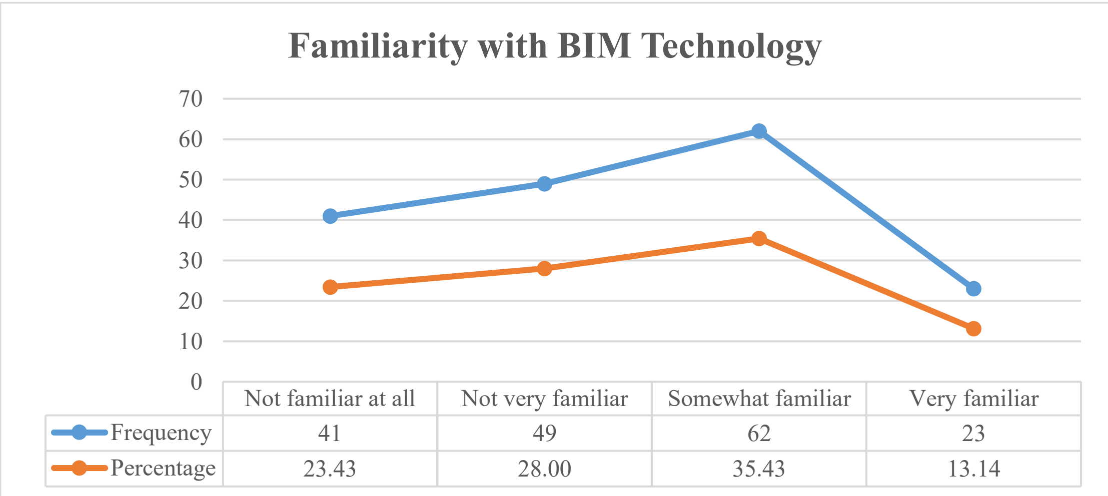
Nonetheless, majority of the respondents seemed to believe that the combination of SHM and BIM would help reduce building collapse in Nigeria. Out of those, 52.57% agreed while additional 32.57% even indicated strong support for this integration. Only 0.57% disagreed while 14.29% chose not to take sides; this indicates that most participants appreciated the advantages offered by DOI, nevertheless some of them may still be skeptical and need more convincing evidence. This is pointing out that there is a great demand for advanced technologies like SHM and BIM in order to fortify safety measures against structural failures in the buildings in Nigeria.

Fig. 9 shows the response on the perceived benefits of integrating SHM and BIM technologies, The expected benefits of combining SHM and BIM technologies have demonstrated a strong concern of early detection of structural defects among most respondents (44.57%), who say it is mostly beneficial. This means that most people have the notion that integration would be helpful in preventing situations where structural deficiencies are already present but can be identified and solved before they lead to destruction. Other notable advantages entail enhanced construction quality (16.57%), increased maintenance practices (15.43%) and enhanced security (13.14%) which indicates that the people perceive this as a way of enhancing the reliability of the structure over time. Behaving in accordance with regulations (6.29%) and economics (2.29%) were reported less frequently hence these factors are still important but less urgent since they do not concern immediate safety and quality issues. At the same time, the integration of SHM and BIM technologies is expected to face the chief difficulties of lack of technical experience and its correlated costs as demonstrated in Fig. 10. A significant 40% indicated lack of technical expertise as a major hindrance, showing concerns about the existence of trained personnel fitted to implement these technologies. Also, 20.57% indicated the presence of high costs to enact these measures as another major challenge showing that there are some financial constraints here that cannot be ignored.



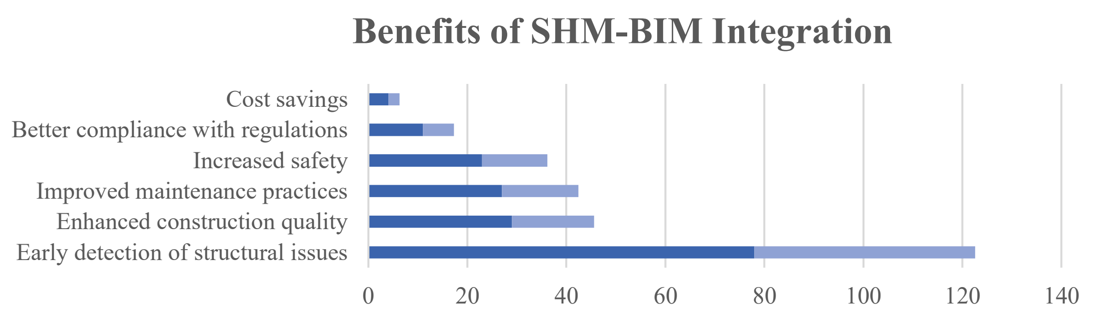
Source: *Authors Electronic based survey, 2024.*

Figure 7. Response on familiarity with SHM Technology



Source: *Authors Electronic based survey, 2024.*

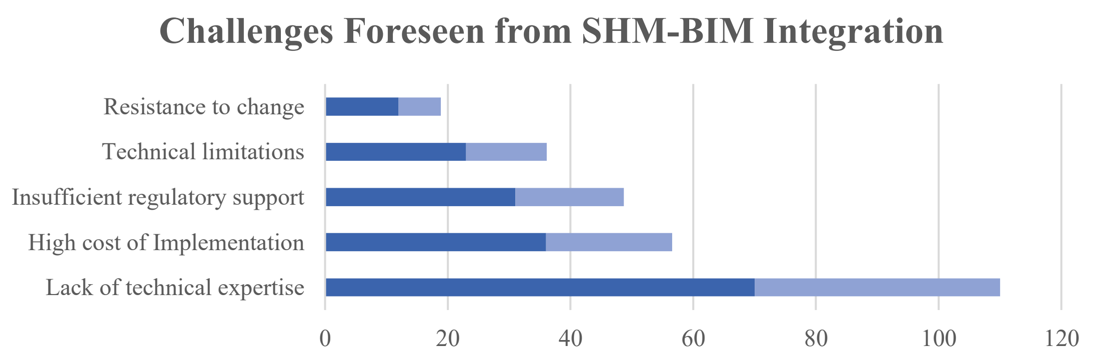
Figure 8. Response on familiarity with BIM Technology



	Early detection of structural issues	Enhanced construction quality	Improved maintenance practices	Increased safety	Better compliance with regulations	Cost savings
Frequency	78	29	27	23	11	4
Percentage	4457.00%	1657.00%	1543.00%	1314.00%	629.00%	229.00%

Source: *Authors Electronic based survey, 2024.*

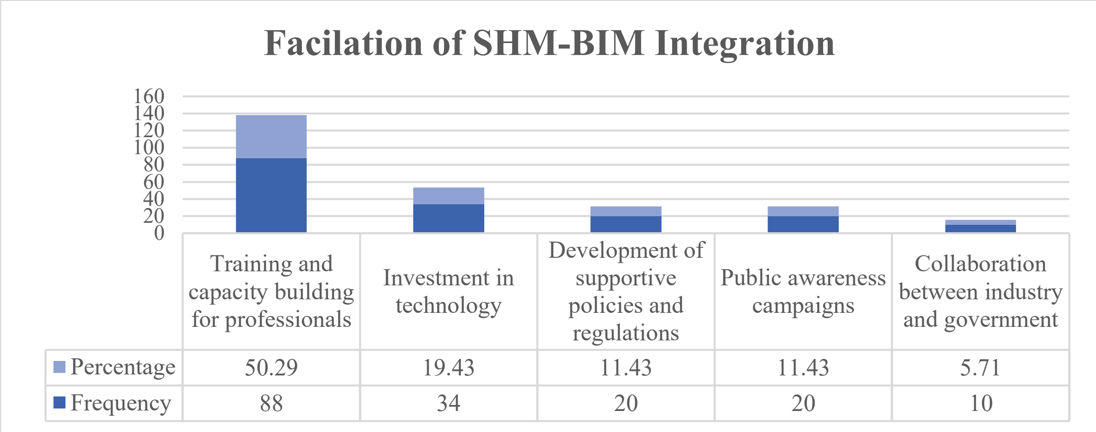
Figure 9. Response on perceived benefits from integrating SHM-BIM technologies



	Lack of technical expertise	High cost of Implementation	Insufficient regulatory support	Technical limitations	Resistance to change
Frequency	70	36	31	23	12
Percentage	40	20.57	17.71	13.14	6.86

Source: *Authors Electronic based survey, 2024.*

Figure 10. Response on challenges foreseen from SHM-BIM Integration



Source: *Authors Electronic based survey, 2024.*

Figure 11. Response on steps to facilitate the Integration of SHM and BIM Technologies

As demonstrated in Fig. 11, the most important step that needs to be taken in Nigeria to improve the implementation of SHM and BIM technologies is 'Training and capacity building for professionals' which 50.29 percent of the respondents selected. This denotes that there is a need for extensive educational activities to enable the professionals to develop the requisite skills and knowledge. Further, it was noted that other factors with a high cost of technology were rated at 19.43%.

Another critical measures something as a standing policy includes institutions' systems and regulations (11.43%) along with creating awareness (11.43%), both suggest how both the systems and people work towards the integration are very necessary. The last one involved industry and government's indirect link as 5.71% addressed this as a step towards this technology. The facts above definitely suggest that integrating Structural Health Monitoring (SHM) and Building Information Modelling (BIM) can be a strategy to control the problem of building collapse in Nigeria. More than a half of Respondents in this study were males within the age range of 25 – 34 years that are either civil servants or construction personnel. Most of them had no experience on how SHM or BIM works, but a good number understood how the two systems could be integrated to help in the timely solving of the questions of structural defects, enhance quality during construction and promote safety on the sites. Even so, drawbacks such as the high cost of establishment, lack of personnel with the necessary expertise and lack of legislative back up came out as major challenges. Training and capacity building and investment in technologies in particular were found to be critical enablers in the effective SHM and BIM implementation in the Nigerian construction sector. The results also pointed to the importance of training and capacity building as well as technological investment to facilitate the successful adoption of SHM and BIM in the Nigerian construction industry. This finding shows that both technical problems and also policy related obstacles should be dealt with separately so as to fully exploit the advantages resulting from SHM-BIM merging in Nigeria.

Conclusion

This research has demonstrated how useful it would be to combine Structural Health Monitoring (SHM) with Building Information Modelling (BIM) as a measure of preventing building collapse in Nigeria. Apparently, the connection which the results depict indicates a very high level of enthusiasm and expected advantages by the industry practitioners such as minimal detection time of the structural issues and improved quality of construction. Notwithstanding these advantages, there are formidable challenges such as scanty of technical personnel and high expenses. The construction sector will inevitably be affected by such findings, the introduction of SHM and BIM strategies will enhance the infrastructure and will curtail the occurrence of building failures while maintaining higher protective levels.

These findings are important for policymakers as they point out the need for regulations that encourage the uptake of technology and the training of people in those technologies. Additionally, plans for the future should also invest in more in-depth struggles and policies for the application of such advanced technologies as SHM and BIM in building codes for their efficient use up and down the industry.

Nevertheless, this study has its discrepancy. There was gauged as the main vet data collection means a questionnaire which is likely lunched into perspective how practical implementation issues were. Moreover, the study was limited to the construction sector of Nigeria, thus other regions may benefit from more comparison studies. In the future, it would be beneficial to carry out longitudinal research in order to determine how useful the integration of SHM and BIM will be borne in the long run and look into cheaper alternatives of reducing the technological and monetary hindrances of doing so.

Recommendations

1. Capacity building and training programs should be implemented to enhance technical expertise in SHM and BIM technologies which will involve university collaboration, training institutes and the industry.
2. Increased investments into SHM and BIM technologies by public-private partnerships together with subsidies in order to cut down on the high implementation costs should be encouraged.
3. Public awareness campaigns should be initiated to educate policymakers, construction professionals, and the general public about the importance of SHM and BIM in preventing building collapses.
4. Development of regulatory frameworks focus on making SHM and BIM integration compulsory in building projects, with a view to ensuring that they are well implemented and adhered to through proper guidelines and standards.

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