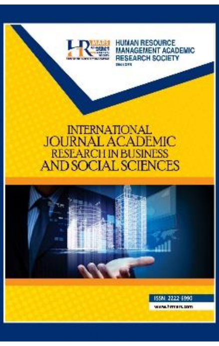

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Relationship of Construction Waste Causes and BIM-IBS Practices in Reducing Waste through Project Design Stage

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Abstract
Lack of Industrialized Building System (IBS) deployment in the construction industry and issues that arise during the design phase both contribute to an increase in waste. Thus, the government introduced BIM in IBS construction as a technology to improve project quality while lowering project costs. In this study, the effectiveness of BIM-IBS and the identification of waste source, awareness of waste cause, and implementation in BIM-IBS were examined. The purpose of this study is to evaluate the efficacy of BIM-IBS practices for waste reduction at construction projects and to establish a link between the causes of waste and the effectiveness of BIM-IBS practices for waste reduction during the design phase. A review of the literature and a questionnaire survey were done to determine the study's goal. The required values, such as Cronbach's alpha, mean value, standard deviation, and correlation, have been determined by analysis of the data using the SPSS Software. This study was able to ascertain a very important connection between waste cause, design phase issues and the advantages of BIM and IBS in lowering construction waste in the construction industry. The vast majority of respondents concurred that using BIM and IBS in the construction process is very effective and efficient in reducing construction waste in the industry.
Keywords: BIM, IBS, Construction Industry, Construction Waste Minimization.

Introduction

Building construction projects are getting bigger and bigger each day, and the waste coming from the construction site is unprepared, resulting in pollution of the environment. Construction and demolition waste produce over 10 billion tons each year, with China accounting for over 2 billion tons, Europe contributing 858 million tons, and the United States contributing 534 million tons (Povetkin & Isaac, 2020). Waste management problems occur at construction sites, which cause this pollution. Although many different approaches to waste management have been put forth, the construction waste keeps the waste percentage rising yearly. The management of the public works department has already prepared a procedure for the waste management needs of the construction industry. However, construction sites are not in favour of the waste management solution because the cost of removing waste from these sites is too high.

The Industrialized Building System (IBS) and Building Information Modeling (BIM)are two new technologies that have been made available to Malaysia's construction industry players in an effort to address the issue. These two technologies are used in the construction sector to simultaneously improve quality and cut costs. IBS can significantly improve a building's performance and quality. Over time, more construction projects have used the IBS system. The manufacturing companies increased from 15 in 2009 to 36 in 2011, indicating a growing number of IBS manufactured factories (Saar et al., 2019). In 2018, the government intends to mandate the use of industrialized building systems (IBS) for all construction projects. Nevertheless, the survey conducted by the Construction Industry Development Board (CIDB) revealed that, despite the government's target (an implementation rate of between 70 and 90 percent), the private sectors had a low implementation of IBS, at only about 15 percent. However, as more people and construction players gain knowledge, the acceptance level and implementation level of IBS gradually rise.

Building Information Modeling (BIM) enables the design, digital representation, scheduling, as well as a method of controlling costs and time associated with a project. Construction Industry Development Board (CIDB) has proposed that BIM is incorporated into all construction projects, and is now mandatory for projects over RM10 million. BIM is predicted to be integrated in IBS work flow in the same way that it provides support for standardizing prefabrication. BIM can be used to improve the quality of IBS and its productivity through re-engineering. For collaboration to be efficient and effective, it should focus on design intent, fabrication, and other production details, along with the interface of two systems, such as pass through and connections (Saar et al., 2019). It is possible that different infrastructure types will require different approaches to BIM, as challenges arising on each are different. For instance, tunnels and dams might require a very different approach, to mention but a few.

Public Works Department (PWD) introduced BIM technology in Malaysia in 2007, and the first government project that used it was carried out in 2010. The National Cancer Institute (NCI) is one of the earliest projects to use BIM technologies, and this project was cited as the example of a successful BIM project during the seminar and workshop (Haron et al., 2017). Due to a lack of knowledge and BIM operators, BIM usage is still relatively low in Malaysia. Despite the advantages of BIM, conflicting viewpoints make it unclear what those advantages would actually be. Therefore, most of the construction players are willing to take a risk on their project or spend money on the new technology.

Every project begins with the design phase, during which documentation must be created before construction can begin. Since it involves taking into account every aspect of the design and prevents unnecessary material waste, construction waste minimization designed into a project before operation is generally regarded as an effective way to reduce waste. This approach has been used sparingly in construction, which reduces waste production. For instance, in 2012 the Chinese National Housing and Urban-Rural Ministry designated Shenzhen as a national pilot city for the minimization and comprehensive utilisation of construction waste. Shenzhen has implemented several design guidelines for reducing construction waste, which call for modularly constructed buildings and an understanding of dimensional coordination in the Housing and Construction Bureau. Several successor nations have moved forward and used BIM-IBS techniques during the design phase.

Consequently, waste reduction is possible if the technique is used during design (Wang et al., 2014).

Problem Statement

Waste materials processed by the construction industry get higher every year due to a lack of ability to do waste management. In the construction industry, the quantity of material proposed is more than the amount needed to run some projects to ensure there is no shortage at the end of the construction. The material order will cause waste materials from that construction development. As a result, the construction industry tends to be well-known among the worst types of environmental polluters. Proper waste management in construction will help minimize waste in the construction industry by implementing it at the design stage. The method of using BIM and IBS is one of the new technologies introduced in the construction industry and has been implemented in many construction sites as a practice.

This BIM-IBS is supposed to help the project progress faster and assist construction site management with waste management. However, in most construction sites, a lot of waste is generated due to many factors, such as the wrong size produced by the fabricated company. This situation tends to be one of the factors for the waste material increase event ought the BIM-IBS have been implemented (Begum et al., 2010). Therefore, this study is very important to assess the relationship between construction waste causes and BIM-IBS practices and how these two are connected to reduce waste material in the design stage. Management of the waste material must be implemented from the design stage to make sure the waste material can be managed.

Literature Review

Construction Waste

Construction waste was very crucial due to the growth of population in Malaysia. Waste is known as any inefficiency in the construction process that results in the use of more machinery, resources, labor, or capital. Construction waste is not just solid waste; it includes the execution of work that are unnecessary to the project but required additional cost. Natural waste, direct waste, indirect waste, and consequential waste are the four categories of construction waste. Construction waste is not reducible in natural waste because the expense of reducing it is substantially higher than the cost of treating the waste. There is an acceptable tolerance for the site to produced waste in this situation. Direct waste is produced on construction sites as a result of a variety of activities such as material distribution, material storage in warehouses, reworks, inexperienced staff, and poor management. Indirect waste such as material modifications, extra supplies, contractor errors, and the risk of waste in the form of material and labor costs. Consequential Waste is a cost connected with production delays or rework to correct any product flaws (Nagapan et al., 2012).

Waste Cause

The number of infrastructure and residential development projects increased in Malaysia due to the country's growing population. As a result, waste production also continues to increase. Poor site management and supervision, a lack of experience, insufficient planning and scheduling, mistakes and errors in design as well as mistakes made during construction are some of the factors that contribute to waste generation (Nagapan et al., 2012). Lack of knowledge and experience in management has an impact on certain aspects of the construction process because decisions made could lead to the execution of incorrect work.

In a recent research, lack of awareness, excessive off-cuts due to poor design, and rework and variations are the top causes of material waste (Nazech et al., 2008). For instance, a change in drawing could be the main contributor to waste production. Changes in design are typically brought on by insufficient designs, which cannot support the structure's load. Due to the abrupt change in the drawing, demolition work and a new reconstruction of the structure were required (Rounce, 1998). All of these will unquestionably increase the production of waste.

BIM-IBS Practices

The Malaysian construction industry has embraced the Building Information Modelling (BIM) technology. BIM eliminates the main causes of unnecessary and non-value-adding activities on the construction site before the project starts. It is an excellent platform for developing the analysis of construction waste and the implications of design because BIM gives a design team a tool to assess how design choices will affect the entire construction process. Its technologies and methods for 3D virtual building modelling can produce some very useful outcomes (Baldwin et al., 2008). The Multipurpose Hall of University Tun Hussein Onn Malaysia (UTHM) in the Southern region of Malaysia was the first project in Malaysia that involved the implementation of BIM.

Other BIM initiatives in Malaysia include the National Cancer Institute of Malaysia, the Educity Sports Complex in Nusajaya, Johor, and the Ancasa Hotel in Pekan, Pahang (Latiffi et al., 2013). Adoption of BIM is seen in Malaysia as being more appropriate for challenging and high-risk projects. The use of pre-cast concrete beam-column elements and panelized systems has been a part of IBS implementation in Malaysia since the middle of the 1960s. The CIDB has developed the IBS Score in the construction industry to gauge the extent of IBS usage in buildings. For a project to qualify for a construction levy exemption, the CIDB stipulates that all public buildings must achieve a minimum IBS Score of 70%, while private residential structures must do so at a minimum of 50%.

Sustainable environmental practises have improved with the implementation of IBS because it guaranties strong emphasis on building quality, as a result benefited the industry. Numerous eminent Malaysian developers have opted for IBS over conventional methods for major projects like the Petronas Twin Towers, Putrajaya, KL Sentral, and KLIA (Din et al., 2012). German, Japanese, Finland, and Swedish construction challenges were successfully addressed by the adoption of IBS (Kamar & Hamid, 2011). Utilising IBS products for buildings not only satisfies customers, but it also lowers costs and shortens project timelines.

Challenges Implementation of BIM and IBS

In many countries, the adoption of BIM in the construction industry has grown. Organisational culture, technology, process, and policy are just a few of the obstacles that industry participants must surmount. Additionally, new technological innovation might have an effect on how the construction industry is managed. In addition, a lack of top management support and ineffective leadership could also hinder the project's BIM implementation. In most cases, the organisations that opt not to use BIM technology in their projects think it is challenging to adapt to new technology and that doing so will disrupt the ongoing process. On top of that, the hardware and software required for BIM may be expensive to purchase because of its high-tech nature (Musa et al., 2018).

Since the current industry is monopolised and controlled by a small group of manufacturers who have already acquired technologies, prefabrication facilities, and are supported by substantial financial resources, the transition to IBS also entails a high upfront cost. IBS is a new technology that cannot guarantee cost savings to industry participants, especially in small-scale construction. In some instances, the IBS system was used to award and construct buildings, but this led to project delays and subpar workmanship (Abd Rahman & Omar, 2006; Kamar et al., 2009). Indeed, implementing new technology in the project carries a higher risk than practicing the conventional method.

Waste Minimization After the Implementation BIM-IBS in Construction Industry

BIM is the most recent technology for the construction industry that the PWD introduced in 2007. It helps to improve project quality while reducing costs and time spent during the design and planning phases by identifying conflicts in the project before the project is carried out on the construction site. The primary objective is to eliminate or reduce waste at all design and construction-related stages, including concept, detail, production information, specification, procurement, first- and second-tier suppliers, logistics, site planning, and construction. BIM offers technology that can cut out unnecessary non-value-added activities from the project. Prior to construction, BIM can be used to analyse and simulate the project in finding errors or conflicts (Azman et al., 2012).

Similarly, IBS is a waste-reducing construction technique. IBS is typically manufactured in a factory, which lowers the amount of waste produced in the construction industry. The project's completion time was shortened due to the IBS process's ease of use and speed (Kasim et al., 2019). There are many ways that this technology can reduce the damaging effects that construction activities have on the environment. For instance, it can fix a previous design flaw or mistake, which enhances the component used in IBS. Additionally, prefabrication is encouraged by the process orientation, which also promotes controlled manufacturing and standard operating procedures in an industrial setting (Ariffin et al., 2018)

Methodology

Data for the research study was collected using a questionnaire containing questions relating to the effectiveness of BIM-IBS practices of construction waste and to develop relationship between waste causes and the BIM-IBS practices in reducing waste through design stage. There were four sections included in the questionnaire, namely section A, section B, section C and section D. Accordingly, Section A identified the background of the respondent, Section B identified the waste cause in the construction industry, Section C identified BIM-IBS implementation practices in Malaysia, and Section D identified the efficiency of BIM-IBS implementation and the reduction of waste cause.

Respondents were asked to indicate the relative significance of the questionnaires by indicating if the source was 'strongly agree', 'agree', 'moderately', ‘disagree’ or 'strongly disagree'. Samples were selected using convenience sampling because participants were chosen based on availability and willingness. The questionnaires on the relationship between waste cause, BIM, and IBS, questionnaires were distributed to various civil engineering companies, including consultants, contractors, authorities, and universities. For this study, the margin error was set at 8% with a level of confidence of 90% using RaoSoft Sample Size Calculator.

Based on the Raosoft sample size calculation, the sample size was 96 respondents. To ascertain the validity of the questionnaire, a pilot study was conducted involving a total of 30 people were chosen as respondents to determine whether the questionnaire was pertinent to the research goal. Some of the respondents came from the industry, while others were university lecturers. The reliability data was identified by finding the Cronbach alpha value using SPSS Analysis version 26. The table shows the internal consistency of the Cronbach's alpha, and the range of the alpha is significant. The Cronbach alpha value is 0.942, which means it is excellent in internally consistent.

Result and Discussion

Table 1
Respondent's background

		Frequency	Percent
Gender	Male	153	50.5
	Female	150	49.5
Company	Client	168	55.4
	Consultant	54	17.8
	Contractor	81	26.7
Designation	Executive	81	26.7
	Senior Management	66	21.8
	Junior Management	156	51.5
Experience	< 5 years	201	66.3
	5-10 years	57	18.8
	10-15 years	33	10.9
	> 15 years	12	4.0
Involvement in BIM-IBS project.	Never	156	51.5
	1-3 years	120	39.6
	3-6 years	24	7.9
	> 7years	3	1.0

Table 1 shows the respondents' background. Out of 303 respondents, clients made up the largest percentage of respondents (55.4%), followed by contractors (26.7%) and consultants (17.8%). In addition, 26.7% of respondents were from the executive level of management, 21.8% from the senior management level, and 51.5% from the junior management level. Furthermore, 10.9% and 18.8%, respectively, had between five and ten and fifteen years of experience working in this field. On the other hand, majority of respondents (66.3%) were those who have worked in the sector for less than five years, while only 4.0% of respondents had more than 15 years of work experience in the construction industry. Nevertheless, only 48.5 % of the respondents stated that they had the experience of using BIM and IBS in their projects. Therefore, this suggests that the majority of respondents who belonged to the inexperienced group (less than five years of working experience) were still not well exposed to modern construction technology using BIM and IBS in the construction industry.

Table 2
Correlations Waste Cause and BIM-IBS practices

Correlations						
		Waste Cause (8 qns.)	Design Phase Issues (9 qns.)	IBS toward Red Waste (practices) (5 qns)	BIM toward Red Waste (practices) (5 qns.)	BIM-IBS toward Red Waste (practices) (6 qns.)
Waste Cause	Pearson Correlation	1	.796**	.418**	.421**	.398**
	Sig. (2-tailed)		.000	.000	.000	.000
	N	303	303	303	303	303
**. Correlation is significant at the 0.01 level (2-tailed).						

Table 2 displays the findings of the correlation analysis for each mean average for each section. The questionnaire's mean average for the waste cause section was based on eight (8) questions, whereas the design phase issue was an average of nine (9) questions. On the other hand, the means on the benefits of using IBS and BIM toward reducing construction waste were based on 5 questions, respectively. With reference to the final section, the use of BIM-IBS toward reducing waste mean was based on the 6 questions posed.

The correlation analysis reveals positive trends between the waste cause factor in construction and design phase issues, the benefit of using IBS, the benefit of using BIM, and the BIM-IBS benefit factor, which points to a significant correlation in the reduction of construction waste. The sections on waste cause and design phase issues showed the highest positive tendency in lowering construction waste, with a correlation coefficient of 0.796.

Table 3
Correlations with BIM-IBS effectiveness factors

Correlations					
		Waste Cause (8 qns.)	Design Phase Issues (9 qns.)	BIM-IBS toward Red Waste (practices) (6 qns.)	BIM-IBS Effectiveness (16 qns)
Waste Cause	Pearson Correlation	1	.796**	.398**	.275**
	Sig. (2-tailed)		.000	.000	.000
	N	303	303	303	303
Design Phase Issues	Pearson Correlation	.796**	1	.428**	.291**
	Sig. (2-tailed)	.000		.000	.000
	N	303	303	303	303
BIM-IBS Toward Red Waste	Pearson Correlation	.398**	.428**	1	.387**
	Sig. (2-tailed)	.000	.000		.000
	N	303	303	303	303
BIM effectiveness	Pearson Correlation	.275**	.291**	.387**	1
	Sig. (2-tailed)	.000	.000	.000	
	N	303	303	303	303
**. Correlation is significant at the 0.01 level (2-tailed).					

Table 3 shows that all sections have a positive correlation with the "BIM-IBS effectiveness" factor. A correlation value of less than 0.5 indicates that all sections have a low positive correlation. The correlation between the parts obtained is very significant where the alpha value is less than 0.05 and 0.01.

Conclusions

The majority of respondents in this study either were recent graduates or were still relatively inexperienced in the construction industry, having less than five years of work experience. The majority of them had never worked on projects involving IBS or BIM. However, the study demonstrates a significant correlation between waste cause, design phase issues and the benefits of using BIM and IBS in reducing construction waste in the construction industry. The vast majority of respondents conceded that using BIM and IBS in the construction process greatly reduces waste in the sector.

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