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The Effectiveness of Utilising the Building Information Modelling Based Tools for Safety Training and Job Hazard İdentification

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Abstract: The fields of architecture, engineering and construction (AEC) have kept pace with recent technological developments in design and construction. However, it is difficult to obtain information on the breadth of applications of BIM -based tools throughout the life cycle of construction projects. Hence, this study attempts to empirically identify and evaluate the applications of pre-construction tools, with a focus on safety training and workplace hazard recognition. A questionnaire in the form of a survey was used to collect data. The results show that the ten predictors account for 52.3% of the variation in BIM knowledge (F (10, 56) = 6.133, $p < 0.001$). It is also found that site analysis and safety instructions have no effect on the measured variable. The study represented a comprehensive blend of research to improve the use of BIM -based tools for safety training and workplace hazard identification. It also contributed to the knowledge of how to use BIM -based tools in the pre-construction phase. The development of the BIM -process flow framework for safety training and hazard identification will be the main focus of future work.

Keywords: Building Information Modelling (BIM), BIM-based tools, task applications, safety training, job hazard identification, pre-construction stage

1. Introduction

Architecture, Engineering, and Construction (A.E.C.) have kept pace with the latest technological advances in design and construction (Becerik-Gerber & Kensek, 2010). Professor Charles M. Eastman developed the concept of Building Information Modeling (BIM) in 1970, which has been widely used in construction and other fields (Eastman et al., 2011). Even though the concept of BIM has been around since the 1970s, its implementation only began in the mid-millennium (Wong et al., 2011). BIM can be found in design and construction in the last 20 years or more (Wetzel & Thabet, 2015). BIM can offer a resourceful, operative, flexible, and advanced system while contributing to construction productivity and economic growth. The United States of America is the world's first country to use BIM in the construction industry (Wetzel & Thabet, 2015). However, BIM was introduced in Malaysia in 2009 (Latiffi et al.,

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2013) to transform the country's construction industry into a world-class, innovative, and informed about the latest technological advancements (Enegbuma & Ali, 2013; Zakari et al., 2014). Many Malaysian construction stakeholders agreed that BIM-based tools could provide numerous benefits, especially during the project's design phase (CIDB, 2016). The first BIM project in Malaysia demonstrated that the technology enhanced the reliability of the roof structural connections and reduced the time required for roof installation and rework on working drawings (Mohd & Ahmad Latiffi, 2013). Also, the National Cancer Institute project showed that BIM could save time and money and make work more efficient, all of which are good things (Latiffi et al., 2015).

There are numerous pre-construction applications of BIM-based tools. Pre-construction applications of BIM-based tools can enhance the planning, design, and coordination to establish projects. BIM-based tools can assist in reducing development time and costs, improving safety, and minimising the risk of errors and delays by giving stakeholders access to a 3D project model, virtual walkthroughs, and precise quantity take-off and estimating. But the extent of their utilization in the actual construction project life cycle is rarely available (Chen et al., 2019; Elghaish et al., 2020; Li et al., 2018; Sidani et al., 2021). The application of BIM-based tools can significantly reduce the problems associated with traditional safety management methods like training and job hazard identification (Khan et al., 2020). Construction worker safety and safety training are still significant concerns in the industry. Attempts to remedy the issue of low danger recognition with traditional hazard recognition methodologies have failed (Uddin et al., 2020). There is an urgent need for improvement. Construction employees' ability to perceive and analyse hazards is developed through safety training. Adopting new safety training programmes can assist employees in improving their danger recognition abilities (Li et al., 2015). According to studies, more than 56 per cent of job site hazards go unnoticed by construction workers (Jeelani et al., 2019; Perlman et al., 2014).

Modern safety training methods and job hazard identification are needed to tackle the inefficiencies of the traditional counterfeit. It has been found that BIM-based tools can help safety managers better plan safety actions (Choe & Leite, 2017). There is rarely a piece of information about that in the literature, and the study decided to get first-hand knowledge from the relevant professionals on the widely used BIM applications in the construction industry. This study intends to empirically identify and rank the BIM-based tools applications utilised at the pre-construction stage with a specific interest in safety training and job hazard identification. How often does the survey population use BIM-based tools for well-known applications in Malaysia, especially for safety training and job hazard identification?

2. Literature Review

2.1 Introduction

The ability to create a 3D model of the project is an important pre-construction implementation of BIM-based tools. This model can simulate the construction procedure, identify potential conflicts, and optimise the construction sequence. BIM-based tools can reduce construction time, costs, and risk by identifying potential conflicts and optimizing the construction sequence. The ability to create a virtual walkthrough of the project is a further pre-construction implementation of BIM-based tools. This enables stakeholders to envisage the project before construction and identify any design issues that may need to be resolved. By identifying and resolving design issues before construction, BIM-based tools can help reduce the risk of construction errors and delays. Tools based on BIM can also be used for quantity estimation and departure. By extracting data from the 3D model, BIM-based tools can provide precise and comprehensive estimates of the materials required for the project. This can increase the accuracy of cost estimates and reduce the likelihood of cost overruns. Table 1 outlines the ten well-known uses of BIM-based tools in the pre-construction phase that were utilised to generate the questionnaire for this study. However, the emphasis is on safety training and job hazard identification in this study.

Table 1 - BIM-based tools application at the pre-construction stage

S/No	Application	Definition	Reference
1	Existing conditioning modelling	A project team makes a 3D model of the current site conditions by using BIM modelling software, 3D laser scanning, and traditional surveying tools.	(Matos et al., 2021) , (van den Berg et al., 2021)
2	3D presentation	Using building information modelling (BIM) 3D visualizations, clients may see the finished product of their project, including the price, scope, and quality of the goods, materials, and services.	(Ma, 2021)
3	Planning and schedulings	It specifies what steps must be taken in what order, how much it will cost, what supplies, labour, tools, and machinery will be required, and so on. With BIM, a 3D interactive model is expanded into a 4D or nD model by incorporating information about planning and scheduling.	(Nawaz et al., 2021), (Amer et al., 2021)
4	Design and	It helps visualise design alternatives and data throughout the	(Mattern & König, 2018),

	Analysis of the design options	project life cycle. BIM-based tools may investigate many design possibilities to determine the best solution during pre-construction, promoting team communication and collaboration. They can also access, synthesise, compute, and compare real-world data.	(Hamidavi et al., 2020), (Khan et al., 2021)
5	Cost estimation and quantity take-off	These are done during pre-construction to determine if the project cost is within budget to avoid changes during construction. A BIM-based tool makes accurate cost calculations instant if the relevant data is added quickly.	(Naneva et al., 2020), (Hasan & Rasheed, 2019)
6	Site analysis	It is one of the best techniques to create a complete design foundation. Examining a prospective site utilising BIM modelling software, G.I.S., drones, and other tools determines the ideal placement for future development.	(Rojas et al., 2019), (Bortolini et al., 2019)
7	Energy simulation, also known as energy modelling	This is a computer-based, systematic procedure used to evaluate the energy performance of a building or facility and make it more energy efficient by modifying its design before construction.	(Schlueter & Geyer, 2018)
8	Other performance simulations	Sustainability performance, lighting, daylighting, HVAC, sun and shadow patterns, airflow, carbon footprints, solar radiation, and so forth are examples of other performance simulations.	(Azhar et al., 2011), (Díaz-Vilariño et al., 2014), , (Bank et al., 2011), (Jin et al., 2019)
9	Job hazard identification	As a result, workers in a visually stimulating setting are better able to analyze the situation, identify potential dangers, and implement the necessary precautions.	(Clevenger et al., 2014), (Getuli et al., 2017), (Guo et al., 2017; Zhou et al., 2012)
10	Safety education and training	Trainers (e.g., health and safety officer) can utilise BIM-based tools to educate construction workers in spotting potential hazards and performing jobs in a safe manner.	(Getuli et al., 2017; Volk et al., 2014), (Khoshnava et al., 2012)

2.2 BIM Application in Safety Training and Job Hazard Identification

Multiple analyses have demonstrated that BIM has the potential to significantly benefit the A.E.C. sector as a tool that can increase safety through the coordinated efforts of project teams at every stage of the construction process (Getuli et al., 2017; Volk et al., 2014). Incorporating the BIM-based model into worker safety education, construction, planning, and investigation is possible (Khoshnava et al., 2012). Workers trained with 3D BIM modelling understood safety training better than workers trained traditionally (Ahn et al., 2020). They can better evaluate and identify hazards in a visual setting, which enhances and accelerates the learning process during safety instruction (Clevenger et al., 2014). Digitising the construction site allows virtual reviews and data-driven inquiries to identify early project and construction hazards (Getuli et al., 2017). Visualization technology and safety management rules and standards help workers understand potential dangers throughout a project's life cycle (Guo et al., 2017; Zhou et al., 2012).

3. Methodology

A questionnaire was developed to determine how often the survey population uses the BIM-based tool for safety training and job hazard identification. The respondents were asked to indicate their BIM knowledge, the number of BIM projects handled, years of working experience, nature of the organisation, type of services rendered, years, and size. They were also asked if they had used BIM-based tools for safety training or job hazard identification. They were further requested to rate how they utilise BIM-based tools for the ten applications identified at the pre-construction stage on a five-point Likert scale. Where one = 'never,' two = 'rarely,' three = 'sometimes,' four = 'often,' and five = 'always.' Before disseminating the questionnaire, roughly six appropriate professionals did a pilot study to assess the survey's feasibility and then made necessary adjustments. It was vital to ensure that the questionnaire items addressed the study question adequately. The issues include examining the appropriateness of the questionnaire scope, identifying unclear wording, and checking the validity of related notions.

The study's target respondents include clients/owners, consultants, and contractors. The number of stakeholders that work in the Malaysian construction industry is enormous. There is no database to get the correct number of clients, consultants, and contractors in Malaysia. Therefore, using actual data to determine the required sample size is impossible. The sample size is critical to any empirical study that aims to conclude a population from a sample. The sample size is obtained in construction based on age, gender, work experience, trade work, and other relevant variables to provide adequate statistical power. Several approaches could precisely determine sample size based on the statistical power required for significance or non-significance. Choosing an appropriate sample size for a survey is difficult and tiresome. There are multiple techniques for estimating the sample size. There is no specific formula for the perfect sample size (Naing et al., 2006). There are, however, formulas that can be used to compute desired sample sizes for specific populations. Additional sample size calculators are available online to assist researchers in determining sample sizes. Thirty responses are enough to get acceptable statistical results as a rule of thumb (Akintoye, 2000; Dulaimi et al., 2003; Proverb et al., 1999). A formula for calculating the sample size of the infinite population, as in this study, is given in equation 1 for the maximum estimation error, d (Groves et al., 2011).

The standard error of the sample estimate is a measure of the predicted dispersion of sample estimates around the true population parameter. The standard error is less than one, indicating that the sample represents the population. For instance, if your confidence level is 90%, your results are certainly 90% accurate. The most frequently used confidence intervals are 90% confident, 95% confident, and 95% confident (Thompson, 2007). However, this study had a 90% confidence level for the sample size computation. Furthermore, it presupposes that the obtained n is large enough to produce an approximately normal distribution (Creswell & Creswell, 2017). Calculations of confidence intervals assume a real random sample of the relevant population.

$$n = \frac{Z^2 x P(1-P)}{d^2} \qquad (1)$$

Where; n = Sample size, Z = Z value (for instance, 1.645 for 90% confidence interval), P = Percentage picking a choice, expressed as a decimal (0.30 used for sample size), and d = Maximum error of estimation (usually 0.05).

$$n = \frac{1645^2 x 0.3(1-0.3)}{0.05^2}$$

$$n = 228$$

The study was done in Malaysia, collecting data specifically in Selangor, Kuala Lumpur, and Perak because of the limited fund, and that is where we have acquaintances. The simple random sample method was used for this study because it ensures that all target audiences have the same chance to participate in the survey. But using random sampling would necessitate the number of respondents included to be large enough to reflect the population (Creswell & Creswell, 2017). It is also critical that such a demographic accurately represents the construction industry. The questionnaires were sent to 300 relevant professionals who were randomly chosen. They were sent both online and in paper form. Sixty-seven people answered the questionnaires that were given out. The response rate was about 22%, similar to that obtained by Othman et al. (2012) (27.4%) but higher than that of Abdul-Rahman et al. (2006) (7%) and Alaghbari et al. (2007) (17%) related to this area of study. The low response rate could be attributed to the global spread of the COVID-19 epidemic. More than six months were needed for the data to be gathered. Statistical software (S.P.S.S.) was used to evaluate, amend, code, and analyze the results of the returned surveys. The data analysis methods used in this study include reliability, validity, normality, multiple linear regression (M.L.R.), and the relative importance index (R.I.I.). S.P.S.S. was used for this study because it includes all necessary capabilities and a user-friendly interface for fundamental analysis and resolving complex research issues. Additionally, legitimate replies were analyzed descriptively and reported in the subsequent section.

4. Results and Discussion

This section explains the information obtained from the research and how the data is analysed.

4.1 Demographic Characteristics

The level of education, age range, specialisation in the industry, number of BIM projects handled, years of professional expertise, nature of the organisation, type of services rendered, years, and size are all shown in Table 2. About 79 per cent of the participants in the survey have either a bachelor's or a master's. In addition, many respondents (84 per cent) are between 25 and 44 years of age, and most of the survey participants are in consultancy services (42%). In this paper, about 57% (i.e., about 38 of the survey participants) of the survey respondents handled BIM projects; the results should be interpreted with caution because there could be potential bias.

Several studies, however, demonstrate that thirty survey responses are sufficient for statistical Analysis, as discussed in the methodology section. The years of professional expertise of the survey respondents are between 5 to 10 years, and they are primarily from a private organisation (61%). Most are in architectural design, engineering services, and project management, with 73%. The organisation's years of operations and size vary significantly. About 48% of respondents are 'very' and 'extremely' aware of BIM. Lastly, only about 31% of the survey participants answered 'yes' that their organisation used BIM-based tools for safety training and job hazard identification. About 40% answered 'no,' and the remaining did not know.

Table 2 – Demographic characteristics ($N = 67$)

Category	Characteristic	Percentage (%)
Educational level	Diploma	6
	Bachelor's degree	35.8
	Master's degree	43.3
	Doctorate	14.9
Age bracket	18 – 24	1
	25 – 34	21
	35 – 44	63
	Over 45	15
Speciality	Client	27
	Consultant	42
	Contractor	31
Number of BIM projects handled	None	43
	1 – 5	42
	6 – 10	4.5
	11 – 15	6
	More than 15	4.5
Nature of organisation	Public undertaking	39
	Private organisation	61
Professional expertise	Project management	17.9
	Engineering services	13.4
	Architectural design	35.8
	Funding	13.4
	Education/teaching	19.4
Size of organisation	Small (3 – 20 people)	20.9
	Small to medium (20 – 50 people)	20.9
	Medium to large (50 – 200 people)	17.9
	Large (More than 200 people)	40.3
Level of BIM awareness/knowledge	Slightly aware	24.5
	Moderately aware	26.9
	Very aware	25.4
	Extremely aware	22.4

4.2 Reliability and Validity Test of the Instrument

The Cronbach's Alpha (α) coefficient value is used in this study to quantify internal consistency dependability because it is the most widely used and reasonable consistency metric. It represents the average correlation between all scale items (Golafshani, 2003). Cronbach's alpha coefficient values range from 0 to +1, and the higher the value, the better the internal consistency of the data. The computed Cronbach's alpha value is 0.787 based on ten variables. The overall validity (v) of an instrument is determined by square rooting the alpha coefficient (Salkind, 2017). The calculated v is 0.887. An instrument's validity is measured by a number that ranges from 0 to +1, and the higher the number, the better the tool is at being accurate (Taherdoost, 2016).

However, a Pearson test is used to check the internal validity questionnaire for the second test. It is used to test the validity of the questionnaire structure by examining each variable's validity and the overall validity of the questionnaire (total degree). However, it calculates the correlation coefficient between one variable and all other variables with the same scale or measure. It is discovered that the correlation coefficients are significant at $p = 0.01$ and 65 degrees of freedom. The Pearson coefficients must be greater than 0.314 and marked in Table 3 below with (**), so it can be said that the variables are valid to measure what they were set to achieve.

Table 3 - Pearson correlation of each variable against the whole questionnaire

S/No	Variables	Pearson correlation coefficient	P-value (Sig.)
1	Existing condition modelling	0.605**	0.000
2	3D presentation	0.451**	0.000
3	Planning and scheduling	0.493**	0.000
4	Designing/ Analyzing design options	0.656**	0.000
5	Cost estimation	0.538**	0.000
6	Site analysis	0.758**	0.000
7	Energy simulation	0.604**	0.000
8	Other performance simulation	0.601**	0.000
9	Job hazard identification	0.627**	0.000
10	Safety education and training	0.578**	0.000

4.3 Normality Test

This study did two tests to determine which statistical tests best fit the collected data. To determine if data follows a normal distribution, researchers frequently employ the Kolmogorov-Smirnov and Shapiro-Wilk tests. The results show whether the data can be used for parametric or non-parametric tests. If different approaches give different results, Shapiro-Wilk is better than the Kolmogorov-Smirnov test (Razali & Wah, 2011). This study utilised a parametric statistical test because it dictates that data is normally distributed (Kolmogorov-Smirnov test = 0.200, and Shapiro-Wilk = 0.392, i.e., $p > 0.05$).

4.4 Multiple Linear Regression (M.L.R.) Analysis

The study was conducted to investigate whether the task applications of BIM-based tools (independent variables) at the pre-construction stage could significantly predict the level of BIM knowledge (dependent variable). The use of BIM-based tools for these applications indicates or predicts the survey participants' level of BIM knowledge. Multiple linear regression was used in this research to test this hypothesis. The level of BIM knowledge was regressed in predicting variables of existing condition modelling, 3D presentation, planning and scheduling, design/Analysis of the design options, cost estimation, energy simulation, other performance simulation, and job hazard identification; the independent variables significantly predict the level of BIM knowledge, $F(10, 56) = 6.133$, $p < 0.001$. The test results indicate that the survey respondents hardly use BIM-based tools for site analysis and safety education & training at the pre-construction stage. However, site analysis and safety education & training have an insignificant impact on the dependent variable. Also, the $R^2 = 0.523$ depicts that the model explains 52.3% of the variance in the level of BIM knowledge. Table 4 shows the summary of the M.L.R. findings.

Table 4 - Summary of the model findings

Independent variable(s)	Slope (B)	*Std. Error*	*β*	*t*	*Sig*
Existing condition modelling	-0.330	0.122	-0.316	-2.699	0.009*
3D presentation	-0.199	0.094	-0.216	-2.116	0.039*
Planning	-0.244	0.111	-0.237	-2.189	0.033*
Designing/ Analysing design options	-0.321	0.104	-0.349	-3.097	0.003*
Cost estimation	0.277	0.088	0.332	3.150	0.003*
Site analysis	0.182	0.119	0.221	1.528	0.132
Energy simulation	-0.560	0.172	-0.520	-3.259	0.002*
Other performance simulation	0.525	0.175	0.492	2.994	0.004*
Job hazard identification	0.490	0.208	0.472	2.361	0.022*
Safety education and training	-0.622	0.327	-0.383	-1.899	0.063
Constant	5.502	0.492		11.184	0.000
$R^2 = 0.523$					
$F(10, 56) = 6.133$					
Std. Error of the Estimate = 0.829					

$n = 67$

Note: p is significant at 0.05*

4.5 Ranking of BIM-based Tools Application

The Relative Importance Index (R.I.I.) ranks the respondents' views irrespective of the degree of agreement or disagreement. It has been widely used in construction management research to evaluate attributes concerning questionnaire variables. The R.I.I. produces an index ranging from 0 to 1, with a value closer to 1, indicating a more significant impact on the subject matter (Khatib, Poh, & El-Shafie, 2020). The variables used in this research are rated where one = 'never,' two = 'rarely,' three = 'sometimes,' four = 'often,' and five = 'always.' The R.I.I. was calculated using equation (2) below, and the obtained overall rankings are presented in Table 5. It was discovered that the survey respondent used BIM-based tools for the design/analysis of the design options the most and safety education and training the least. Table 6 presents the R.I.I. based on specialisation (client, consultant, and contractor). There is no difference in opinion regarding the hierarchy of the task applications between the contractor and consultant. It could be because the consultant is usually the client's representative and often works with the contractor to realize the project goals on-site.

$$n = \frac{\sum w}{AxN} = \frac{(1 * n1) + (2 * n2) + (3 * n3) + (4 * n4) + (5 * n5)}{5 * N} \quad (0 \leq R.I.I \geq 1) \qquad (2)$$

Where:

w = the weight given to each factor by the survey participants or respondents, ranging from 1 – 5.
A = the highest weight (i.e., 5), and
N = the total number of responses obtained in the study

Table 5 - Overall Relative Importance Index (R.I.I.)

BIM-based tools applications	R.I.I.	Rank
Design/Analysis of design options	0.7493	1
Planning and scheduling	0.7164	2
3D presentation	0.6537	3
Cost estimation	0.6478	4
Site analysis	0.4925	5
Other performance simulation	0.4090	6
Energy simulation	0.3821	7
Existing condition modelling	0.3731	8
Job hazard identification	0.3701	9
Safety education and training	0.3104	10

Table 6 - R.I.I. based on specialisation

BIM-based tools applications	Client		Consultant		Contractor	
	RII	Rank	RII	Rank	RII	Rank
3D presentation	0.6778	1	0.6357	4	0.6571	3
Design/Analysis of design options	0.6667	2	0.8500	1	0.6857	2
Cost estimation	0.6667	3	0.6857	3	0.5810	4
Planning and scheduling	0.6000	4	0.7571	2	0.7333	1
Site analysis	0.4111	5	0.5929	5	0.4286	5
Other performance simulation	0.4111	6	0.4643	6	0.3333	6
Job hazard identification	0.4000	7	0.4071	9	0.2952	9
Energy simulation	0.3667	8	0.4357	8	0.3238	8
Existing condition modelling	0.3000	9	0.4571	7	0.3238	7
Safety education and training	0.3000	10	0.3571	10	0.2571	10

Based on the number of survey participants that did not handle any BIM projects (43%), BIM adoption/implementation is still low in Malaysia. Malaysian construction companies, for example, have a meagre adoption rate of BIM implementation (Al-Ashmori et al., 2020). The inadequate adoption could be due to many factors. More technical support and skills are needed, and the expense of training and the learning curve should be lowered. Also, the client's lack of enforcement and the government's support, the nature of the organisation (e.g., small, or large firms), and BIM-based tools are costly, especially for small- to medium-sized companies, and the transition period is extended. In addition, it requires much effort between traditional and BIM methods, and most professionals need help understanding what BIM can do. Other factors include:

- unwillingness to let go of traditional processes,
- some confidence in BIM processes, and
- no national standards or guidelines for BIM to evaluate its use.
- unavailability of the parametric library
- interoperability issues between the BIM-based tools
- legal issues in terms of data ownership
- and privacy and risk-sharing.

The stakeholders should identify and encourage the most effective strategies to improve BIM implementation in construction projects (i.g. the provision of trial BIM-based tools or affordable ones with easy interoperability, government support, especially to small and medium-sized companies, national standards or guidelines for BIM implementation, frequent seminars, workshops, and training for company employees and industry stakeholders, and inclusion of BIM in higher institutions curricula.

Irrespective of the respondents' educational qualifications and age brackets, they rated the BIM-based tools applications at the pre-construction stage similarly. The younger generation is enthusiastic about BIM technology (Wang & Chien, 2014), which is evident because about 84% of the survey respondents are between 25 to 44 years. Also, the years of working experience, nature of the organisation, types of services offered, years of operation, and size had no impact on the ranking. It implies that the use of BIM-based tools is independent of these factors. There is no difference in opinion regarding the hierarchy of the task applications between the contractor and consultant. It could be because the consultant is usually the client's representative and often works with the contractor to realize the project goals on-site. The respondents that had handled BIM projects also have an almost similar ranking. The reason could be that the experience they might have had while working on the BIM projects is identical. M.L.R. was conducted to investigate whether the task applications of BIM-based tools at the pre-construction stage could significantly predict the level of BIM knowledge. The results indicate the potential task applications used by the survey respondents based on their BIM knowledge awareness. It was discovered that site analysis and safety education & training have an insignificant impact on the dependent variable.

Based on the study findings, the client uses BIM-based tools for 3D presentation the most at the pre-construction stage. It could be a powerful tool for disseminating information about a proposed project or development. The consultant ranks the design/Analysis of design options first. The reason could be that they usually provide the proposed project or development designs (for example, architectural, structural, and M.E.P. designs). Furthermore, the contractor ranks planning and scheduling first; this could be because they handle the physical development of the proposed project. The client and contractor rank design/analysis of design options second, while the consultant ranks planning and scheduling second. Both the client and the consultant ranked cost estimation third.

In comparison, the contractor ranked 3D presentation third. The client ranks planning and scheduling fourth, the consultant ranks 3D display fourth, and the contractor ranks cost estimation fourth. They all ranked site analysis, other performance simulation, safety education and training, and energy simulation as fifth, sixth, eighth, and last, respectively. The consultant and the contractor ranked job hazard identification second to last, while the client ranked it seventh. The client ranks existing condition modelling second to last, while the consultant and contractor rank it seventh. A claim is that 3D presentation, design/Analysis of design options, cost estimation, planning, scheduling, and site analysis are the most widely applied tasks at the pre-construction stage using BIM-based tools (Sidani et al., 2021).

5. Conclusions

Due to its advantages, numerous studies have been conducted on BIM for various purposes. Parametric and object-oriented models can be created using BIM-based tools and other relevant tools for various tasks. There were no statistically significant differences in task applications of BIM-based tools in the pre-design phase based on educational attainment, age group, work experience, type of organisation, type of services provided, years in operation, and size. However, a statistically significant difference was found in specialisation, the number of projects worked on BIM, and questions related to identifying workplace hazards or safety education and training. Survey respondents were found to be most likely to use BIM-based tools for design/Analysis of design options and least likely to use safety education and training.

The study provided a comprehensive research mix that increased knowledge about the role of BIM-based tools for safety training/job hazard identification and other task applications at the pre-construction stage that can serve as a reference point to increase the use of advanced technology. The paper contributes to the body of knowledge on the significant applications of BIM-based tools in the pre-construction phase by expanding readers' understanding. The study also creates a research gap; researchers might want to know why the practitioners in question do not fully utilise some task applications. Researchers could further investigate the neglected areas of task applications of BIM-based tools such as safety training. BIM-based safety training tools have not been thoroughly investigated (Fargnoli & Lombardi, 2020). Industry practitioners could explore and benefit from some of the task applications of BIM-based tools that they have not used before. The results of the study may also encourage practitioners to use advanced technologies for the safety training of construction workers and reduce the number of accidents and injuries on construction sites.

The study has certain drawbacks. The results cannot be generalised due to the limited number of responses and the survey location, although some studies indicate that thirty responses are enough for any statistical analysis. The study also relied on participants' perceptions and knowledge about BIM. Also, the well-known task applications of BIM-based tools at the pre-construction stage used in this study may not be exhaustive. The number of survey participants that did not handle any BIM projects is 43%. This indicates that BIM implementation is considerably medium in Malaysia, and BIM in the Malaysian construction industry is not as developed as the literature portrays. Because of this limitation, therefore, the results of this research should be interpreted with caution. Similar research should be conducted elsewhere else for comparison. Future studies should focus on creating a BIM process flow framework (for example, struck-by incidents) for safety training and detecting workplace dangers.

Author Contributions

A.D.R: Writing – original draft, Conceptualisation, Writing—review and editing, Data curation, Formal Analysis, Methodology, Validation. **N.S**: Conceptualisation, Supervision, Project administration, Visualization, Validation. **I.O**: Conceptualisation, Supervision, Project administration, Validation. **M.M.A**: Data curation, Validation, Visualization. **H.A**: Writing – original draft, Writing—review and editing, Visualization. **A.I**: Writing—review and editing, Data curation. **N.S.A.Y**: Writing – original draft, Writing—review and editing.

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