Advancing Construction Waste Reduction through Building Information Modelling

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Abstract
The construction industry is one of the most significant industries for sustainable development due to its contribution towards economic and social development. However, the construction industry produces excessive amount of Construction and Demolition (C & D) waste. The excessive amount of construction waste results in land degradation and contamination of the environment. This prompts construction professionals to practice effective waste management which will lead towards ensuring that there is zero waste in future. Construction waste management assists in minimizing the amount of waste that goes to landfills during construction through diverting waste. Recyclable waste can be redirected to manufacturing processes and reusable materials back to suitable construction sites. A good waste management plan indicates how the recycling rate can be achieved. Construction waste management can reduce contamination from and extend the life existing landfills. Building information Modeling (BIM) brings the potential to reduce waste in construction and leads to sustainable construction. This research presents an approach to reducing construction material waste through a BIM-based design project. The theoretical study in making using BIM approach towards zero waste of BIM is lacking. The purpose of this study is to determine how BIM can be used to achieve zero waste. A systematic literature review is used. The results are summarized to provide information on how to minimize waste for sustainable construction practice. BIM technology and construction waste minimization practices are examined, and the findings obtained are evaluated. BIM applications are being proposed to be developed to minimize waste in the built environment.

Keywords
BIM, Construction Waste, Waste Minimization

1. Introduction
The construction industry is growing which stimulates a large scale of production of construction waste. The construction and demolition (C&D) industry is a major contributor of this waste Loizou et al (2021). .Purchase et al, (2021) observed The world's urbanization has grown tremendously in recent decades along with the increase in the human population; as a result, more material resources are now being used. In addition, This complexity was further influenced by the nature of the sector, population growth, the presence of more players, rising demand, a lack of information reuse and management, and weak inter-disciplinary communication(Saka et al,2021). This then relatively increases construction waste. Construction waste is produced through construction activities such as renovation, demolition and construction of infrastructure at al (2017), confirms that the volume of construction and demolition waste continues to increase. Construction waste is a growing problem that affects the entire world (Othman & El-saeidy,2021).Thus, the construction industry has been criticized for being inefficient; often generating too much waste

, emitting significant amounts of greenhouse gases and consuming too much energy compared to other industries (Abanda et al ,2017).

Backchan,et al (2019) refer to waste as waste generated from new construction activities. According to Ajayi ,et al (2018), waste generated by construction activities is more than by other by more than double the proportion in different nations of the world. Othman & El-Saeidy (2021) define waste as any inefficiency that results in the use of more materials than are required for the construction of a building. This creates problems in the environment such as depletion of natural resources, land deplete, on and global warming (Han,et al; 2021). Ajayi & Oyedele (2018); Othman & El-Saeidy (2021) agree that waste on landfill has significant impact on the environment. This means that waste management is an important requisite for environmental sustainability. In addition, it also means that waste management practices should effectively be put in place to ensure that natural resources are preserved and waste generation is minimized (Akinade, et al 2018).

Building Information Modeling (BIM) is a technology that has been introduced to the Architecture, Engineering and Construction (AEC) for effective information management and quantifying. BIM is defined as the digital representation of the physical and functional characteristics of a facility (Guerra et al,2020). BIM is a significant technological innovation in the architecture, engineering and construction (AEC) industry and simulates the construction project in a virtual environment (Tulubas & Arditi,2017).According to Ajayi et al (2015) that the adoption of BIM is becoming common in the construction industry due to its collaborative facilities because it is influenced by government leads. Therefore, BIM and off-site manufacture to improve performance in the global construction industry has been long overdue (Abanda et al, 2017). (BIM can specifically predict waste generation and output. This is because there is a direct link between the early stages of construction planning and designing and the production of waste (Akbarieh et al;2020). Furthermore, BIM is a recent development in the Architect, Engineering and Construction industry and allows the development of an accurate digital model of a building Projects that are designed using traditional 2D CAD lack accurate information flow between players throughout the project stages. In contrast, on BIM design projects, there is flexibility in interaction and transparency between different users (Hattab & Hamzeh 2013:761). This indicates that information flow and the interaction of participants can be improved during the design phase using BIM.

2. Methods

2.1 Search for publication

To achieve the main objective of this study, a systematic literature review method is adopted for this study. A Scopus search engine was used to search articles. The keywords used were . "building information modeling" OR " building information modeling" AND waste AND "waste minimization" OR "waste minimization." A number of 427 documents resulted from the search.

The PRISMA flow diagram was used to illustrate studies that were eligible for the study. The diagram below depicts the articles that were reviewed and included in the study.

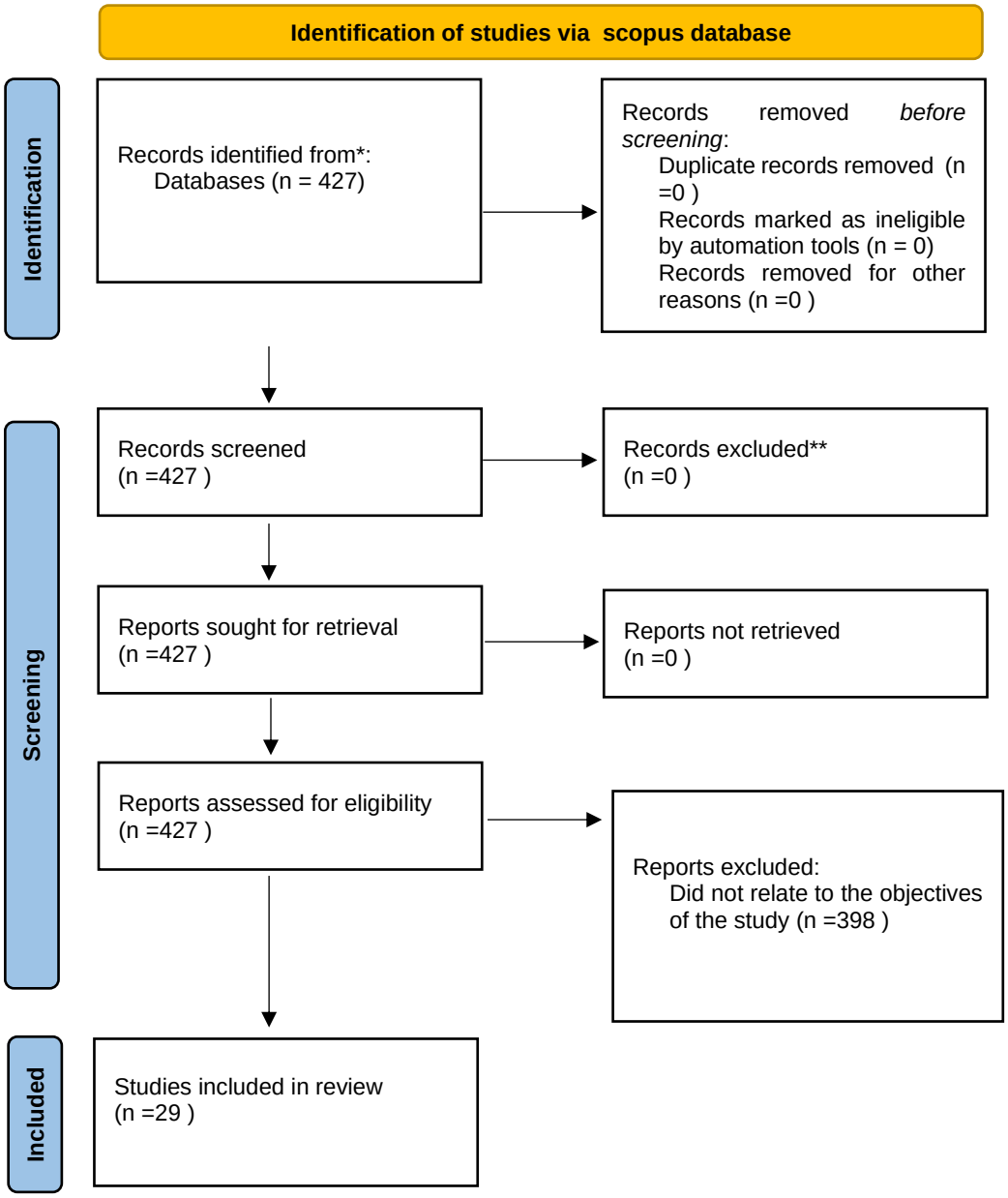

Figure 1 PRISMA flow diagram for systematic review which included searches of databases

3. Results

3. 1 Results (Contextual Background)

Table 1. Quantification of CDW in construction projects (Dauod et al, 2021)

Material type	Unit	Weighted mean value %
Timber	m3	11.77
Sand	M3	2.68

Concrete	M3	1.95
Cement	Tons	3.23
Reinforcement	Tons	0.00

Datta,et al (2022) researched and found out that bricks, steel, electrical wiring ,rebar, mortar concrete and wood are the most common solid waste in a construction project. In order to tackle the challenge of excess waste generation, waste management strategies need to be implemented. The use of tools to reduce waste could be effective.
Aslam et al (2020), states that there is a current challenge of insufficient number of tools and techniques for strategies of waste.

Aslam et al (2020) state that an estimate of 33% of waste on site is related to poor design and if improved it could reduce construction and demolition waste. According to Atta,et al (2021) the prioritization of waste management has brought a concept of reduce, reusing and recycle for sustainability. These strategies are only able to address waste after it has occurred therefore, making them less effective. Datta, et al (2022) state that the most effective way to manage waste is to design accurately, estimate accurately, recycle and re-use. This is supported by Ajayi et al (2015) that waste recycling and sorting has been adopted in the construction industry as a waste management strategy. Omer et al (2022); Porwal & Hewage (2012) agree that construction waste recycling is a common practice in several developed countries as a construction waste management play. However, Porwal & Hewage (2012) states that the focus on reduction of waste at the source was negligible in the past year. Waste reduction at the source may still be the best approach toward minimizing the intensity of the construction waste problem.

The use of waste prediction tools have emerged in order to effectively manage waste in the construction industry. The waste prediction tools assist the project designers in selecting the suitable strategies which are suitable for improving waste management effectiveness through quantifying and estimating in a project. In addition,the transition from demolition to deconstruction is a favored end of life (Eol) disposal strategy for minimizing waste (Obi,et al 2021). This is because deconstruction supports component reuse and material recycling through dismantling building structures. It also enables recovery of materials therefore diverting it from landfills therefore supporting principles of environmental sustainability. However, this suggests a need for technological tools which can enhance the planning.
Building Information Modelling (BIM) is an innovation that is recently gaining more attention to support deconstruction (Obi et al,2021). BIM is a . In addition, Bim promotes coordination of project participants to optimize project performance throughout the building's lifecycle. It also makes it possible to explore different design alternatives more efficiently by avoiding the time-consuming and error-prone method of recreating all the building geometry attributable to a change in structural analysis and design (Porwal & Hewage,2012).

3.2 Results (The drivers and barriers to BIM as a tool to manage construction waste in the built environment)

The adoption of BIM is becoming common in the construction industry (Ajayi,,et al: 2015). Quinones et al (2021), agree that in the recent years, the use of BIM in the AEC sector has increased. BIM offers major means of making construction projects sustainable (Nikmehr et al,2021). Additionally, BIM minimizes the impact of wasteful processes across the life cycle of projects. Although this is the case, there are still some barriers that prevent the implementation of BIM in the construction BIM is seen as high cost technology, but it has been shown to give a better clarification on the issues that happened in construction (Zaini et al,2020)..According to Akinade ,et al (2018) stakeholders lack knowledge on the use of BIM for construction and demolition waste management raises serious concerns on how BIM could be implemented for waste management. Chan,et al (2019) highlights the major BIM barriers of BIM implementation to be Stakeholders' resistance to change and Insufficient organizational support structure to implement BIM. Also highlighted lack of education and training, legislative barriers and limitation interoperability and fragmentation as some of the barriers for BIM implementation. In addition, lack of government support is also a challenge to the adoption of BIM (Saka et al,2020).

3.2.1 How BIM can be used to minimize construction waste

BIM software packages are used in managing (i.e. modelling, analysis and sharing) project information, thereby fostering collaboration amongst project team. he most common are BIM authoring software packages, e.g. Revit, Bentley, ArchiCAD; BIM project management/coordinating software, e.g. Bentley Project wise and BIM energy analysis tool, e.g. Green Building Studio, Energy Plus and Integrated Environmental Solution. Modelling buildings in these software, can allow different project partners including clients to view and confirm or disapprove exact details and finishes virtually in the very early design stage (Abanda et al,2017). BIM allows greater precision in specifying material requirements, which can reduce over-ordering and thus decrease construction site waste (Abanda et al,2017).

BIM is leveraged to propose an automated CW quantification method, in which the CW is defined as the portion of purchased but not incorporated into the actual building structures materials (Guerra et al,2019). BIM also has the potential for the planning and scheduling of construction activities. (Eze et al, 2022). Therefore, at the scheduling stage, the project manager and contract can see at a glance the materials, activity sequence, track progress and equipment against logistics and timelines. In addition, BIM ensure that there is effective communication and collaboration between the design team members, which enhances and influences the quality details provided in the design (Eze et al,2022). BIM model aids cost estimation and allows for faster cost comparisons of various design options at the concept stage (Eze et al, 2022). By integrating the temporal dimension to BIM, CW generation can be visualized as construction activities are performed, therefore facilitating the planning of CW reuse on-site, and CW recycling off-site (Guerra et al,2020).

BIM makes it likely to obtain the whole cycle of construction planning from design plans to computerized models. This is because BIM can be used in every stage of a construction project from inception to demolition (Tulubas Gokuc & Arditi ,2017). This is because BIM can present all of the individual elements.

Therefore, better BIM collaboration could improve the work submitted and the work of all teams. Moreover, better BIM collaboration reduces construction time and thus eliminates errors and oversights (Mohammed et al,2022). Additionaly, BIM model assists to identify design conflicts,design errors, sequencing constraints, access issues, fabrication details and procurement constraints that impact the efficiency of the project.

Table 2. How BIM can be used to minimize construction waste

Reference	Journal name	How BIM can minimize waste
Akinade & Oyedele (2019)	Journal of cleaner production	Automatic capture waste information and reporting
Aleksanin (2018)	MATEC Web of conferences	Speed of information exchange which allows the management of construction materials
Atta, et al 2021	Journal of Building Engineering	Using BIM technology to digitalize the proposed material passport determining the correct quantity of material needed for building elements
Bakchan et al 2019	Resources, Conservation and Recycling	Projecting schedule,purchasing records, determining actual construction generated on site

4. Discussion

There are environmental problems that are caused by the failure to effectively manage construction waste. Environmental problems caused by construction waste led to pollution and economic losses. Therefore, it is important to ensure that effective waste management is practiced by stakeholders in order to prevent or minimize waste. Building Information Modeling (BIM) is a technology that poses as the potential to reduce waste. However, there are quite a number of barriers to the implementation of BIM for waste minimization. This study indicated the type and quantity

of waste that is currently generated in construction projects. In addition, the study highlighted the barriers to the implementation of BIM and how BIM can be used for the minimization of construction waste.

5. Conclusions

Ge et al (2017), combining BIM with interactive visualization one can understand where materials are placed so that arears that need special attention are identified. This means that the amount of waste can be predicted therefore making it easier for managers to develop waste management strategies. In addition, the digital model that emerges from BIM contains all information of materials and quantities which can be used for planning of construction and demolition waste by prompting waste estimation (Jayasinghe & Waldman,2020). Moreover, incorporating virtual reality (VR) into Building Information Modeling (BIM) enhances the ability to visualize and interact with the construction process in a simulated environment. This immersive approach allows project managers to foresee potential issues and optimize resource allocation. This integration of VR with BIM not only improves spatial awareness and collaboration among stakeholders but also aids in identifying design flaws early in the planning stages. Consequently, this leads to more accurate project timelines and cost estimations, further supporting effective waste management strategies by minimizing errors and rework.

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