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Waste Minimization in Construction Using Building Information Modeling (BIM) Approach

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Abstract: Construction waste is no longer a new problem in the construction industry. This is due to the rapid development of the construction industry, which has become a serious problem. Implementing the building information model (BIM) can minimize waste, but BIM is not a popular method for waste minimization in Malaysia. BIM is defined as a digital representation of the physical and functional characteristics of a facility and it is used to integrate data collection, exchange, and visualization during the life cycle of a construction project. This study aims to determine the current implementation of BIM in minimizing construction waste and study the perception of contractors in the challenge of implementing BIM in minimizing waste. The scope area of the study will focus on contractors and construction companies in the Kuala Lumpur area. By the way, this study uses a qualitative method to get the required information and there are 11 respondents will be interviewed. After collecting all the information, analysis of the information collected from the interview will be carried out. The finding of this study, the current implementation of BIM in minimizing waste is still low and the main challenges faced by construction players can be divided into three categories, which are process, people, and technology. In conclusion, the research objectives are achieved and the research study will help to develop the knowledge on the BIM in minimizing waste. So that encourages people to implement BIM in the project and push the Malaysia construction industry into a higher path.

Keywords: Building Information Modeling, Construction Waste, Challenges

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1. Introduction

Building Information Modeling (BIM) refers to one of the software technologies that is used to design, construct, test, and manage new buildings and infrastructure for architects, engineering, and construction (AEC). This technology helps build design professionals move toward to be more professional and successful ways of working. BIM software not just for AEC (Ganbat *et al*., 2018). BIM is applicable to users in many different fields within the building industry due to that software holds massive amounts of information within the platform. For example, people in mechanical, electrical, and plumbing (MEP) which can quickly and accurate estimation of systems (Mehrbod *et al*., 2019). In addition, BIM generates a 3D representation of a physical structure and all of its characteristics. BIM is a process used to manage the physical and functional information of the project. BIM as an output if the process that is the digital files that are used to describe the different aspect of the project is used to support any decision that is made throughout the project cycle (Roads, 2017).

1.1 Research Background

According to Nagapan *et al*., (2012), construction industry has faced a lot of challenges with the issues of construction waste. Construction waste includes any objects which is generated from construction activities, such as, materials that are surplus to requirements, damaged or spoiled materials, temporary and expendable construction materials and aids not included in the finished project, packaging materials and waste created by the workers. Besides that, deconstruct or demolish building will generate significant amounts of waste (Stanley *et al*., 2017). BIM can be used to construct buildings virtually before the actual building is built provides an effective means to check its constructability in the real world and resolve any uncertainties in the process. This allows for more efficient and better designed structures, thereby limiting waste of resources, optimizing energy use and promoting passive design strategies (Ahankoob *et al*., 2012).

1.2 Problem Statements

BIM is a method to minimize waste in construction but BIM is not a popular method used for waste minimization in Malaysia due to the lack of knowledge in using BIM to reduce waste. According to the study of Othman *et al*., (2018) there are several studies that have shown the potential of building information modeling (BIM) to design waste, but none has provided clear instructions on how to use BIM for this purpose. Besides that, based on the report published by CIDB, (2017), there are shown that 55% of the total respondents lack knowledge of BIM and 45% claimed that they have knowledge of this technology. In addition, the adoption rate in Malaysia is still low when compared with other countries (Ahmad Jamal *et al*., 2019) that is affected by the lack of knowledge in BIM technology.

1.3 Research Questions

(i) How efficiency of BIM in the reduction of the construction waste?
(ii) What is the perception of contractors about the challenge in using BIM to minimize waste in a project?

1.4 Research Objectives

This section should include research objectives of the study.

(i) To determine the current implementation of BIM in minimizing construction waste.
(ii) To study the perception of contractors in the challenge of implementing BIM in minimizing waste.

1.5 Scope of the Study

The scope area of the study will focus on contractors and construction companies in the Kuala Lumpur area. The reason for choosing Kuala Lumpur is that Malaysia has mainly promoted BIM in the central area and many construction companies in Kuala Lumpur have actively participated in learning and using BIM in the project. The study was conducted to determine the current implementation of BIM in minimizing construction waste and study the perception of contractors in the challenge of implementing BIM to minimizing waste so respondents will target contractors and construction companies who register under CIDB. The purpose is to ensure that the data collect is accurate.

2. Literature Review

2.1 Definition of Construction Waste

Based on Rahim *et al*., (2017) and Tam & Lu (2016) mentioned that construction wastes are any wastes that unused from construction activities from the pre-construction phase to the post-construction phase and even demolition. Additionally, construction waste also viewed as undesired or discarded materials that arise from human activities. According to the study of Ng *et al*., (2018), the definition of construction waste is the waste generated by the construction industry during construction activities, building renovation, cleaning of construction sites, road construction, and demolition activities including soil excavation. Construction waste is defined as a lack of efficiency in building effort (CIDB, 2018).

2.2 Definition of BIM

According to the research of Mordue *et al*., (2015), BIM is the process of link information and technology to create a digital representation of a project. BIM also can be defined as a tool for data communication and the spatial analysis used to integrate data collection, exchange, and visualization in the life cycle of construction projects. BIM platform assists managers and engineers by improving the quality of design and construction activities (Hergunsel, 2011). it can be used as a shared knowledge resource for building information, providing a reliable basis for decision-making from the beginning of the building to the life cycle (Conover *et al*., n.d.).

2.3 The Cause of Construction Waste

(a) The Phase of Design

Some causes of construction waste are the lack of attention of the designers in the construction process and the constructability of design intention. Besides that, customer may change design at the last minutes. Designs not taking standard sizes into consideration may generate waste due to cutting to fit the shape or size of an installed area (Luangcharoenrat *et al*., 2019).

(b) The Phase of Procurement

According to Raja *et al*., (2019) in the shipping error many mishandling or incorrect placements of orders or less placements of orders or incorrect shipping are found. In addition, the error in the order is the highest frequency.Specific data collection procedures/methods require to be described clearly.

(c) The Phase of Material Handling

Handling construction materials and happens due to human error. Therefore, the materials will turn up as waste due to improper storing methods and inappropriate protection strategies (Sasitharan Nagapan

et al., 2011). Material transport from the manufacturer to the construction site or on-site with no procedures may damage the material and then discard it (Luangcharoenrat *et al*., 2019).

(d) The Phase of Operation

Human error, weather and equipment failure may occur in operation phase and it is caused by mistake on workers. In addition, Equipment failure and workers using the equipment may cause material damage (Stanley *et al*., 2017).

(e) The Phase of Residuals

The poor attitude of project managers and workers is the cause of this residue. Material leftover on-site after construction is completed. The leftover construction materials on the construction site are classified as tangible waste (Sasitharan Nagapan *et al*., 2011).

2.4 How BIM can help to Minimize Construction Waste

In the design stage, BIM can be used for parameter design and collision detection. In addition, implementing BIM can reduce waste generation rates by synchronizing data between models, optimizing building design, providing 3D visualization services, and facilitating data capture during the design phase (Won *et al*., 2016).

In construction phase, BIM monitors the scale and speed of construction (Liu *et al*., 2015). BIM-based schedule management is achieved by adding a time dimension to the design information model. Then a sub-information model is established, which can intuitively and accurately reflect the construction progress. It can be compared with the actual construction schedule and the planned construction schedule to find gaps and make adjustments and controls to ensure the timely completion of the task (Xu *et al*., 2014). By BIM, the project team can more easily evaluate selected and designated building materials to achieve high post-consumer recycled content, fast renewable materials, and extraction and manufacturing of locally sourced materials (Chen *et al*., 2017).

In operation phase, through the functions of BIM in visualization, coordination, simulation, and optimization to promote sustainable building and integrated management of construction waste, the project team can better perceive the dynamics of the building system and thus try different solutions and optimize the overall sustainability Building design-oriented design reduces the need to recollect or reformat information needed for building life-cycle information management (Chen *et al*., 2017).

2.5 BIM Tool

(a) Revit Architectural

Revit Architectural has data interoperability with other BIM solutions and has unique functions in sustainable design analysis, collision detection, construction planning, and material manufacturing (Autodesk, n.d.).

(b) Revit Structural

Autodesk Revit Structure provides structural design drawings with real visualization, and establishes a data sharing bridge between architects and structural design teams. Revit Structural allows structural engineers to perform structural design and analysis by modeling the building using basic components of walls and foundations (Autodesk, n.d.).

c) Revit MEP

Autodesk Revit MEP is a building information modeling solution for mechanical, electrical, and plumbing designers. Revit MEP is interoperable with other BIM design software such as Revit

Architecture for collecting building model data and other Revit software such as Revit Structural. (Autodesk, n.d.).

(d) Naviswork

Autodesk Navisworks software is used for advanced analysis processes. Project managers can also use Autodesk Navisworks to create a multidisciplinary model to simulate and optimize plans, identify and coordinate conflicts, and establish collaboration between contractors and design teams (Autodesk, n.d.).

(e) Cost-X

CostX allows quick and extremely simple extraction of cost geometry and building dimensions from CAD files and BIM models, providing a faster and more accurate take-off for measurement, estimation, analysis, and options analysis (Exactal, n.d.).

2.6 Challenges of Implementing BIM

(a) People

Lack of knowledge on BIM, insufficient BIM training, and lack of awareness of BIM benefit is the main reason in this challenge (CIDB, 2017). Besides that, there are many construction players who like traditional or traditional processes construction projects (Ahmad *et al*., 2016) so they resistant to adopt new technology in a project.

(b) Process

Lack of time for experimentation and implementation in fast-paced projects and lack of references to help implement BIM be a main reason to consider using BIM technology in a project (CIDB, 2017). Besides that, there are many companies that lack the direction of BIM and unfamiliar with the use of BIM (Ahmad *et al*., 2016).

(c) Technology

Technology-related issues may be due to the fact that BIM is a new technology, and the reason is that users are concerned about the complexity of hardware and model-based software. The overall problem may be that there are not enough financial resources to invest in BIM because it is very costly in the early stages (Teng *et al*., 2018).

(d) Policy

The ownership of BIM needs to be protected by copyright law and other legal channels to ensure the security of data and the interests of the owner (Teng *et al*., 2018). AIA has officially formulated and recorded the laws and regulations of the digital design system and claims that the ownership of the final product should belong to the customer. But the passive effect of this regulation is that designers are no longer willing to take risks (Musa *et al*., 2018).

3. Research Methodology

3.1 Research Flow Chart

Figure 1 in appendix show the research flow chart. The flowchart is a detailed logical visual representation of all actual steps to complete an entire task or process (Granfelt, 2017).

3.2 Research Design

(*a) Qualitative*

The qualitative method will apply to collect data. This is a method which more focused on obtaining the data through open-ended and conversational communication.

3.3 Research Instrument

(a) Primary Data

For this research, the semi-structural interview has chosen to obtain the information from interviewees. This is a set of question papers that are prepared based on the to.

(b) Secondary Data

Journals, articles, books, and websites related to the title and purpose have been used as a reference in this study. In addition, reference material also will be searched at Tunku Tun Aminah Library, UTHM. Through browsing the Tunku Tun Aminah Library website, to get the related information or research.

3.4 Population

The target population or respondent for this research is contractors and construction companies in Kuala Lumpur. The target populations for this research are contractors and sub-contractors who are knowledgeable in the field related to waste management and Building Information Modeling. The target group of respondents in this research are contractors and construction companies who register under CIDB and in Kuala Lumpur. In addition, respondents will answer questions base on objective 1 and 2. Besides that, there are 11 respondents will be chosen to answer.

3.5 Data Analysis

In this study, qualitative content analysis will be used to analyze the data collected from interviewees because it can provide a detailed and in-depth description of the content.

4. Results and Discussion

4.1 Interview Session

In order to complete this research, a qualitative method was conducted. Due to the cases of COVID-19 pandemic in Kuala Lumpur is very high so will collect the data through email, WhatsApp and google form. The data collection process took about 2 months to complete.

4.2 Background of Respondent

The target respondents of this study are contractor and construction companies who register under CIDB and located in Kuala Lumpur. For this research, there are 11 respondents have involved in this interview. These respondents provided data to achieve the objective of this research. Below is the Table 1 show that the information of respondent.

Table 4.1 Background of Respondent

Respondent	Company Name	Position	Year of Service in Industry	Registration Grade
R1	Meng Kei Construction Sdn Bhd	Site Supervisor	1	7
R2	Sribinaraya Sdn Bhd	Site Supervisor	2	7
R3	China Communication Construction Company (M)	Civil Engineer	3	7

	Sdn Bhd			
R4	Mudajaya Corporation Berhad	Managing Director	28	7
R5	JTR Excel Enterprise	Site Coordinator	2	3
R6	MES Asia Sdn Bhd	Manager	8	-
R7	China Railway 17th Bureau Group (M) Sdn Bhd	M&E Engineer	6	7
R8	Grand Dynamic Builders Sdn Bhd	Planning Engineer	2 (months)	7
R9	Khzam Engineers Sdn Bhd	Inspector of Works	20	Registrar in 2018
R10	Kejuruteraan Bumi Utama	Project Manager	5-6	6
R11	Sunway Construction Sdn Bhd	Engineer	1	7

4.3 Objective 1: To Determine the Effectiveness of the Implementation of BIM in Minimizing Construction Waste

(a) The Type of Method Used to Reduce Construction Waste in A Project.

Base on the Table 2 in appendix, 3 respondents (R3, 6, 11) stated that their company have implement BIM in their project to reduce waste on site. There are 2 respondents (R2, 5) estimate the amount of material will be used. Besides that, 2 respondents (R4, 7) apply precast product on site while the others 3 respondents (R1, 8,9) using different method such as 3R terminology, 5S approach and shear wall. Last, there is 1 respondent (R10) did not use specific method to reduce on site waste.

(b) The Current Definition of Building Information Modeling (BIM).

Based on the Table 3 in appendix, 3 respondents (R1, 3, 7) definition BIM is a 3D model. 1 respondent (R10) commented BIM is a software able to identify problems at the early stage. There are 2 respondents (R2, 3) said that BIM can corporate with other department and combine all various scopes of work. R9 said that BIM is used in design MEP services. While 2 respondent (R4, 11) defined BIM as building information management and building information modeling. And 1 respondent (R5) didn't answer this question.

(c) The Experiences of Company in Building Information Modeling (BIM).

Base on the Table 4 in appendix, there are 5 respondents (R1, 2, 5, 9, 10) haven't any experience in using BIM. Next, 4 respondents (R3, 8, 6, 7) said that the BIM adoption level in their company at level 1 which using BIM for design work. While R4 stated that adoption of BIM in his company is usually at level 1 to 2. Last, R11 commented that his company have achieves level 2.

(d) The Suitability of BIM in Minimizing Construction Company.

Base on the Table 5 in appendix, there are 8 respondents (R1, 4, 6, 7, 8, 9, 10, 11) agreed that implementation BIM is suitable for all company. However, 3 respondents (R2, 3, 5) don't agreed that BIM is suitable for all the company due to the cost of BIM is very high.

(e) The Effectiveness of Implementation of BIM in Term of Minimize Waste During Design Phase.

Base on the Table 6 in appendix, all respondents have provided different opinions. R1 said that BIM able to give a picture to all construction parties. While 5 respondents (R2, 3, 7, 8) believed that BIM able to avoid drawing error. R4 stated that implement BIM in design phase need time before it

become effective. But R5 commented that the effectiveness of BIM needs to depends on the scale of project. R6 stated that BIM able to prevent from variation order and ensure the design are ready. Next, R9 believed that after implement BIM, decision making will be effective at in phase. Last R11 didn't answer this question.

(f) The Effectiveness of Implementation of BIM in Term of Minimize Waste During Construction Phase.

From the Table 7 in appendix, all the respondents have given different comments. R1 said that BIM could manage or prevent the huge amount of construction waste progressively onsite. There are 2 respondents (R2, 8) commented that BIM can define and minimize the clash happen. R3 stated that have obvious information in every process. R4 stated that implement BIM in design phase need time before it become effective. Next, R5 It provides a prior insight to avoid and waste reduction, however, it still requires site personnel action. R6 stated that BIM able to prevent from variation order and ensure the design are ready. R7 commented that, BIM gives an accurate estimation to planners for having the correct order of material. R9 said that using BIM during the construction phase can help to installation of MEP services. Besides that, R10 said that it depends if there are any changes that need to do the simulation for testing purposes. Last, R11 believed that BIM able to the accurate and precise building will happen.

(g) The Effectiveness of Implementation of BIM in Term of Minimize Waste During Operation Phase.

Based on the Table 8 in appendix, all the respondents provide different opinion. 4 respondents (R1, 6, 8, 9, 10) commented that similar with the phase in above. While 2 respondents (R2, 3) said that BIM able to improve maintenance work. 1 respondent (R7) said those extra materials won't be existed on site. And 1 respondent (R5) commented that it may show positive effectiveness, however, with poor construction knowledge and experience waste are still bound to be created. Last R11 didn't answer this question.

(h) The Implementation of Building Information Modelling (BIM) help in Minimizing Construction Waste.

Based on the Table 9 in appendix, all the respondents believed that the implementation of Building Information Modelling (BIM) will help to minimize construction waste. Some respondents have explained that because BIM able to find out clash or mistaken at an early stage.

(i) The Suitability of using BIM in minimizing construction waste in Malaysia.

For this statement as in Table 10 in appendix, all respondents agree that the application of Building Information Modeling (BIM) in minimizing construction waste is applicable to Malaysia. Because some respondents believed that using BIM will bring benefit to project and there is no different if the comparison is intended by countries.

(j) The Recommend Implementing BIM in a Building Project to Minimize Construction Waste.

Table 11 in appendix shows that all the respondents like to recommend implementing BIM on building projects to minimize construction waste. If the building projects in Malaysia implement this BIM system so that these issues being resolved in the construction site in Malaysia.

4.4 Objective 2: To Determine the Effectiveness of the Implementation of BIM in Minimizing Construction Waste

(a) The Main Challenges that Causing the Implementation of BIM in Minimizing Construction Waste in Malaysia Nowadays.

Based on the Table 12, the respondents' views on the main challenges can be divided into three categories which are process, people and technology. 3 respondents (R1, 5, 7) stated that the process is the main challenge. For the term of people, 5 respondents (R2, 3, 6, 8) had mentioned. Last, 3 respondents (R9, 10, 11) believed that technology is the main challenge in implement BIM.

(b) The Challenges in the Term of Policy in Implementing BIM to Minimize Waste.

Based on Table 13 in appendix, there are 3 respondents did not answer to this question and 1 respondent (R10) said that he is no sure about this challenge. While the other respondents have provided different opinion. So, it will be list out. The penetration of BIM in Malaysia construction industry is still in the infant stage. The understanding of BIM by policymakers, government agencies, asset owners, professionals, and management of companies is very basic. Need to depends on company standard operating procedure, there are many policies need to be amended and others.

(c) The Challenges in the Term of People in Implementing BIM to Minimize Waste.

Based on the Table 14 in appendix, there are 4 respondents (R1, 3, 8, 9) point out about lack of skill worker, experience and technology problem. And 3 respondents (R2, 10,11) mentioned that company need to provide time and cost for training. While 2 respondents (R5, 6) believed there is due to the mindset of people. Next 1 respondent (R7) said that designers, constructors and maintainers cannot collaborate with the end-users because they may not yet have been hired during the construction process. Last 1 respondent didn't answer to this question.

(d) The Challenges in the Term of Process in Implementing BIM to Minimize Waste.

Based on Table 15 in appendix, there are 4 respondents (R1, 3, 8, 9) point out about lack of skill worker, experience and technology problem. And 3 respondents (R2, 10,11) mentioned that company need to provide time and cost for training. While 2 respondents (R5, 6) believed there is due to the mindset of people. Next 1 respondent (R7) said that designers, constructors and maintainers cannot collaborate with the end-users because they may not yet have been hired during the construction process. Last 1 respondent didn't answer to this question.

(e) The Challenges in the Term of technology in Implementing BIM to Minimize Waste.

From Table 16 in appendix, there are 5 respondents (R1, 2, 3, 5, 8) stated that because of the high cost of BIM software. 1 respondent (R11) mention the software and hardware of BIM. And 1 respondent (R4) stated that BIM software is developed by IT engineers that do not understand construction. Next, 2 respondents (R6, 9) mention the way to operate the software. Last R7 provide the answers that were not relevant to the question.

(f) The Difficulties that Need to be Concern When Implementing BIM.

From Table 17 in appendix, 3 respondents (R1, 2, 3) stated about the skilled worker. Next, the other respondents have provided different opinion that are software pricing strategy, the conventional tender process, the coordination to all services, the overall BIM process, the scale and complexity of project and the mindset of people.

(g) The Greatest Impact That Will Affect the Industry After the Implementation of the BIM in Minimizing Construction Waste.

According to Table 18 in appendix, there are 7 respondents (R1, 2, 3, 5, 6, 7, 8) stated that able to reduce waste on site and the cost of project. Because BIM techniques and tools have been successfully used to enhance planning and construction relate. Next, 3 respondents (R9, 10, 11) believed that will shorten project time and the construction process will become more efficient and effective. Last, 1 respondent didn't answer to this question.

(h) The Big Changes in the Industry After the Implementation of the BIM in Minimizing Construction Waste.

Base on Table 19 in appendix, there are 5 respondents (R1, 3, 5, 8, 11) stated that BIM able to control waste and be a greener environment on site. Next, 3 respondents (R2, 6, 9) pointed out that BIM able to increase project productivity and reduce project costs and duration. Besides that, R7 mentioned about cooperated. BIM makes resource management easier; it helps people to stay in touch throughout the project, and it enables enhanced collaboration. Last, 2 respondents didn't answer to the question.

(i) The Advantages After Applying the BIM in the Industry.

Based on Table 20 in appendix, there are 3 respondents (R2, 3, 10) believed that the process on site will be more efficiently after apply BIM. Besides that, other respondents have stated different view to this question that are BIM can bring better development and ease the process of construction, BIM is a tool that helps designers and contractors to plan ahead their works and help to identify the problem, enables the main contractors to share the relevant models with subcontractors, able to bring better environment on site and construction industry will be digitalizing. Last, 1 respondent didn't answer to this question

(j) To Identify the Implementation of BIM in Minimizing Construction Waste in Pushing the Malaysia Construction Industry into a Higher Path.

Base on Table 21 in appendix, all the respondents are in favor of implement BIM in minimizing construction waste will push the Malaysia construction industry into a higher path. Because BIM can complete the project effectively and reduce on-site construction waste. Besides that, there are many countries have been implementing BIM in the industry for some time. Last the LEED, GreeRE and other green certificates will be common in the future.

5. Conclusion

All the survey results in the interview have been collected and explained to further explore the survey results and have a deeper understanding of the survey results in the interview from the perspective of the interviewees. First objective of this study is to determine the current implementation of BIM in minimizing construction waste. Base on the data in chapter 4, respondents have understood BIM technology, but there are still low adoption BIM in their project for minimize construction waste. There are 6 respondents out of 11 respondents said that their company has experience in implementing BIM but most of them still in level 1 BIM and only two companies have reached in level 2 BIM. However, there are only 3 respondents have adopted BIM technology to minimize construction waste on-site. Nevertheless, all the respondents believed the effectiveness of implementing BIM to minimize waste during the life cycle stages of design, construction, and operation projects. In the design stage BIM can help to minimize waste by planning and check the change in drawing so that design team can change error early. Next, in the construction stage, BIM tool can provide exact quantity take-off and give an accurate estimation in materials. Besides that, BIM tool will able to show the obvious information or the clash detection of building so in the construction stage, BIM able to provide an accurate and precise building to minimize waste by reducing wrong built happened. While in the operation stage, BIM tool can develop an annual maintenance plan and easily find out the locate parts. Last, some respondents said that implementing BIM in minimizing waste is not suitable for small company due to the cost of BIM is quite expensive. However, all the respondents are still recommended implement BIM technology in minimizing waste in Malaysia due to save time, cost and increase the quality effectiveness in a project.

The second objective of this study is to study the perception of contractors in the challenge of implementing BIM to minimizing waste. Different respondents with different experiences have the different perspective on the implementation of BIM in minimizing waste. Regardless of their different views, all the challenges faced when implementing BIM to minimize waste is related to the three categories of process, people and technology. And three categories challenge need to be concerned by companies when implementing BIM. In the term of process, BIM technology is still an emerging technology in Malaysia, which may not be widely to most construction player, and there is a lack of references to assist in the implementation of BIM. Next, in the term of people. The lack of experience and knowledge in employees. Some companies need to pay time and cost to provide training. Besides that, the mindset of user also affects the adoption of BIM. In the term of technology, the software of BIM is costly. It may not be affordable for all companies, especially to SME. Last, respondents stated that after implementing BIM in minimizing construction waste in Malaysia, the construction industry in Malaysia can be pushed to a higher level because the project can be effectively completed, a greener environment can be created on site, and the construction industry can be digitized.

The adoption rate of BIM in a project should be improved in Malaysia construction industry. Below is the way to encourage BIM usage:

(i) Malaysia's government can hold more events about the BIM technology and set up a standard guideline for all the construction players.
(ii) Company should provide more training or seminar to employees so that employees able to improve their knowledge and skill in BIM.
(iii) Government Agencies such as MyBIM Centre should create more training class for those people who are interested to learn BIM technology.
(iv) Government Agencies can provide consulting to SME companies to help them determine the most suitable plan in implementing BIM.

To conclude that the objectives of this study are achieved. Implementing BIM in the design phase, construction phase, and operational phase able to reduce construction waste. However, the current implementation of BIM in minimizing waste is still low. The adoption rate low is due to there are many challenges that need to be a concern when implementing BIM. The main challenges faced by construction players are divided into three categories, which are process, people, and technology. The reference to assist BIM technology and the cost in training and software is the factor that needs to be concerned before implement BIM in reducing construction waste in a project. Actually, the most serious issue facing when implementing BIM in minimizing waste is the mindset of users. This research is hopeful to be able to show to all construction parties about the effectiveness of the implementation of BIM in minimizing construction waste so that BIM technology should be promoted to implement as soon as possible because it can be pushing our construction industry to a higher path.

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Appendix A

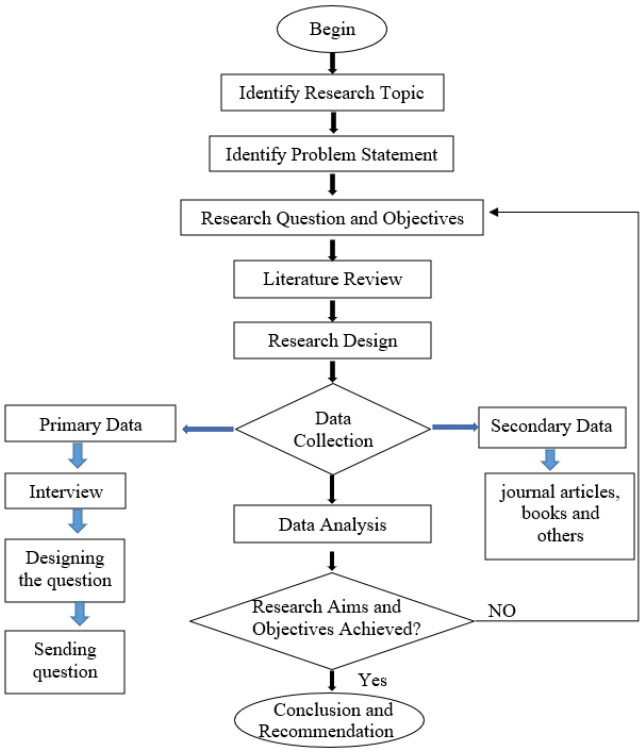

Figure Error! No text of specified style in document.**1: Research Flow Chart**

Table 2: Type of Method Used to Reduce Construction Waste in A Project

Respondent	Annotation
Respondent 1 (R1)	'By using 3R terms in construction site (Reduce, Reuse, Recycle) the materials on site. We also plan and organize the construction site accordingly before the possession of site have been taken'.
Respondent 2 (R2)	'We will calculate the need for material in a project and then we also will try to reuse material on site'.
Respondent 3 (R3)	'We use Navisworks to calculate the quantity of material needed before procure and on site will be control the quality'.
Respondent 4 (R4)	'Optimisation of design, construction method and sequence, shop drawings and material of pre-cut/pre-bend/prefabricated/re-useable

	form'.
Respondent 5 (R5)	'Estimating and purchasing material wisely'.
Respondent 6 (R6)	'BIM Coordination Works'.
Respondent 7 (R7)	'Precast and cast-in situ'.
Respondent 8 (R8)	'5S approach'.
Respondent 9 (R9)	'Shear wall'.
Respondent 10 (R10)	'I don't use any specific method so far, just make sure plan ahead and not to do mistakes a lot by working closely with the supplier'.
Respondent 11 (R11)	'BIM'.

Table 3: The Current Definition of BIM

Respondent	Annotation
Respondent 1 (R1)	'Building Information Modelling in which an intelligent 3D model-based process that gives architecture, engineering, and construction (AEC) professionals the insight and tools to more efficiently plan, design, construct, and manage buildings and infrastructure'.
Respondent 2 (R2)	'A system that can corporate with others department immediately'.
Respondent 3 (R3)	'A 3D model that illustrates the project'.
Respondent 4 (R4)	'Building Information Management. Although we have this capability within the technical team, its only use for study of specific areas'.
Respondent 5 (R5)	-
Respondent 6 (R6)	'Construction's Cheat'.
Respondent 7 (R7)	'3D model-based process that gives architecture, engineering, and construction (AEC) professionals the insight and tools to more efficiently plan, design, construct, and manage buildings and infrastructure'.
Respondent 8 (R8)	'BIM is process of integrating various scopes of work to reduce the effect of working in silos as well as providing visualisation'.
Respondent 9 (R9)	'Integrated designed Electrical Mechanical and Plumbing services'.
Respondent 10 (R10)	'It is a software that help the construction industry running the simulation to identify problems at the early stage'.
Respondent 11 (R11)	'Building Information Modeling'.

Table 4: The Experiences of Company in BIM

Respondent	Annotation
Respondent 1 (R1)	'No'.
Respondent 2 (R2)	'No'.
Respondent 3 (R3)	'Have, a basic level which is just cut section, hide to see the thing needed'.
Respondent 4 (R4)	'We have this capability within the technical team. Typically, level 1 to 2'.
Respondent 5 (R5)	'No'.
Respondent 6 (R6)	'Design, Construction, As-built, Facilities Management'.
Respondent 7 (R7)	'My company have experience with BIM since our current project now using BIM for the interfacing design works'.

Respondent 8 (R8)	'Level 1'.
Respondent 9 (R9)	'No'.
Respondent 10 (R10)	'Nope'.
Respondent 11 (R11)	'4D'.

Table 5: The Suitability of BIM in Minimizing Construction Company

Respondent	Annotation
Respondent 1 (R1)	'Yes. It could provide effective plan in managing or minimizing the construction waste during the design and construction stage of the project'.
Respondent 2 (R2)	'Due to the price of using BIM system is quite expensive, I think it's suitable for big company rather than small company'.
Respondent 3 (R3)	'No. I think is suitable for large company because the cost of BIM is quite high'.
Respondent 4 (R4)	'Theoretically it should. In many cases it doesn't work as intended as the market is not ready and the compatibility of the drawings and correct flow of design process will take few more years to be ready'.
Respondent 5 (R5)	'No'.
Respondent 6 (R6)	'Yes'.
Respondent 7 (R7)	'Yes. Those problems are solved early in the design and hence there will be fewer controversial problems in the plans and fewer hassle'.
Respondent 8 (R8)	'Yes'.
Respondent 9 (R9)	'Yes. It all the participant that understanding they responsibilities and initial cost is higher rather than conventional tender'.
Respondent 10 (R10)	'Yes of course'.
Respondent 11 (R11)	'Yes'.

Table 6: The Effectiveness of Implementation of BIM in Term of Minimize Waste During Design Phase

Respondent	Annotation
Respondent 1 (R1)	'It could control the amount of construction waste on site by planning early in design phase, BIM able to give a picture to all construction parties including all professional bodies by minimizing the waste'.
Respondent 2 (R2)	'It can show what design had been change by others department in order to minimize the misunderstanding'.
Respondent 3 (R3)	'Can direct know the error in drawing and change it'.
Respondent 4 (R4)	'It will take some time before it will become effective. It is tedious process as the cost of investment will need to be justified with cost of saving. Promotion and encouragement from government agency is critical'.
Respondent 5 (R5)	'It depends on the scale of the project and work'.
Respondent 6 (R6)	'Great Tools to ensure the designs are ready to be constructed that can prevent from variation order'.
Respondent 7 (R7)	Any design changes entered to the building model is automatically updated. Hence, there will be less rework due to possible drawing errors or omissions.
Respondent 8 (R8)	'Certainly. Much as with visualisation, it can aid in reducing abortive works as well prefabrication works.
Respondent 9 (R9)	'Yes. The period of design and make decision making will be

	effective'.
Respondent 10 (R10)	'Very effective as during the design phase when u can do simulation first then u can identify the problems early'.
Respondent 11 (R11)	-

Table 7: The Effectiveness of Implementation of BIM in Term of Minimize Waste During Construction Phase

Respondent	Annotation
Respondent 1 (R1)	'During construction stage, the implementation of BIM could manage or prevent the huge amount of construction waste progressively on site without delay which could damage the environmental health instead of only find the solution to resolve the huge amount of waste after the event happened'.
Respondent 2 (R2)	'It can define and minimize the clash happen'.
Respondent 3 (R3)	'Have obvious information in every process'.
Respondent 4 (R4)	'It will take some time before it will become effective. It is tedious process as the cost of investment will need to be justified with cost of saving. Promotion and encouragement from government agency is critical'.
Respondent 5 (R5)	'It provides a prior insight to avoid and waste reduction, however it still requires site personnel action to give better effectiveness'.
Respondent 6 (R6)	'Great Tools to ensure the designs are ready to be constructed that can prevent from variation order'.
Respondent 7 (R7)	'Exact quantity take-off means that materials are not over-ordered. This BIM gives an accurate estimation to planners and engineers for having correct order of material'.
Respondent 8 (R8)	'Similarly, with during design stage where clash detections are done, it could reduce those wastage'.
Respondent 9 (R9)	'Installation of MEP services'.
Respondent 10 (R10)	'It depends if there's any changes that need to do the simulation for testing purpose'.
Respondent 11 (R11)	'Accurate and precise building will happen and hence, reduce wastages of wrongly built'.

Table 8: The Effectiveness of Implementation of BIM in Term of Minimize Waste During Operation Phase

Respondent	Annotation
Respondent 1 (R1)	'During operation stage, the implementation of BIM could manage or prevent the huge amount of construction waste progressively on site without delay which could damage the environmental health instead of only find the solution to resolve the huge amount of waste after the event happened'.
Respondent 2 (R2)	'It can use to develop an annual maintenance plan in order to easily locate parts that require maintenance'.
Respondent 3 (R3)	'Reduce maintenance work, using BIM system can directly find out the problem'.
Respondent 4 (R4)	'I have yet to experience this but from the operation process, it should help to minimize the waste. The herder on the system and technical personnel readiness would be a great challenge. Malaysian asset owner is also known for tight maintenance budget'.

Respondent 5 (R5)	'It may show positive effectiveness, however, with poor construction knowledge and experience waste are still bound to be created'.
Respondent 6 (R6)	'Great Tools to ensure the designs are ready to be constructed that can prevent from variation order'.
Respondent 7 (R7)	'Extra materials won't be existed on site which would be deployed by poor weather or movement'.
Respondent 8 (R8)	Similarly.
Respondent 9 (R9)	'Coordination and making decision'.
Respondent 10 (R10)	'It depends if there's any changes that need to do the simulation for testing purpose'.
Respondent 11 (R11)	-

Table 9: The Implementation of Building Information Modelling (BIM) help in Minimizing Construction Waste

Respondent	Annotation
Respondent 1 (R1)	'Yes. BIM able to help in minimizing the construction wastes effectively in which I have mentioned in previous section'.
Respondent 2 (R2)	'Yes. It can define the accurate quantity used and clash detection for the construction. Therefore, less of clash will less wastage of material'.
Respondent 3 (R3)	'Yes, BIM help to find out clash or mistaken at early'.
Respondent 4 (R4)	'I strongly believe it will eventually. There is a lot more effort to do before it gets popular in the construction industry. ACAD probably takes almost 15 years to get popular, l*et al*one BIM is a more complicated tool. On software side, it's still a black box with lots of uncertainty from legal, security and sustainability'.
Respondent 5 (R5)	'Yes, to a certain extend'.
Respondent 6 (R6)	'Yes, statistic shows that BIM can reduce 20% - 30% of project cost and completion period'.
Respondent 7 (R7)	'Yes. The cost of construction material is growing significantly and every amount of material waste has an irreversible effect on cost and project earnings. Therefore, the best methodology should be applied by using application of BIM in every stage of the project'.
Respondent 8 (R8)	'Certainly'.
Respondent 9 (R9)	'Yes'.
Respondent 10 (R10)	'Yes, of course'.
Respondent 11 (R11)	'Yes'.

Table 10: The Suitability of using BIM in minimizing construction waste in Malaysia

Respondent	Annotation
Respondent 1 (R1)	'Yes, if BIM imply in Malaysia, the huge amount of construction wastes in construction site nowadays in Malaysia will be resolved without causing environmental pollution'.
Respondent 2 (R2)	'Yes, because it can perform a more accurate cost estimation and a clash detection to determine the main building layout'.
Respondent 3 (R3)	'Yes, Using BIM will bring benefit to project'.
Respondent 4 (R4)	'There is no different if the comparison is intended by countries'.
Respondent 5 (R5)	'Yes, but depending on the scale of the project and complexity of the work'.
Respondent 6 (R6)	'Yes, because BIM is a tool that helps designers and contractors to

	plan ahead their works and help to identify the problem that they might face during the construction stage and resolve it before the work even started'.
Respondent 7 (R7)	'Yes. BIM provides an accurate model of the design and the material resources required for each segment of the work, it provides the basis for improved planning and scheduling of subcontractors and helps to ensure just-in-time arrival of people, equipment, and materials. This reduces cost and allows for better collaboration at the jobsite'.
Respondent 8 (R8)	'In Malaysia, I believe we still have a long way to go for implementing to Level 2 BIM. However, it is suitable as BIM as BIM can enable simulations and visualisation before construction'.
Respondent 9 (R9)	'Yes, and due to cost, time and quality effectiveness'.
Respondent 10 (R10)	'Indeed, it is suitable to any country that has the ability to run a new system for them to innovate'.
Respondent 11 (R11)	'Yes, because it helps the construction to save time and cost. Malaysia needs this'.

Table 11: The Recommend Implementing BIM in a Building Project to Minimize Construction Waste

Respondent	Annotation
Respondent 1 (R1)	'Yes, I recommend that the building projects in Malaysia to implement this BIM system so that these issues being resolved in construction site in Malaysia'.
Respondent 2 (R2)	'Yes'.
Respondent 3 (R3)	'Yes'.
Respondent 4 (R4)	'Yes'.
Respondent 5 (R5)	'Yes, if it involves complex works and project'.
Respondent 6 (R6)	'Yes'.
Respondent 7 (R7)	'Yes'.
Respondent 8 (R8)	'Certainly'.
Respondent 9 (R9)	'Yes'.
Respondent 10 (R10)	'Yes definitely'.
Respondent 11 (R11)	'Yes'.

Table 12: The Main Challenges that Causing the Implementation of BIM in Minimizing Construction Waste in Malaysia Nowadays

Respondent	Annotation
Respondent 1 (R1)	'There are still many construction companies are still not familiar with BIM where the company I worked for as one of the examples. However, the implementation of BIM as the advance technology system where there is only small amount of construction companies to implement this system especially in Malaysia'.
Respondent 2 (R2)	'Lack of professional to implement it and also the price of the system is expensive'.
Respondent 3 (R3)	'Lack of skilled employees'.
Respondent 4 (R4)	'There are different type of challenges at different phases of implementation'.
Respondent 5 (R5)	'Knowledge on analyzing and utilizing the system'.
Respondent 6 (R6)	'Most of the Old-timers in the industry don't want to use BIM as they think is a waste of time'.
Respondent 7 (R7)	'Lack of understanding BIM enough to implement it (challenges), the lack of familiarity with BIM use and lack of the capital to invest'.

Respondent 8 (R8)	'Mindset'.
Respondent 9 (R9)	'Design and cost of project implementation'.
Respondent 10 (R10)	'Pricing for the software is still at the high side and many small contractors can't afford it'.
Respondent 11 (R11)	'Learning of new technology'.

Table 13: The Challenges in the Term of Policy in Implementing BIM to Minimize Waste

Respondent	Annotation
Respondent 1 (R1)	-
Respondent 2 (R2)	-
Respondent 3 (R3)	-
Respondent 4 (R4)	'The penetration of BIM in Malaysia construction industry is still in the infant stage. The understanding of BIM by policy maker, government agencies, asset owners, professionals and management of companies is very basic. From legal and contracts perspective, if mistakes due to BIM, who is taking the responsibility? Or from another perspective, can a legal judgement be made by relying on BIM analyses?'.
Respondent 5 (R5)	'Depends on the company standard operating procedure and adoption of system'.
Respondent 6 (R6)	'Usually, they will miss out some of the job scope in the contract'.
Respondent 7 (R7)	'Factor that contributes to materials wastage is wrong material storage which is always connected with an inappropriate protection strategy. Inadequate stacking and insufficient storage can result in waste'.
Respondent 8 (R8)	'Much legal policies needed to be amended to include BIM'.
Respondent 9 (R9)	'Everyone should be understanding the designed and cost'.
Respondent 10 (R10)	'I'm not sure about this'.
Respondent 11 (R11)	'Client's needs and wants'.

Table 14: The Challenges in the Term of People in Implementing BIM to Minimize Waste

Respondent	Annotation
Respondent 1 (R1)	'Difficult employ professional employee'.
Respondent 2 (R2)	'Need time and cost to provided training for worker'.
Respondent 3 (R3)	'Lack of skilled employees, need time to training'.
Respondent 4 (R4)	-
Respondent 5 (R5)	'Older site personnel tend to reject new system that makes it not fully effective'.
Respondent 6 (R6)	'They don't want to use BIM'.
Respondent 7 (R7)	'Designers, constructors and maintainers cannot collaborate with the end-users because they may not yet have been hired during the construction process'.
Respondent 8 (R8)	'Technology and skill'.
Respondent 9 (R9)	'Experience and have knowledge in respect their expertise'.
Respondent 10 (R10)	'Lack of training and expertise yet in Malaysia'.
Respondent 11 (R11)	'Need training to learn BIM'.

Table 15: The Challenges in the Term of Process in Implementing BIM to Minimize Waste

Respondent	Annotation
Respondent 1 (R1)	'Requires a professional team in implementing BIM in which to minimize construction waste'.
Respondent 2 (R2)	'This may a challenge for those company which first time using BIM in project'.
Respondent 3 (R3)	'Need to explore new software'.
Respondent 4 (R4)	'In competitive environment, there is no incentive to use BIM unless there is cost savings. With the asset owners do not understand or have the will to own BIM date for operations & maintenance, they are expecting zero cost by the contractors using BIM. This won't work'.
Respondent 5 (R5)	'If the project scale is small and less complexity of work, the system would not be ideal'.
Respondent 6 (R6)	'Implementation Platform usually not been used'.
Respondent 7 (R7)	'Changes were not updated in the 3D model during the construction and the maintenance'.
Respondent 8 (R8)	'Again mindset'.
Respondent 9 (R9)	'Skill and Knowledge'.
Respondent 10 (R10)	'BIM is still not widely available yet to most contractors. So, it's hard to use it if all the consultants also don't have the expertise to understand it'.
Respondent 11 (R11)	'Knowledge transfer'.

Table 16: The Challenges in the Term of technology in Implementing BIM to Minimize Waste

Respondent	Annotation
Respondent 1 (R1)	'High cost in software'.
Respondent 2 (R2)	'I think this is a big challenge because of the high software cost'.
Respondent 3 (R3)	'Software quite expensive, not all company can afford'.
Respondent 4 (R4)	'BIM software is developed by IT engineers that do not understand construction. BIM is therefore a platform. The entry of data that requires a lot of engineers that understand engineering & construction of their own trades is a major challenge. Software licence and continuity. There is a worry if the software could not be continuing or having compatibility issue in future, all the data will lose'.
Respondent 5 (R5)	'Cost of having a competent hardware and software technology to run the system'.
Respondent 6 (R6)	'Not everyone knows how to operate the software'.
Respondent 7 (R7)	'Reduced wastage in design materials and on-site production'.
Respondent 8 (R8)	'BIM is not cheap and affordable to SME. Not even all G7 contractors have BIM. It is again, Mindset and Money to invest in such technologies'.
Respondent 9 (R9)	'Understand design of Structural, Mechanical, Electrical and Plumbing services will be imposed of functional'.
Respondent 10 (R10)	'The software needs a highly specs of computer to use it'.
Respondent 11 (R11)	'Software and hardware'.

Table 17: The Difficulties that Need to be Concern When Implementing BIM

Respondent	Annotation
Respondent 1 (R1)	'Need to requires professional worker'.
Respondent 2 (R2)	'People and software'.
Respondent 3 (R3)	'Skilled employees'.

Respondent 4 (R4)	'Implementation of BIM will require a revamp of the conventional tender process to make a breakthrough for most of the typical contracts'.
Respondent 5 (R5)	'Scale of project and complexity of works'.
Respondent 6 (R6)	'To get the correct BIM Model that follow the required standard'.
Respondent 7 (R7)	'BIM was used by the construction site management but not by others'.
Respondent 8 (R8)	'Again, various difficulties but most important are mindset'.
Respondent 9 (R9)	'Coordination to all services during contraction phase'.
Respondent 10 (R10)	'Software pricing strategy'.
Respondent 11 (R11)	'Overall BIM process'.

Table 18: The Greatest Impact That Will Affect the Industry After the Implementation of the BIM in Minimizing Construction Waste

Respondent	Annotation
Respondent 1 (R1)	'Reduce material waste'.
Respondent 2 (R2)	'Reduce cost in material and waste disposal'.
Respondent 3 (R3)	'Less the amount of construction waste onsite'.
Respondent 4 (R4)	-
Respondent 5 (R5)	'It may provide significant reduction of construction waste for big scale projects and companies'.
Respondent 6 (R6)	'Reduce project cost'.
Respondent 7 (R7)	'BIM techniques and tools have been successfully used to enhance planning and construction relate such as reduce waste-related costs and materials in construction projects'.
Respondent 8 (R8)	'Reduce in construction waste thus reducing pollution'.
Respondent 9 (R9)	'Rating of Quality due less the defect work and effective the functionality of system'.
Respondent 10 (R10)	'Less mistakes definitely and it will shorten the construction duration as a whole when everything has been simulated to do the testing first'.
Respondent 11 (R11)	'Construction will be much more efficient and effective'.

Table 19: The Big Changes in the Industry After the Implementation of the BIM in Minimizing Construction Waste

Respondent	Annotation
Respondent 1 (R1)	'Construction waste being controlled and minimizing concurrently and effectively'.
Respondent 2 (R2)	'Help to shorten project time'.
Respondent 3 (R3)	'Yes, it will make the construction site cleaner'.
Respondent 4 (R4)	-
Respondent 5 (R5)	'Reduction of material purchasing and wastes'.
Respondent 6 (R6)	'Reduce project completion duration'.
Respondent 7 (R7)	'Many construction companies are already starting to use BIM technology, and it isn't hard to see why. There are lots of benefits to using BIM, it makes resource management easier, it helps people to stay in touch throughout the project, and it enables enhanced collaboration'.
Respondent 8 (R8)	'Greener environment in construction sites.'
Respondent 9 (R9)	'Time period and quality toward reduce the defective work'.
Respondent 10 (R10)	'Not really sure because I don't have experience yet'.
Respondent 11 (R11)	'Construction waste will be reduced'.

Table 20: The Advantages After Applying the BIM in the Industry

Respondent	Annotation
Respondent 1 (R1)	'In my opinion, there are advantages for the construction industry nowadays where the construction waste being managed effectively and without time consuming'.
Respondent 2 (R2)	'Complete projects more efficiently'.
Respondent 3 (R3)	'Improve construction process onsite effectively'.
Respondent 4 (R4)	-
Respondent 5 (R5)	'It can bring better development and ease the process of construction especially during the prior stage'.
Respondent 6 (R6)	'BIM is a tool that helps designers and contractors to plan ahead their works and help to identify the problem that they might face during the construction stage and resolve it before the work even started'.
Respondent 7 (R7)	'BIM enables the main contractors to share the relevant models with subcontractors to ensure smooth design and pre-construction operations in the project'.
Respondent 8 (R8)	'Better environment'.
Respondent 9 (R9)	'The cost and time during planning, construction and handing over during DLP it can be more less issue'.
Respondent 10 (R10)	'Construction become easier and shorten the time frame'.
Respondent 11 (R11)	'Construction industry is digitalizing'.

Table 21: To Identify the Implementation of BIM in Minimizing Construction Waste in Pushing the Malaysia Construction Industry into a Higher Path.

Respondent	Annotation
Respondent 1 (R1)	'Yes. The application of BIM can complete the project effectively and reduce on-site construction waste'.
Respondent 2 (R2)	'Yes, because it can minimize a lot of mistake happen therefore can complete the project on time even earlier'.
Respondent 3 (R3)	'Yes, Implementation BIM in construction projects is quite common in other country'.
Respondent 4 (R4)	-
Respondent 5 (R5)	'Yes, because adopting new system is a new and better improvement to the older system'.
Respondent 6 (R6)	'Yes, as the other country have been started using BIM for quite some time this will lift Malaysia to be as good as them'.
Respondent 7 (R7)	'Yes. BIM can collect data project team and contractors detailing so that all the strands of information agree with each other with clashes identified upfront. This will reduce rework, conflicts, waste and delays'.
Respondent 8 (R8)	'Certainly, as in the future, getting Green Certificates such as LEED, GreenRE will be common'.
Respondent 9 (R9)	'Yes, because it will be benchmark and standardised of SOP'.
Respondent 10 (R10)	'High technology will lead to more efficiency'.
Respondent 11 (R11)	'Yes, it will help to make construction more efficient and hence, save cost and time'.