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# ADOPTING BUILDING INFORMATION MODELLING FOR SUSTAINABLE CONSTRUCTION

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**Abstract**

Buildings are responsible for almost 40% of greenhouse gas emissions, making the construction industry a major contributor to carbon emissions globally. Despite the escalating need for sustainable construction due to rising energy costs and increased environmental concerns, the construction sector continues to face significant challenges in minimising its environmental impact. Building information modelling (BIM) can help in this situation by doing intricate building performance assessments to guarantee an ideal sustainable building design. The construction industry will gain from this research since it will encourage BIM technology to play a significant role in sustainable structures, thereby reducing carbon emissions from the construction sector. Mainly at the design stage, BIM enables the resolution of practical challenges by utilising environmentally friendly and highly effective information strategies. The first objective of this research is to identify several advantages of adopting BIM technology for sustainable buildings. However, its main benefit is that it provides valuable information for energy and sustainability analyses. This also elevates the design and value of a sustainable construction project. The second objective of this study elaborates on the challenges of adopting BIM in the construction field and, hence, potential solutions to encourage its integration for green construction. The primary challenge is perceived to be high implementation and maintenance costs. Quantitative analysis was carried out for this research, targeting around 385 construction players in Malaysia. All data collected was analysed and interpreted in this research to reach the desired outcome. Therefore, this research aims to raise awareness of BIM technology capability to mitigate carbon emissions from the construction sector through sustainable construction.

Keywords: Building information modelling, Carbon emissions, Sustainable construction, Technology.

## 1. Introduction

Global warming has been identified as a worldwide environmental issue that must be tackled responsibly. Carbon emissions are said to have increased as a result of human activity. The worldwide $CO_2$ concentration is now 408.8 ppm, according to the American Chemical Society (2017). The current intensity is known to be 46% higher than the mean Carbon dioxide concentration during the last two centuries. The construction sector, which includes the mining of raw materials, construction, transportation and structural operations, is one of the leading producers of worldwide greenhouse gas emissions [1]. As a result, the building industry is predicted to account for more than 52% of world emissions by 2050 [2]. According to data in Malaysia, buildings account for almost 20% of all greenhouse gas emissions due to the resources utilised, primarily fossil fuels. Therefore, Malaysia is ranked 30th globally among nations that generate the most carbon emissions.

The construction industry must unavoidably replace its traditional operating processes with a novel approach that prioritises environmental concerns while paying attention to environmental consequences. The building sector is the first to work to satisfy environmental safety and sustainable demands [3]. One major approach to encourage sustainable construction to reduce the emissions of greenhouse gases is by utilising digital technology in the industry to replace certain construction activities behind those emissions. Digital technology such as building information modelling (BIM) is believed to being increasingly implemented [4].

BIM (Building Information Modelling) is a virtual depiction of a structure comprising all the information needed to construct the structure utilising computers and software. When physical attributes are associated with structural components and time is added to 3D, a 4D model is achieved, and when cost data is included, a 5D model or nD (for sustainability, energy, facility management, etc) is attained. BIM is defined as the method and technology for creating, maintaining, and exchanging functional and physical data of a facility in a collaborative setting utilising digital representative models throughout the project's lifecycle [2].

Technology is important in helping the construction industry with green construction. BIM can result in a formidable application that effectively generates features that produce a sustainable construction practice. Sustainable design aims to reduce the adverse effects of greenhouse gas emissions by employing ecologically friendly design and building approaches. The purpose of sustainable construction is to create buildings that are environmentally friendly, economical, and healthy places to live and work. Its goal is to improve the building's overall efficiency and performance while reducing carbon generation. Hence, with BIM, those features can be done quickly and promote green construction.

On the other side, new technologies are difficult to incorporate in the largely traditional field of civil engineering. In general, when a modern technology is launched, the claims regarding the technology's potential must be reviewed, tested, and validated over a set amount of time. One of the limitations of BIM is that it is a single detailed model whereby alternative design choices and the management of "what if" situations are not possible. Secondly, firms frequently have their own software; however, for BIM to work, all firms must adopt the same software standard across the fully built asset phase [5]. An analysis of stakeholder dynamics shows that in Malaysia, decision-making authority often depends on developers rather than professionals. This leads to a gap between those who comprehend the technical capabilities of BIM and those who decide on its implementation. For instance, procurement decisions often prioritise cost savings over long-term sustainability benefits. Thus, the purpose behind this research is to encourage the use of BIM in the construction industry to help reduce carbon emitted from the construction sector.

The remainder of the paper is as follows: Section 2 presents a literature review; proposed research methods are delineated in Section 3. Section 4 illustrates the results and analysis. Concluding remarks, limitations and future works are presented in Section 5.

## 2. Literature Review

Early in the new millennium, BIM was developed for use in the construction, engineering, and architecture industries. It resulted from the building industry's practises using information and communication technology (ICT). It is now acknowledged as a stimulant for productivity and innovation in the construction industry [6].

Additionally, it was developed to deal with problems like collaborating and handling massive amounts of data [7], cutting project time and cost, and enhancing construction performance. It also aids in the evaluation and analysis of green buildings. It is regarded as an excellent platform for creating environmentally friendly structures, reducing construction industry risks, resolving complexity, and resolving project management issues [8]. BIM can be considered as a digital technology tool capable of ensuring the completion of a construction process and as a set of related methodologies for creating, transmitting, and interpreting digital data for architectural applications [9, 10].

The first objective of this research is to focus on the benefits of using BIM for sustainable construction. Therefore, the advantages BIM provides to prevent carbon emission in the construction industry are identified in Table 1, which has supporting evidence.

**Table 1. Benefits of BIM for sustainable construction.**

| Factors | Benefits | Reference |
|---|---|---|
| **Predictable environmental performance** | Designers may conduct energy performance studies with BIM tools like Autodesk Revit, which helps them consider energy-conscious suggestions ahead during the design phase and assists contractors in detecting and enhancing energy-inefficient construction phases. | [11-13] |
| **Generate quantities automatically and precisely** | BIM database contains detailed engineering information on materials and components that can be used to calculate quantities automatically and precisely, thus minimising material wastage. | [11-14] |
| **Recyclability and Reusability attributes** | BIM provides details on whether materials used can be recycled or reused, making the building sector ecologically friendly. | [12] |

**Table 1 (continue). Benefits of BIM for sustainable construction.**

| Factors | Benefits | Reference |
|---|---|---|
| **Less time-consuming and more cost-effective** | BIM reduces project length and expense, improves maintenance management, and boosts the building's value. It also estimates and increases project productivity by analysing the relationship between time and cost. | [12, 14] |
| **Early risk identification** | BIM software can help detect clashes/ risks early during the design stage. | [12, 14] |
| **Visualisation and simulation encourage sustainable practice** | The features of BIM, such as visualisation and simulation, allow stakeholders to monitor the energy performance of the building, thereby leading to a more sustainable building. | [12-14] |

The second objective is to determine the challenges of adopting BIM in the construction industry, as shown in Table 2.

**Table 2. Barriers to implementing BIM in the construction industry.**

| Factor | Barriers | Reference |
|---|---|---|
| **Lack of Knowledge and Awareness** | Without enhanced knowledge or proper awareness of BIM tools, construction firms will not consider the adoption of BIM but will instead find it a challenging change. | [15, 16] |
| **Shortage of skilled professionals** | Lack of employees who can navigate the BIM software explicitly. | [16] |
| **Lack of government initiatives** | Governments are not enforcing strict laws to encourage the construction industry to move towards the adoption of BIM. Although some regional governments have made the use of BIM mandatory, Malaysia's policy environment is still fragmented. Clear instructions or incentives are frequently overlooked for local contractors. | [15, 16] |
| **High cost of implementations** | The initial cost of setting up BIM software is high. The lack of locally relevant training programs that meet Malaysian industry standards exacerbates the high upfront expenses of software and training. | [15, 16] |
| **High training cost** | The cost to train employees and provide the facilities is high. | [15] |
| **Resistance to change from traditional method** | Most firms still use traditional methods of construction and are reluctant to adopt the technology. Conventional building methods dominate Malaysia, and mid-sized businesses continue to be resistant to implementing digital technologies. | [15, 16] |
| **Lack of national standard** | The development of a national BIM strategy will establish national priorities and provide information to the entire sector. For their implementation, BIM processes and reporting procedures must be normalised. | [15, 16] |
| **Legal and contractual issues** | Building project owners may dispute the possession of the design documentation as they bear the architectural design cost. License difficulties may arise when parties other than owners and architects supply information to be incorporated into BIM. | [15] |

Lastly, the third objective of this research is to deduce the potential solutions that could enhance the implementation of BIM for sustainable construction. Table 3 shows the factors examined as the probable keys for increasing BIM usage.

**Table 3. Potential solutions for increasing the adoption of BIM in the construction industry.**

| Factor | Solutions | Reference |
|---|---|---|
| **Increase BIM competency** | BIM usage may be increased by fostering BIM knowledge through training. Increased BIM coaching for new employees can lead to improved BIM management capabilities. Employees need software training to become specialists in BIM software, and this can reinforce BIM manager competencies, leading to the formation of more BIM leaders. | [17-19] |
| **Spread BIM awareness** | Raising public awareness about the current carbon pollution from the construction industry and the benefits of BIM towards the success of a project. It is necessary to hold workshops, lectures, and conferences to emphasise the construction sector's need to incorporate sustainability through BIM into their projects. | [17-19] |
| **Integrate BIM in higher education** | Students in higher education should be proficient in BIM. By laying the groundwork for BIM early on, new graduates can either convince the organisation to go to BIM or adapt to firms already using it. | [17-19] |
| **Support from senior management** | Senior management should encourage BIM use and provide facilities for employees to learn BIM software. | [19] |
| **More research on BIM for sustainable construction** | There should be more research done on BIM for sustainable construction to increase the confidence of firms towards the benefits of BIM adoption. | [19] |
| **Compulsory laws** | The government should impose strict laws in the construction industry to reduce carbon emissions by using BIM for sustainable construction. | [19] |

## 3. Methods

The methodologies for this study were a thorough literature review and quantitative analysis, in which questionnaires were prepared and disseminated to obtain responses that would be evaluated to validate the research's outcome. The factors listed for the quantitative analysis were selected based on key components identified in the literature review. The research methodology flowchart in Fig. 1. shows the research pathway and how data will be collected and evaluated.

For this research, the targeted respondents are construction players such as architects, contractors, quantity surveyors, engineers, and project managers from around Klang Valley, Malaysia. Figs. 2(a) and (b) show the demographic details of the respondents, while Table 4 shows the approximate population of the construction players around Klang Valley, according to the CIDB report and the respective board of members. Based on Table 6, Krejcie and Morgan's data from 1970, 384 surveys are needed for a population of 100,000. As a result, 385 questionnaires have been distributed at random.

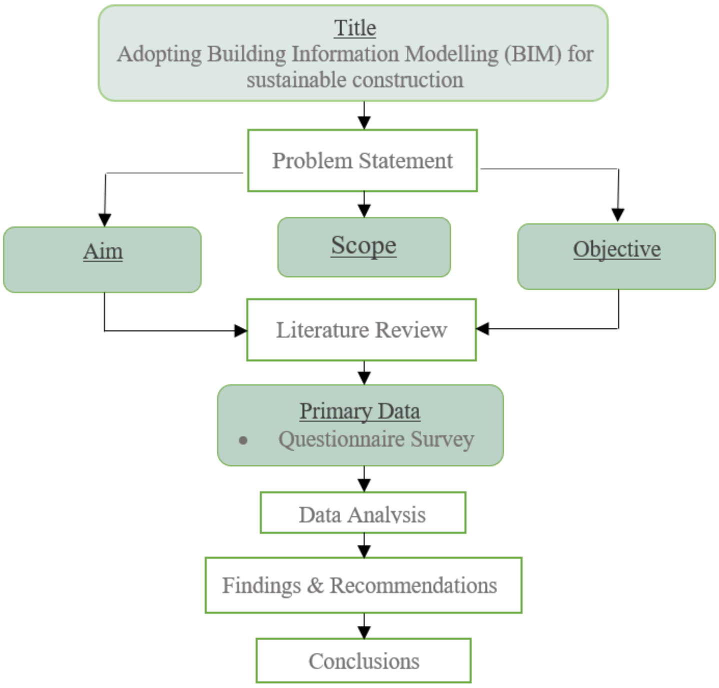


**Fig. 1. Research methodology flowchart.**

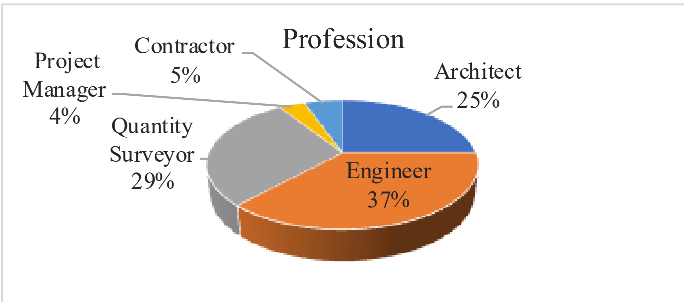


**Fig. 2(a). Profession of respondents.**

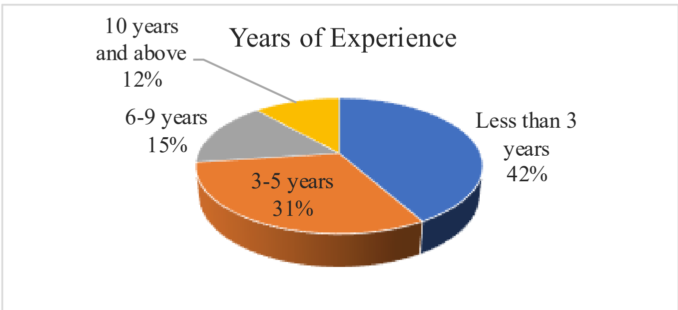


**Fig. 2(b). Years of experience of respondents.**

**Table 4. Population of each construction player around Klang Valley.**

| Category of Construction players | No. |
|---|---|
| **Registered QS (PVQS, QST, PQS, CQS, CQSP)** | 3,112 |
| **Contractors G7** | 3,650 |
| **Graduate Engineers** | 169,331 |
| **Project Manager and Site Manager** | 58,646 |
| **Architects** | 4,987 |

All primary data gathered were analysed to form the questionnaire. The data collected from the survey will then be assessed through the SPSS software tool to find the mean, median and standard deviation and thus interpreted by graphical representations such as bar charts.

For the reliability and validity test, Cronbach's alpha measures the internal consistency of a set of objects or how closely related they are to a category. The range of Cronbach's Alpha is 0 to 1, with higher values indicating more internal accuracy and reliability. The following are common suggestions for evaluating Cronbach's Alpha: 00 to .69 is regarded as weak, .70 to .79 as fair, and .80 to .89 as strong. The reliability statistics for the three research objectives are within the range of .80 to .89, as shown in Table 5, indicating that the results are good to exceptional.

**Table 5. Reliability analysis for all scales.**

| Variable | No. of items | Cronbach's Alpha | Remarks* |
|---|---|---|---|
| Benefits | 6 | 0.872 | Strong |
| Barrier | 8 | 0.884 | Strong |
| Potential solutions | 6 | 0.836 | Strong |

## 4. Results and Discussion

The survey findings will be collated, analysed, and summarised in tables, charts, and figures that show the percentage of responses for each aspect of the data analysis. Referring to Krejcie and Morgan's Table, 1970, the number of respondents for such a population is estimated to be around 384 because the construction players in this area comprise a large population and are assumed to be a group of 100,000. However, 328 responses were obtained out of the 385 targeted surveys, giving this research study a response rate of 85.2%. To provide an accurate depiction of the information received and make it simpler to develop a suitable conclusion, the data obtained were analysed using the SPSS software tool. Data collected for 1$^{st}$, 2$^{nd}$, and 3$^{rd}$ objective as shown in Figs. 3-5 respectively.

Likert scaling was used in this section, which is a bipolar measuring tool that evaluates a positive or a negative response to a query. From the scale provided, 1 and 2 represent totally disagree and disagree, 3 is moderate, and 4 and 5 indicate agree and totally agree.

When comparing these results to previous research, the following is revealed:

- Consistency: This study's high-reliability scores align with other studies, indicating that the survey report is strong and dependable.

- New Insights: The strong response rate and reliability emphasise the survey's effectiveness and relevance to the target population. This study offers new perspectives on adopting BIM technology in green construction and its impact on sustainability practices.

Overall, the results of this study support previous research findings while providing new insights into BIM technology in sustainable construction. Further exploration in future research could validate and expand upon these perspectives.

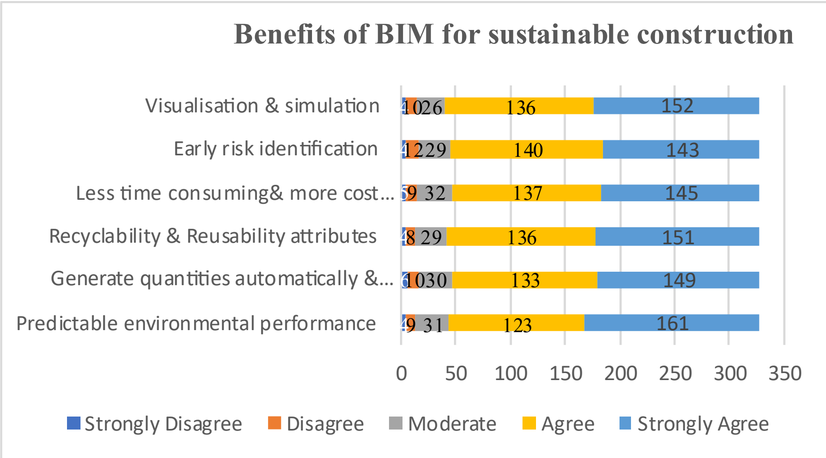


**Fig. 3. Data collected for 1st objective.**

**Table 6. Data analysed for benefits of BIM for sustainable construction.**

| Items | Mean | SD |
|---|---|---|
| Predictable environmental performance | 4.30 | .845 |
| Generate quantities automatically and precisely | 4.25 | .880 |
| Recyclability and Reusability attributes | 4.29 | .822 |
| Less time-consuming and more cost-effective | 4.24 | .854 |
| Early risk identification | 4.24 | .852 |
| Visualisation and simulation encourage sustainable practice | 4.29 | .833 |
| Total mean score | 38.38 | 5.368 |
| Maximum total score | 45.00 | |
| Minimum total score | 9.00 | |

Based on Table 6, the responses on the benefits of BIM for sustainable construction have been analysed using the SPSS tool. All answers are above the 4.00 mean score, indicating that the answers are Agree to Strongly Agree. The highest mean is the first benefit.

Based on Table 7, the mean and standard deviation of the data collected for the barrier of BIM implementation in the construction industry has been analysed. All answers are above the 4.00 mean score, indicating that the answers are Agree to Strongly Agree. The highest mean is the first barrier: the lack of knowledge and awareness.

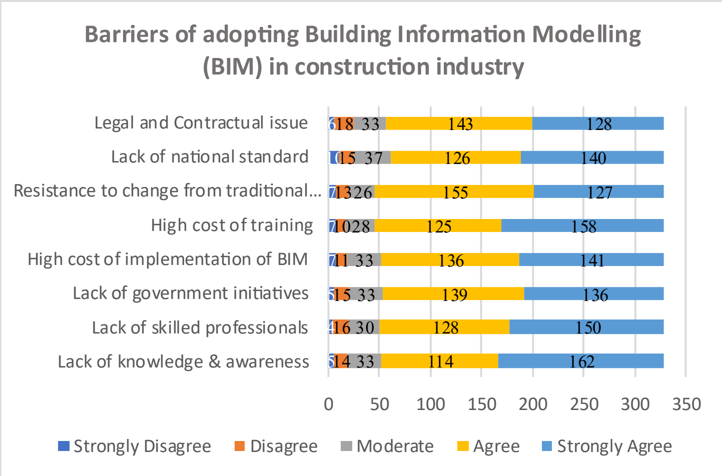


**Fig. 4. Data collected for 2nd objective.**

**Table 7. Data analysed for barriers to adopting BIM in the construction industry.**

| Items | Mean | SD |
|---|---|---|
| Lack of knowledge and awareness | 4.26 | .914 |
| Lack of skilled professionals | 4.23 | .896 |
| Lack of government initiatives | 4.18 | .898 |
| High cost of implementation | 4.20 | .906 |
| High cost of training | 4.27 | .900 |
| Resistance to change | 4.16 | .890 |
| Lack of national standard | 4.13 | .991 |
| Legal and contractual issues | 4.12 | .928 |
| Total mean score | 33.56 | 5.442 |
| Maximum total score | 40.00 | |
| Minimum total score | 8.00 | |

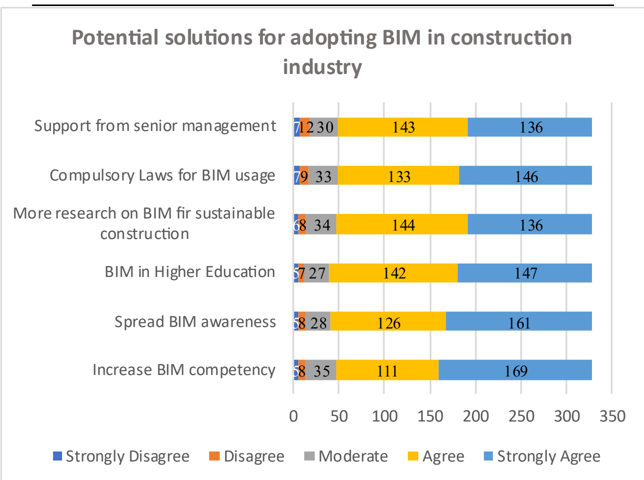


**Fig. 5. Data collected for 3rd objective.**

Based on Table 8, the mean and standard deviation for the potential solutions to increase BIM implementation have been analysed. All answers are above the 4.00 mean score, showing that the answer is Agree to Strongly Agree. The highest mean is the first and second factor.

**Table 8. Data analysed for potential solutions of adopting BIM in the construction industry.**

| Items | Mean | SD |
|---|---|---|
| Increase BIM competency | 4.31 | .872 |
| Spread BIM awareness | 4.31 | .846 |
| Integrate BIM in higher education | 4.28 | .823 |
| Support from senior management | 4.21 | .860 |
| More research on BIM for sustainable construction | 4.23 | .894 |
| Compulsory laws for BIM usage | 4.19 | .901 |
| Total mean score | 25.52 | 3.856 |
| Maximum total score | 30.0 | |
| Minimum total score | 6.00 | |

## 5. Conclusion

Data were gathered from the evaluation of the questionnaire and through the examination of the literature review. The conclusion was reached based on the findings after carefully considering the response received and the data collected.

According to data collected and analysed from Section 4, the main benefits of BIM for sustainable construction are predictable environmental performance, recyclability and reusability attributes, an increase in productivity and generating quantities automatically. Predictable environmental performance is made possible by BIM software such as solar analysis, lighting design and ventilation that helps to monitor the energy consumption of a building to reduce carbon emissions from buildings.

Recyclability and reusability attributes are features offered by BIM that have the potential to determine whether the material used for the building construction can be recycled or reused. In this way, waste materials can be controlled, reducing the emission of greenhouse gases from disposable materials. BIM is also believed to be cost-effective by making project budgeting and scheduling easier, thus providing quality control of construction works.

Lastly, the benefit of BIM that many respondents agreed on is the generation of quantities automatically, as it helps quantity surveyors to automatically calculate the Bill of Quantities accurately, saving time and being less error-prone compared to the traditional way.

Secondly, most of the respondents identified a barrier to adopting BIM in the construction sector: the lack of knowledge and awareness. Without proper knowledge and awareness of BIM concepts and how they can help the construction industry be more sustainable, thereby protecting the environment from excessive carbon emissions during construction activities, construction players will not consider implementing BIM software. The high cost of training was also considered to be another barrier to BIM usage, as most employers are not familiar with BIM software and features. The third barrier would be the lack of skilled professionals to navigate the BIM software for construction projects.

Finally, for potential solutions, most respondents believe that increasing BIM competency in the construction market would attract firms to adopt the software. Spreading BIM awareness and its benefits to construction projects is another solution that was selected by the respondents the most. Furthermore, integrating BIM in higher education to train graduates and teach about BIM has also been considered a good move for increasing BIM usage.

## 6. Research Limitations

This research has a few limitations. Due to cultural differences and the fact that this study was conducted in Malaysia, the findings may not apply to other countries. However, it is recommended that more investigation be done to contrast the findings. Moreover, in the future, structural equation modelling (SEM) will be required to fully comprehend the methods for integrating BIM in sustainable construction projects.

The statistical analysis is yet another limitation of this study investigation. A total of 385 surveys were set out to represent the population; thus, these samples might not fully reflect the population of Malaysia as the surveys cover only the Klang Valley territory. The population of construction players in Klang Valley is also significant, and the 385 surveys represent a small portion of it.

## 7. Recommendation

According to a study by the McKinsey Global Institute found that the construction industry employs around 7% of the global labour force [20]. This demonstrates the importance of the building industry in the global economy. Even though individuals and corporations spend trillions of dollars annually on activities connected to the building industry, it has advanced slowly. As a result, it is advised that government officials and those in the construction sector begin integrating the use of BIM digital technology in building activities, as BIM can drastically alter a sector's productivity performance.

Undoubtedly, BIM implementation for sustainable construction is important to reduce the impacts caused by construction activities, and it also can produce a better end product for construction projects in terms of time, cost and quality. The building industry players in Malaysia who plan to apply BIM will find all the material in this research study helpful. The study will inform construction industry participants of the realities they must face when using BIM. Additionally, it might guide them while they implement BIM to avoid any unforeseen circumstances.

Exploration of the strategy that can enhance the application of BIM in construction projects has to continue. To achieve this, more surveys and interviews can be undertaken to gather more detailed information about BIM with sustainable construction. Raising awareness about carbon emissions from the construction sector and their harmful effects on the environment will help people understand the urgency of reacting to this matter and thus focus on adopting BIM to achieve sustainable construction.

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