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Analyzing the Potential for IBS and BIM to be used as Tools for Reducing Construction Waste

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Abstract
The encouragement of the use of IBS and BIM in the construction industry by the government is said to have a lot of positive impact on the country. Through the integration of the five fundamental values of Construction 4.0, along with initiatives for well-being, productivity, sustainability, integrity, as well as safety and health, as well as safety and health, the Construction 4.0 Strategic Plan (2021–2025) was launched. The importance of BIM utilisation in the construction industry is also made clear. This study explores the possible application of IBS and BIM as methods to reduce construction waste in the building sector. This research is hoped to assist the reduction of construction waste, which will not only benefit contractors, construction firms and others but will also lessen unlawful dumping and improve the environment. A survey consisting of thorough questionnaire was developed to obtain information from construction professionals from the area around Penang. Research objectives were determined through a literature review and questionnaire survey The data was anlaysed using SPSS software to determine the required values. The findings demonstrated that every contracting company was aware of the level of acceptability of BIM-IBS activities, which include planning, using high-quality technology, controlling behaviour, and having personal competency. More than half of the companies are prepared to adopt BIM-IBS techniques in the future to lessen construction waste. The results of this study suggest that using BIM-IBS can aid in reducing waste generation. Thus it can be concluded that BIM-IBS is efficient and can be utilised to cut waste during construction projects.
Keywords: BIM, IBS, Construction Waste, Construction Waste Minimisation.

Introduction

One of the most significant industrial sectors in any developing nation is the construction industry. This industry is a pillar of support and growth for other sectors. However, construction waste will also flourish as this business develops. Construction waste is generated due to a variety of reasons, including errors made by workers, unavoidable weather conditions, errors made when obtaining building supplies, and shortcomings in the management and planning of storage facilities on construction sites. Therefore, by implementing Industrialised Building System (IBS)based construction techniques and making use of Building Information Modelling (BIM) drivers, the effects of this aspect can be diminished. This study was carried out to determine whether IBS and BIM construction may lessen construction waste at the construction site. The first known instance of IBS use in Malaysia dates back to 1964, when construction work on Tuanku Abdul Rahman's apartment in Jalan Tun Razak Kuala Lumpur was undertaken. This apartment, also known as the Circular Flat, is made up of seven 17-story apartment complexes. These blocks each have 40 shop lots and 3000 affordable housing units. It only took 27 months to complete the project using the IBS approach.

Through the government-enacted Construction Industry Transformation Programme (CITP) policy(CIDB, 2016), BIM was implemented in Malaysia in accordance with the national development agenda. The capabilities of BIM technology have the potential to improve project implementation efficiency, offer a quality construction process, improve cooperation, establish effective communication between project teams engaged, overcome delays, and cut project costs. BIM was introduced in Malaysia in line with the national development program through the CITP policy introduced by the government. The description of the BIM method that will be used is a new technology in the construction industry in Malaysia. The capabilities of BIM technology described have the potential to increase the efficiency of project implementation, provide a quality construction process, can enhance teamwork, establish effective communication between project teams involved, overcome delays and reduce project costs.

The government's encouragement and emphasis on the use of BIM in the construction industry continued with the launch of the Twelfth Plan (RMK12) (CIDB, 2020).

The term BIM was initially introduced by Autodesk in 2002. Since then, the global acceptance of BIM adoption has been extremely positive. The Director of Works (PWD) of Malaysia advocated that BIM be implemented in 2007. The National Cancer Institute in Sepang was the first government project to adopt BIM technology in 2010, and in 2013 Construction Industry Development Board (CIDB) established the Malaysian BIM Steering Committee to aid in the implementation of BIM in Malaysia. Aiming to increase the number of BIM implementers by 2020, CIDB has also started the Malaysia BIM Roadmap to bring BIM to the construction sector.

Literature Review

The study's goals are to investigate the potential for IBS and BIM-based building to reduce construction waste on the job site and to identify the primary causes of waste production there. The information included in this literature review was retrieved from previous readings, research, and investigations.

Construction Waste

Every non-industrialized country requires a development industry. The crucial contribution that development industries provide to a nation's financial stability and economic progress has been acknowledged and accepted by both developing and established nations. The development industry is a financial enterprise that is connected to financial growth. By offering the essential underpinnings and real designs for administration, utilities, and trade, it plays a crucial part in the growth of a nation. The sector also boosts the economy of the nation by adding employment and cash. Despite all these , development waste has escalated due to the industry's quick development, and the current situation has become a major problem in Malaysia.

For emerging nations like Malaysia to prosper and advance economically, the building industry is essential. The nation's economy is significantly impacted by the enormous industry of construction. Due to the magnitude of the construction sector, garbage produced during construction projects makes up a considerable fraction of overall waste. When a building company orders materials for a new site, it is typical to slightly overestimate the quantity needed because ordering too many products is much easier to fix than ordering too few. Once the construction is completed, extra materials become waste. They are often reused or recyled. Construction waste is broadly described as any trash produced during construction, remodelling, or demolition, as well as any unused items or materials produced throughout the pre-construction, construction, and post-construction phases. All building materials, including concrete, steel, wood, and other materials, that are produced during various construction activities are included in the category of construction wastes. Surplus materials produced during construction activity can be included as construction waste as well. Due to ineffective waste management techniques used in construction projects, the amount of construction waste is rising. In 2018, 30 to 40 percent of China's total waste was made up of construction waste. Construction-related industries' long-term survival and society's overall sustainability could both be threatened by the enormous amounts of solid waste they produce. Every type of construction waste produced during building activities has a negative impact on the environment, costs, productivity, time, social conditions, and economic situations. From the standpoint of the construction sector, this problem will reduce construction productivity and a decline in overall project performance (Hasmori et al., 2020).

Type of Construction Waste

There is a large number of waste materials that need waste disposal during construction activities. Construction waste consists of garbage generated during construction activities (such as packaging or demolition goods) and materials that are no longer needed (due to over-ordering or inaccurate estimating). Additionally, as a building reaches the end of its useful life, it may be deconstructed or demolished, resulting in substantial waste. While there are increasing possibilities for reusing and recycling materials and minimizing waste generation in the first place, a significant percentage of construction debris will dispose of in a landfill. Generate most landfill garbage during the construction and deconstruction of structures, and certain materials are disposed of after the waste was sent to construction sites without being used (Kozlovská & Spišáková, 2013). Typical construction waste products are like concrete. Concrete is an extraordinarily prevalent sort of building waste, according to the Environmental Protection Agency. According to Wang (2014) by weight, it accounts for 67.5% of all building and demolition trash (Wang et al., 2014). Each year, the globe consumes 50 billion tons of sand and gravel aggregate, which our deltas and coastlines cannot sustain. The use of crushed concrete aggregate from building and demolition projects is a desirable option. Bricks are another typical construction waste product. Brick waste is frequently contaminated with impurities such as mortar and plaster, which detracts from the recyclability of bricks. Next is Porcelain and tile. These waste products are frequently found on building or

demolition sites are ceramic and tile trash. These materials could be demolition debris, or the site could have extra materials on hand following the completion of the project Materials for insulating. Insulation materials include the following: [Cellulose, fiberglass, foams, natural fibers, perlite, and polystyrene] Waste insulation materials, particularly those from the demolition of older structures, may include asbestos, which is harmful due to the health concerns it causes.
Even relatively low quantities of asbestos particles in the air can put a person at risk of developing illness in the lungs. Construction materials frequently generate a variety of various types of plastic trash. Plastic roof and wall components and plastic pipes, cable ducting, polyvinyl chloride (PVC) siding and window components, smoke detectors, and light switch cover become debris during demolition. Metal ferrous also referred to as iron and its alloys, such as steel, are frequently derived from old pipes during demolition efforts. Metal that is not ferrous other metals besides iron includes aluminum, copper, lead, and zinc. In pipe and component manufacturing, these frequently used metals, such as nails, rebar, and electrical wiring. Occasionally, construction and demolition projects generate stone and clay debris. Outstanding stone may be a suitable option for reuse in future projects. Otherwise, crushing techniques will reduce the stone and clay to fine particles suitable for aggregate filler. When grading a site for construction or digging the foundation for a building, enormous amounts of earth are frequently generated as trash. Dredging waste refers to removed natural things as part of preparing an empty site for construction. Apart from dirt, trash frequently contains the following materials: - [Rocks, shrubs, tree stumps, and tree branches]. Dangerous waste such as potentially hazardous materials on a building or demolition site includes the following: - Adhesives, aerosol cans, asbestos, and the use of fluorescent lighting (For example formaldehyde is a byproduct of adhesives and urea-formaldehyde foam insulation), mercury was found in thermostats and boiler systems. Plasterboard, paint, Paint thinning agents Remover of paint and Solvents.

Cause of Construction Waste

Global construction waste concerns are increasing due to rapid development growth. Construction waste harms the environment, expenses, time, productivity, and society. According to Ikau (2016), the main contributors to the increase in construction waste on construction sites are design, procurement, construction material handling, and the construction process itself (Ikau et al., 2016). Aside from design changes, inattentive working attitudes and behaviours, insufficient planning and scheduling, and material storage can all contribute to high waste generation in the construction industry (Luangcharoenrat et al., 2019).

Industrialised Building System (IBS)

Industrialised Building System (IBS) is a construction technique that uses components made in a factory, either on-site or off-site, that are then assembled into the structure with the least amount of additional work required on the construction site. IBS is defined as the total integration of all subsystems and components into the entire process using industrialised manufacturing, transportation, and assembly processes (Badir et al., 2002). IBS was additionally described as a construction system with prefabricated parts. The components are made using machines, formwork, and other mechanical tools. IBS-guided construction is based on best practises that favour long-term affordability, quality, and efficiency while conventional building procedures are driven by short-term economic considerations. At every stage of the building's life cycle, it raises comfort and quality of life while reducing adverse

environmental effects and boosting the project's economic viability. Although IBS is typically linked to environmental protection, it also addresses issues like resource efficiency, ongoing social progress, optimistic economic growth, and a higher standard of living. The main objectives of IBS construction are to satisfy present-day demands for homes, workplaces, and infrastructure without endangering the capacity of future generations to satisfy similar demands.
In the 1960s, IBS was introduced in Malaysia with the goal of resolving and enhancing the nation's building industry processes. The system, even so, had some shortcomings. The reluctant acceptance of the pertinent parties and the challenging process of fostering cooperation and integration among the parties are two of the concerns mentioned. In order to integrate construction supply chains, IBS provision must be created. IBS supply chain stakeholders indicated that identifying integration success factors in IBS project management is necessary to strengthen their tight working connection and get over challenges (Shukor et al., 2016). IBS must be a procedure that calls for collaboration between design, production, and construction. Planning, project management, repetition, standardisation, and supply chain management will be structured properly (Kamar et al., 2010).

Building Information Modelling (BIM)
Applications of Building Information Modeling (BIM) in construction projects offer a variety of advantages to stakeholders in the industry, including increased inter-stakeholder communication and more rapid and effective design decision-making. Additionally, one of the advantages of BIM is how simple its tools are to use. As a result, using BIM can shorten the time spent on design as well as the cost and time it takes to complete the project. BIM can be utilised in all phases of a construction project, including pre-construction, throughout construction, and after completion (Harris et al., 2014). The application of BIM in the pre-construction phase is more visible than BIM during the construction and post-construction phases. This is because many tasks like design, scheduling, and estimating are usually completed within this time. Typically, for these kinds of projects, BIM technology utilisation is necessary.

Potential use of IBS and BIM
BIM has many important benefits for building projects, including helping with the planning, scheduling, and budgeting of constructed assets. It also gives architects a foundation to start the evolutionary design process from scratch. Using the information provided by BIM technology can speed up the design process because it reduces the need for communication with engineers.
Additionally, visualising the construction process with a 4D model improves comprehension of procedures and aids in locating construction issues. By using 4D BIM models, it was possible to show how the construction project will affect traffic flow, entry and departure routes, public transportation, the storage of supplies on-site, and the scheduling of equipment and personnel. BIM also offers a powerful technique for enhancing design and documentation quality. It helps to get a cost estimation accuracy of 3%. Design conflict problems are lessened by including all essential systems in the model. Model viewing systems and design BIM systems both have the ability to identify and highlight conflicts between models and other information entered into the viewer.
BIM also enables visual representation and encourages team members to communicate with one another. The owner can quickly understand the design, which enhances the effectiveness of site planning and task coordination. The procedure can be aided by eliminating wordings

and visual scheduling that are incompatible with the design. However, it is important to make sure that all materials tracking and quantity take-offs are accurate before starting the implementation process. It is crucial to make a visual representation of the effects of design changes before starting the construction. This will make the construction process more predictable and make it easier to forecast how the building will function as a whole. Additionaly, BIM helps to cut down on expensive mistake because it helps to determine how much money will be saved on operating expenses

Methodology
The questionnaire was developed from the key issues identified in the literature and interviews with professionals. The questions were finalized based on a pilot survey conducted with experienced architects, consultants, and contractors. The respondents were asked to rate each component in the questionnaire on a scale from 1 to 5, from highest to lowest level, to indicate the importance of each factor.
The questionnaire was divided into 5 sections. The demographic information for the respondents was covered in Section A. In Section B the questions' were on IBS awareness, BIM, and construction waste and the all the questions in this section were closed ended questions of yes/no. Section C concentrated on the causes of construction waste in the Malaysian industry, while Section D sought to ascertain respondents' thoughts on the deployment of BIM in the construction industry with a view to decreasing construction waste. The final segment, Section E, covered inquiries regarding the application of IBS in the construction sector with the intention of lowering construction waste. All of the questions in Sections C through E used a five-point Likert scale, with 1 denoting a strong disagreement (Strongly Disagree) and 5 denoting a strong agreement (Strongly Agree)

Table 1
Respondent Demographic Data

Respondents' clasifications	Percentage (%)
Gender	
Male	60.0%
Female	40.0%
Zone	
Utara	87.5%
Tengah	7.5%
Selatan	1.3%
Timur	3.8%
Company	
Architect	1.3%
Consultant	31.3%
Contractor	67.5%
Qualification	
Certificate/Diploma	31.3%
Degree	66.3%
Master/PhD	2.5%
Designation	
Project Manager	3.8%
Architect	2.5%

Engineer	78.8%
Supervisor	15.0%
Working experience	
<3 years	17.5%
3 – 5 years	51.2%
5 - 10 years	31.3%
>10 years	0.0%

The respondents' demographics are shown in Table 1. Majority of the respondents were males at 60% while another 40% were females. Only 1.3 percent of respondents were from architect companies; while the majority at 67.5 percent were from contractor companies and, 31.3 percent were from consultants. A large majority of the respondents 87.5 percent of them were from the northern zone. In terms of work experience, 17.5 percent of the construction industry workers had less than three years of working experience, about 51.2 percent had between three and five years working experience while another 31.3 percent had been working for about five to ten years.

Result and Discussion

Awareness of Construction waste, IBS, and BIM

Table 2

Awareness on Construction waste, IBS and BIM

B	Awareness on Construction waste, IBS and BIM	Yes	No
B1	Are you aware of construction waste problem in Malaysia?	100.0%	0.0%
B2	Have you heard zero waste concept or campaign promotion by government?	91.3%	8.8%
B3	Have you heard of BIM before?	97.5%	2.5%
B4	Do you know the application of BIM?	96.3%	3.8%
B5	Do you have any idea how BIM works?	95.0%	5.0%
B6	Are you aware of the main benefits of BIM?	96.3%	3.8%
B7	Are you aware that IBS and BIM able to reduce waste construction?	97.5%	2.5%
B8	Did you think Malaysia's agencies did a good job in implementing IBS?	72.5%	27.5%
B9	Are you satisfied with current IBS and BIM that been implement?	60.0%	40.0%
B10	Do you think that the implementation of BIM and IBS in a construction company would pay off?	95.0%	5.0%
B11	Have you attended any talks on BIM and IBS?	92.5%	7.5%
B12	As a construction professional, do you feel the need for BIM in IBS project?	98.8%	1.3%

Table 2 reveals that the majority of respondents' responses are affirmative, or "Yes," as shown by the results. There is complete awareness of the issue with construction waste on the construction site, hence the response is 100% "Yes." 91.3 percent of respondents were aware of the government-sponsored zero waste concept initiative. The vast majority of respondents were familiar with BIM, BIM applications, BIM functionality, and the advantages of the BIM system. 97.5 percent of respondents said they were well aware of the potential for IBS and

BIM technologies to help the construction sector cut down on waste generated on job sites. According to the responses, the amount of BIM implementation and IBS used at the construction site was not encouraging. However, 98.8% of respondents support the usage of BIM and IBS in the construction sector, and 95% of respondents said that using them was very rewarding. In conclusion, the vast majority of respondents were aware of BIM, IBS, and the significance of these systems in the building sector.

Cause of construction waste in Malaysia construction Industry

Table 3

Cause of construction waste in Malaysia's construction Industry

C	Cause of construction waste	SD	D	M	A	SA	M	SD	Ranks
C1	Lack of attention of the designers in the construction process and constructability of design intention.	1.3%	3.8%	10.0%	83.8%	1.3%	3.80	.581	10
C2	Designs not taking standard sizes into consideration.	1.3%	2.5%	8.8%	83.8%	3.8%	3.86	.566	9
C3	Ordering more materials than the actual amount needed.	1.3%	5.0%	3.8%	76.3%	13.8%	3.96	.699	4
C4	Ordering the wrong materials because of communication or information errors.	1.3%	2.5%	6.3%	72.5%	17.5%	4.03	.672	1
C5	Inappropriate material handling and storage.	0.0%	2.5%	7.5%	75.0%	15.0%	4.03	.571	2
C6	Workers who are not taught and trained, lack skills in assigned tasks.	0.0%	1.3%	7.5%	82.5%	8.8%	3.99	.462	3
C7	Complicated design.	1.3%	3.8%	6.3%	77.5%	11.3%	3.94	.661	7
C8	Shortage of workers problem.	1.3%	3.8%	3.8%	81.3%	10.0%	3.95	.632	5
C9	Shortage of technical personnel (skilled labor).	0.0%	2.5%	8.8%	80.0%	8.8%	3.95	.524	6
C10	Effect of weather.	2.5%	1.3%	12.5%	73.8%	10.0%	3.88	.698	8

Table 3 lists a few of the elements that contribute to wasteful construction practises at job sites. The survey respondents were asked to choose from the following 10 reasons for building waste.The results reveal that construction waste was mostly caused by "*ordering the wrong materials because of communication or information errors*"(M: 4.03; SD: 0.672), a problem that was intricately linked to the issue of poor communication and inaccurate information provided. To prevent misunderstandings and disinformation, site employees must be properly knowledgeable about construction. Fluency in speaking is a must for site workers, as is the ability to communicate in several languages.

The respondents' second-place pick for the main source of construction waste was "*inappropriate material handling and storage*" (M: 4.03; SD: 0.571). On construction sites, improper usage of machines is common. This is because items for the site must be rapidly unloaded for site usage, but sufficient machinery was not available. It was also possible that the driver of the delivery truck that was unloading must be rushed in order for the vehicle to make the subsequent delivery.

"Workers who are not taught and trained, lack skills in assigned tasks" (M: 3.99; SD: 0.462) comes in third place among the causes of construction waste. This occurred when instructions given for performing site work cannot be completed as effectively as possible. This condition would result in mistakes being made when carrying out the task that had been directed by orders from the site manager to the supervisor or orders from the supervisor to the site workers.

The fourth-ranked was "*ordering more materials than the actual amount needed"* (M: 3.96; SD: 0.699) was what lead to building waste. This overordering would unavoidably create space for building trash. For instance, incorrect calculations that disregard variables that could alter the volume and density of concrete. In most cases, site staff would generally order ready mix concrete for slabs or beams by adding 5 to 10 percent to the initial quantity (Bossink & Brouwers, 1996).

Implementation of BIM in construction industry toward construction waste reduction.

Table 4

Implementation of BIM toward construction waste reduction.

D	BIM implementation	SD	D	M	A	SA	M	SD	Ranks
D1	Able to minimize accident on site.	0.0%	1.3%	8.8%	85.0%	5.0%	3.94	.430	7
D2	Enable use material efficiently.	0.0%	1.3%	6.3%	85.0%	7.5%	3.99	.434	5
D3	Reduce on site waste cleaning.	0.0%	2.5%	2.5%	80.0%	15.0%	4.07	.521	1
D4	Improve on site waste management.	0.0%	2.5%	2.5%	81.3%	13.8%	4.06	.510	2
D5	Give a better understanding on the design workflow.	0.0%	2.5%	5.0%	78.8%	13.8%	4.04	.537	3
D6	Model resulting in fewer design changes.	0.0%	3.8%	7.5%	77.5%	11.3%	3.96	.582	6
D7	Less re-work and re-design resulting in less on-site waste.	0.0%	2.5%	8.8%	72.5%	16.3%	4.03	.593	4

Table 4 is on the implementation of BIM toward construction waste reduction. Seven crucial tasks or elements that might help BIM reduce construction waste were listed. Based on the results, using BIM to "*reduce on-site cleaning work*" (M: 4.07; SD: 0.521) was the respondents' top choice and "*improve on-site waste management"* (M: 4.06; SD: 0.510) was their second option for the advantages of implementing BIM in the construction business. In addition, the respondents chose "*give a better understanding on the design workflow"* (M: 4.04; SD: 0.537). as their third choice.

Implementation of IBS in construction industry toward construction waste reduction.

Table 5

Implementation of IBS toward construction waste reduction.

E	IBS Implementation	SD	D	M	A	SA	M	SD	Ranks
E1	High quality product and more accurate dimension due to controlled environment in factory.	0.0%	1.3%	5.0%	87.5%	6.3%	3.99	.404	7
E2	Reduces the requirement of labours for prefabrication element and erection at site.	0.0%	2.5%	2.5%	86.3%	8.8%	4.01	.462	6
E3	Able to reduce overall construction costs e.g., material and labor cost savings.	0.0%	1.3%	8.8%	78.8%	11.3%	4.00	.502	5
E4	Give Improvement on environmental performance. (cleaner environment on site).	0.0%	2.5%	10.0%	67.5%	20.0%	4.05	.632	1
E5	Allows fasters completion time or reduce build time.	0.0%	1.3%	7.5%	76.3%	15.0%	4.05	.524	2
E6	Factory production encourages recycling construction waste, leading to environmental protection and sustainability of the industry.	0.0%	1.3%	6.3%	78.8%	13.8%	4.05	.499	3

E7	Reduce construction cost effectively by adopting prefabrication and mass production of building components.	0.0%	1.3%	6.3%	82.5%	10.0%	4.01	.462	4

Table 5 illustrates the advantages of implementing IBS in the construction industry for reducing construction waste. According to the survey, there were seven advantages to using IBS. The majority of respondents chose "*give improvement on environmental performance. (cleaner environment on site)"* (M: 4.05; SD: 0.632) as the best option while the second most important advantage of implementing IBS chosen by the respondents was " *allows fasters completion time or reduces build time*" (M: 4.05; SD: 0.524). On the other hand "*factory production encourages recycling construction waste, leading to environmental protection and sustainability of the industry*" (M: 4.05; SD: 0.499) was ranked third by respondents. This is consistent with a study by Sandanayake et al (2019), which found that off-site construction has a lower environmental impact than conventional construction.

Conclusion

Overall, the study concludes that the majority of respondents were aware of BIM and IBS, as well as the importance of this system in the construction industry. The study also reveals that based on the respondent's feedback the main causes of construction waste were "*ordering the wrong materials due to communication or information errors,*" "*inappropriate material handling and storage*," and "*workers who are not taught and trained, lack skills in assigned tasks*." It is also clear that, the main benefits of using BIM in reducing construction waste for the respondents of the study were "*reduce on-site waste cleaning."*, "*improve on site waste management*," and "*give a better understanding of the design workflow*," while the main benefit of using IBS in reducing construction waste were "give improvement on environmental performance. (cleaner environment on-site) "," *allows fasters completion time or reduce build time" and* "factory *production encourages recycling construction waste, leading to environmental protection and sustainability of the industry* ". This is supported by a study conducted by Akinade (2018) who stated that the benefits of using BIM tools help a lot in construction waste management as well as improving building process performances (Akinade et al., 2018).

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