

Article

# Building Information Modelling Strategies in Sustainable Housing Construction Projects in Malaysia

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**Abstract:** Building Information Modelling (BIM) plays a very significant role in the construction industry, especially in project management decision-making and data integration efforts during the preliminary planning and design stage. This is aligned with the National Construction Policy (NCP 2030) by the Ministry of Work Malaysia, highlighting that it is timely for the construction industry players to move towards sustainability. BIM must be implemented to ensure the smooth delivery of sustainable housing construction projects in Malaysia due to its critical role in assisting in construction cost optimisation, green building implementation, minimising environmental impact, and waste reduction. However, the BIM implementation rate in Malaysia is still minimal due to the challenges in its execution. Therefore, this paper is aimed to propose BIM's critical strategies in the development of Malaysian sustainable housing construction projects as envisaged in the United Nations Sustainable Development Goals (UNSDGs). A thorough systematic literature review and questionnaire survey of fifty (50) BIM players in housing construction projects in Malaysia shows that from sixteen (16) BIM strategies, three (3) items are identified as critically important strategies, whereas another five (5) items are identified as important strategies. The outcome of the study shall benefit the construction industry players who are involved in the sustainable housing construction project and mainly drives the Public Work Department (PWD) BIM Strategic Plan 2021–2025, thus supporting the earlier mentioned NCP 2030 agenda by the Ministry of Work Malaysia.

**Keywords:** Building Information Modelling (BIM); housing; implementation strategies; construction project; Malaysia



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## 1. Introduction

The housing construction project is one of the main drivers of national development. Based on the Department of Statistics Malaysia year 2022, the construction sector contributed RM29.9 billion to the Malaysian economy [1]. Looking at the economic performance, the Malaysian construction sector needs to be sustainable and viable to maintain its sustainable performance. The lack of affordable housing for Malaysian middle-income levels was a problem for many years. Because of that, the Malaysian government is actively promoting policies to ensure affordable housing is sufficient and of good quality. The housing development is driven by market demand due to increased population growth. Furthermore, as a developing country, a sustainable housing construction project is needed by most Malaysian citizens to grow their families and have a healthy lifestyle. Hence, Malaysia's government introduced the sustainable housing construction project to fulfill Malaysian demands.

Since our nation was pledging to commit to the United Nations Sustainable Development Goals (UNSDG) agenda, especially on the UNSDG11, sustainable cities and communities related to target indicators 11.1 Safe and Affordable Housing as a part of the endeavour towards sustainable cities and communities. Due to this, the developers will normally incorporate the sustainability element into their development to show their support towards the initiatives and to gain government recognition. Additionally, as the Malaysian population increases, it can be seen that the demand for safe and affordable housing will also increase [2]. It is important to have effective sustainable housing construction project planning, which will help to generate more affordable houses for the communities to cater to the Malaysian population to support the UNSDG11 target indicator 11.1 Safe and Affordable housing.

Sustainable housing became a favourable product compared to other developers because it consumes less energy and resources than it produces, while also being environmentally responsible. This includes both the materials and the energy used for construction [3]. Sustainable housing is also called ecological and green housing, which is also well known as energy-efficient housing. Therefore, to help solve the lack of affordable housing problems, the design of sustainable buildings that are energy efficient and environmentally friendly is substantial. These buildings can be designed using BIM software, an integrated suite of applications designed to work together on a single platform to cut costs, speed up time-to-market, and improve quality.

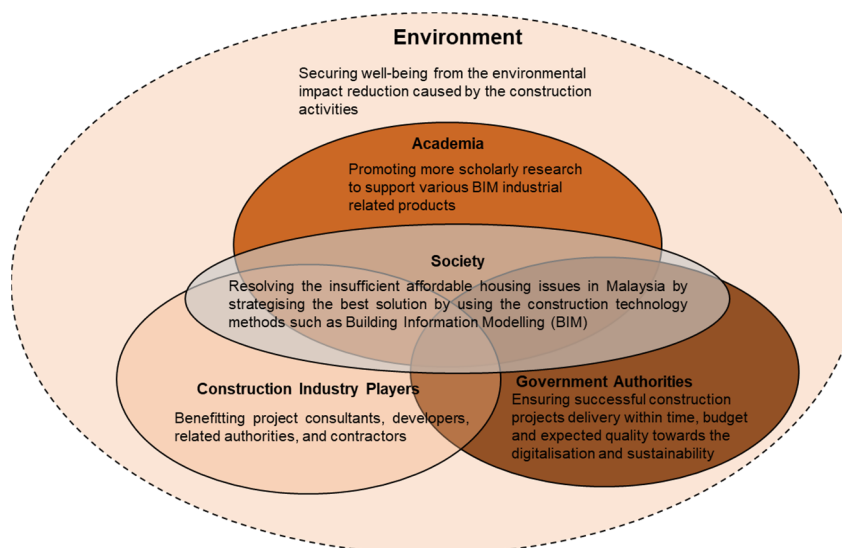
To address the lack of affordable housing in Malaysia, the Construction Industry Development Board (CIDB), Malaysia has launched its technical publication on affordable housing, which reached challenges due to its unsustainable construction methodology [4]. Throughout the years, the government mooted various affordable housing initiatives to cater to the demand for low-income households in Malaysia to ensure that their needs were fulfilled. However, without the sustainable methodology adopted in the housing construction project, the initiatives are difficult to achieve. There is a considerably high amount of research relating to BIM globally assisting the world in the sustainability effort, especially in green building.

Additionally, the recent National Construction Policy 2030 (NCP 2030) launched in the year 2021 by the Ministry of Work in Malaysia highlighted that it is time for the construction industry players, especially housing construction industry players to move towards sustainability [5]. It is critically important to ensure the implementation of the sustainability elements in all construction projects, especially housing construction projects, to improve all of the current major challenges in the housing construction sector, such as improving the project delivery to include more certainties and timely manner, reducing the assets' lifecycle costs, achieving zero carbon initiatives, and improving waste reduction during the construction period, creating a high-quality product, and ensuring the housing units are resilient against weather change and natural disaster [6].

Furthermore, in the NCP 2030 and the Twelve Malaysian Plan (12MP), the government encourages the construction industry players to move toward sustainable construction technology methods, such as using the industrial building systems (IBS) in construction, advanced construction materials, 3D printing, autonomous construction machinery, and BIM [5]. The latest construction technology will help the construction industry to improve their construction delivery and avoid project mismanagement, such as project delay and cost overrun.

Figure 1 shows the quintuple helix model that briefly summarises the BIM implementation strategies in a sustainable housing construction project that will greatly contribute to the five important elements of the academia, environment, government authority's society, and construction industry players. One of them is the construction industry players, who ensure the success of the sustainable housing construction project delivery within time, budget, and expected quality toward the digitalisation and sustainable cities and communities according to the NCP 2030 by the Ministry of Work Malaysia. Additionally, the government authorities achieved the green building initiatives through Malaysia Green

Building Council (MGBC) and drove the Public Works Department (PWD) Strategic Plan 2021–2025 to reach 80% BIM implementation by 2025. On the other hand, the academia will continuously promote more scholarly research to support various myBIM industrial-related products through the CIDB initiatives, while the society can benefit from sufficient sustainable affordable housing based on the demands needed.



**Figure 1.** Significance of study based on quintuple helix model (adopted from [6]).

Moreover, the construction industry contributed 24 percent of carbon emissions compared to the other industry sectors in Malaysia, which gave a negative environmental impact on the community [7]. A total of 11 percent of annual carbon emission is from construction building materials and their work on-site [8]. Thus, there is an urgent need for the BIM implementation strategies to help contribute to Malaysian well-being by using sustainable construction technology to ensure the sustainability of housing construction projects, such as using environmentally friendly materials to reduce carbon emissions, and hence minimising the environmental impact on the communities to support the National Transformation Plan 2050 by the Malaysian government.

In general, Malaysia's government put the sustainable initiatives from the UNSDG as their priority, especially as one of the construction industries' key strategic thrusts to support the NCP 2030 to implement sustainability in all construction projects, particularly in the housing construction project. Other than that, the green building initiatives by the MGBC and the PWD Strategic Plan 2021–2025 are initiated to move towards construction sustainability and digitalisation with the use of technology, such as BIM, to support the efforts of achieving sustainable efforts in the housing construction project in Malaysia.

BIM is defined as a process that facilitates the project management, communication, and information collaborations during the construction process from project planning until project closure [9]. BIM can also help housing construction project industry players to achieve sustainability initiatives set by the government, which is aligned with the UN SDGs, especially in developing sustainable cities and communities. BIM ensures the sustainability of the housing construction project throughout the project life cycle by using software such as Autocad, Revit, Naviswork, and Civil 3D for design, simulations, project costing management, and project scheduling [10]. It is a system that allows all engineering fields, such as architectural, civil and structure engineering, mechanical and electrical engineering, and quantity surveying to collaboratively work together on a project during construction project design planning until the building operation lifespan, inclusive of its demolition stage. However, every new tool has its challenges in its implementation, such as higher investment costs, legal issues, and contract issues that need to be resolved [11].

Even so, the revolution of BIM tools in the construction industry presents a big advantage for the sustainability of the construction sector [5]. BIM is efficiently used globally to ensure the construction project delivery becomes certain to achieve delivery within time, quality, and budget. It will also help to improve the construction project productivity, especially in designing, executing, and maintaining the assets from the planning, design, construction, operation, and management stage of the building [12]. In addition, BIM can also help the construction industry players to achieve the sustainability effort, especially the government bodies and authorities, consultants, and contractors, to successfully implement and deliver the construction project within its budgeted time, costs, and quality toward sustainable housing construction projects. BIM is ideally suited to ease project communication, especially between project professionals for carrying out design improvement and building performance analysis, thus making the construction project more efficient [13].

Therefore, it is suggested that the housing construction industry players should move towards construction sustainability using BIM. Subsequently, this paper will carefully examine the role of BIM and BIM software to grasp their critical roles that will efficiently help in achieving sustainable housing construction projects in Malaysia. Next, the BIM implementation strategies will be articulated to understand which strategies are critical to ensure the project successfully implements BIM. By incorporating these two elements, the paper will propose critical strategies that will help achieve sustainable housing construction projects in Malaysia.

In summary, this paper shall be the guidance of the construction industry players on how to implement the critical strategies that will help the project stakeholders to execute the project smoothly.

## 2. The Challenges in Sustainable Housing Construction Projects in Malaysia

Sustainability in the housing construction project is still a relatively new concept in most developing countries, especially Malaysia. Most of the housing construction project stakeholders, such as project consultants, clients, and contractors, have a limited understanding of sustainable development, which involves the housing construction project, hence causing a slow rate of its implementation [14]. Additionally, lack of knowledge and expertise is another challenge that must be addressed, especially in the housing construction project. The limited number of professionals who are competent and capable of implementing Building Information Modelling (BIM), which regards human resistance, is another factor that limits BIM implementation [7]. The shortage of experts and tradesmen with sufficient qualifications and skills is also an important challenge to tackle because, without proper support from the related parties and enforcement, the implementation rate will be kept slowing down [15]. The concept of sustainable and affordable infill housing projects is an emerging strategy for urban gentrification, but it has limitations and difficulties in achieving its goals, especially in developing countries, such as Malaysia.

Other than that, it is known that the construction industry in Malaysia, especially housing construction projects, plays a major role in the country's development. However, the Malaysian housing sector is suffering from construction project failure due to its unsustainable practice since the early 1980s [4]. For instance, in the year 2020, 75 housing construction projects were abandoned in Malaysia compared to the year 2019, with 85 cases of abandoned housing construction projects, which can be seen as a statistic slowly reducing but that needs to be improved [16]. Although the housing construction industry is one of the priorities for Malaysian citizens, persistent and significant problems, such as project delay and cost overruns are experienced in many construction projects, especially housing construction projects. It is generally found that the main factor in this abandonment of housing construction projects is due to poor project management and unsustainable activities, such as design planning failure, miscommunication between project teams on-site, too much repetitive work on-site, cost overrun, slow decision-making, and high construction waste produced on-site. Hence, it is important to implement the sustainable

method using BIM software in the housing construction project to reduce the abandonment of the project.

In general, construction projects, especially housing construction projects, are susceptible to miscommunication and other project disputes that will lead to an unsustainable construction project [17]. Additionally, other unsustainable construction projects actions, such as the inability to detect design conflict, and constructability issues, also might cause a critical problem in the housing construction project [18]. Inefficient productivity, higher construction wastage, and lack of manpower will also lead to project delay and cost overrun [18]. This is where BIM was introduced to help the construction industry players to ensure their construction projects, especially housing construction projects, become sustainable, and slowly resolve the construction problems contributed by the construction activities. BIM is reported to assist in the reduction in construction waste in the housing construction project, hence, also helping to minimise the pollution created by construction projects and definitely helping to support sustainable housing construction project initiatives in Malaysia [16]. It is difficult to achieve sustainable construction projects if the conventional method does not change and is still widely used [17]. Due to this, BIM's critical roles must be assessed and the related parties can increase BIM awareness to encourage BIM implementation in the Malaysian housing construction project, thus improving the housing construction project sustainability in parallel with the United Nation Sustainable Development Goal (UNSDG) agenda, especially in developing safe and affordable housing in Malaysia.

The government through the Public Work Department (PWD) intends to achieve eighty percent of BIM implementations by the year 2025 [7]. To make the housing construction project more sustainable, the housing construction industry players were encouraged to implement BIM in their projects [15]. Hence, all construction industry players, especially housing construction players, must achieve 100 percent of BIM implementation to maintain its sustainability by executing the BIM's critical role in the housing construction project in Malaysia. Then, suitable BIM implementation strategies can be proposed and executed to avoid the abandonment of the projects, hence, will support the Malaysian government's sustainability effort in fulfilling sustainable housing for future demands.

It is reported that issues with policies also contribute to the challenges in implementing BIM in Malaysia. The issue of the lack of clear policies by the Malaysian government is also a critical challenge that leads to the slow implementation of BIM [7]. Despite all the challenges identified in the previous studies, in order to enhance the rate of BIM implementation in Malaysia, the country has to follow the big step of other successful countries, such as Dubai, Italy, the United Kingdom (UK), Singapore, Australia, and the United States of America (USA), which that mandate BIM for a certain requirement that empowers the BIM implementation in the industry.

### **3. The Building Information Modelling (BIM) Roles in Sustainable Housing Construction Projects in Malaysia**

Building Information Modelling (BIM) is software that is often used to help in sustainable construction projects in Malaysia. It can help to improve project understanding. BIM implementation is always labeled as a complex method to be practiced in projects. Additionally, organisation in Malaysia is not favourable to BIM due to their organisational behaviours and lack of experience with its standards and procedures. In Malaysia, BIM was implemented to improve project understanding, construction planning and monitoring, coordination between client–consultant contractors, visualisation of the project, and collaboration among project team members [19].

BIM can also help reduce the chance of clashes between different parties involved in a project. This is because it allows them to visualise how things will look at different stages of construction and how their plans will interact with each other. Therefore, it is critically significant to develop BIM implementation strategies to yield better-integrated project elements using BIM considering the different maturity levels of each organisation. Based



on [20], the critical roles of BIM in achieving a successful project are improved scheduling, improved project coordination, and improved work quality.

Table 1 shows the summary of the BIM implementation role in the construction industry that can adapt to sustainable housing projects in Malaysia.

**Table 1.** BIM implementation roles in the construction project industry.

No	Building Information Modelling (BIM) Roles	Authors
1	BIM helps to reduce cost and time in construction project.	[21–26]
2	BIM assists in reducing the cost of capital in the construction project.	[21–23,27]
3	BIM helps in reducing carbon from the construction and operation by 20%.	[21–23,27]
4	BIM can help construction project stakeholders to overcome construction problems such as delays and cost overrun.	[23,28–30]
5	BIM can help in coordination and communication in construction project.	[22,23,31]

Source: adopted and modified from [21–31].

Low-cost and high-quality construction is the key to sustainable housing in Malaysia. The Malaysian government is pushing for a more environmentally friendly approach to building, but they need the help of their contractors. Therefore, based on various research in BIM, refs. [21–26] agree that BIM's critical roles are to reduce cost and time in the construction project. As a result, it will uplift the productivity level of the Malaysian construction industry and make it more sustainable in the future.

On the other hand, it is also identified that BIM can alleviate the cost of capital in construction projects to a minimum [21–23,27]. BIM allows contractors or owners to create accurate estimates before they start working on a project. This means that the amount of investment needed upfront will be less than the conventional method. In addition, BIM can also help with reducing carbon emissions by twenty percent [21–23,27]. Hence, using BIM software to design a building creates less pollution over time due to fewer waste products being produced during construction.

As the construction industry continues to grow, it is becoming more and more important for organisations to adopt BIM in the housing construction project and to help minimise the errors made during construction, which translates into less money being spent on labour costs and materials. In a paper published by [22,23,31], it is also stated that BIM can help to ameliorate project coordination and communication during construction projects. For instance, ref. [32] reviews numerous works of literature related to BIM specifically in building life cycles [33], however, mentions that previous work by [33] fails to highlight various BIM applications to help in green building initiatives. Hence, ref. [34] claims the development of the 'Green BIM Triangle' model to easier visualise BIM critical roles to ensure that various sustainability principles throughout the overall life cycle phases of the building can be achieved. Among the dimensions of the triangle include 'green attributes' that highlight sustainability components to be implemented through BIM tools, such as energy, carbon emissions, solar and lighting, ventilation, material, and waste [32]. Taking all of the important literature takeaways and the gap identified in BIM's critical roles in construction and the sustainable housing construction project in Malaysia, this paper aims to propose BIM's critical strategies in the development of Malaysian sustainable housing construction projects as envisaged in the UNSDG.

With the right BIM implementation strategies, organisations can build their experience on related standards and procedures that will help them overcome their major construction problems.

#### 4. The Building Information Modelling (BIM) Implementation Strategies in Construction Projects in Malaysia

Building Information Modelling (BIM) is mostly used in large and complex construction projects [19]. In 2019, BIM implementation in Malaysia is still sprouting at fourty-nine

percent of the total overall implementation [35]. The rate needs to be improved to eighty percent by the year 2025, due to the target aimed by the Public Work Department (PWD) in their Strategic Plan 2021–2025 [34]. However, to make this target achievable, suitable implementation strategies need to be developed and executed in the construction project, especially in the housing construction project. In the year 2021, the National Construction Policy 2030 (NCP2030), established by the Ministry of Works Malaysia, was launched. The government is encouraging the construction industry players to inject digitalisation initiatives into their construction projects, which include the implementation of BIM in affordable housing construction projects [5]. This study recommends that the construction industry players, especially the housing developers, should start moving towards construction digitalisation using BIM software to ensure sustainable housing demands can be achieved and will benefit the Malaysian communities.

There are a lot of BIM implementation strategies that can support sustainable housing construction projects in Malaysia. As the literature review was continuously conducted in the study, several BIM implementation strategies were extracted and incorporated into the questionnaire survey that was designed for fifty (50) BIM experts. Table 2 shows BIM implementation strategies that were identified by authors in construction projects globally.

Table 2 lines up the sixteen (16) BIM implementation strategies that were extracted from the systematic literature review of construction projects globally. It can be seen that the most mentioned BIM implementation strategy is on the training part. It is encouraged that the government provides training grants for the industry players, especially housing developers, to help them to enhance their BIM knowledge [13,21,36–40]. Additionally, it is also important to increase the BIM promotion and awareness for housing developers involved in the construction projects [13,21,36–40], providing adequate BIM training and seminar to ensure the competency of the relevant stakeholders amongst the housing developers in the construction projects [13,21,36–40], and to ensure the BIM syllabus is embodied in the higher learning curriculum, especially in the construction management courses [13,21,36–40]. This shows that early learning, exposure, and awareness should start from academic-based initiatives to create high awareness to move towards digital, especially in project management. These initiatives were strongly agreed upon by most of the authors to increase the BIM implementation rate in construction projects globally.

Apart from that, [13,36,38,39] stated that the establishment of proper guidelines for the construction project will ease the construction project industry players to implement BIM. A clear direction will motivate the project stakeholders to understand BIM and use it in their projects, and it is agreeable by most of the authors that the establishment of the guidelines, especially from the government and related authorities, can help the construction industry players increase their BIM implementation rates and indirectly encourage them to implement BIM in their construction projects. Furthermore, the proper identification of BIM tools in the organisation is also important in implementing BIM in construction projects and ensuring the project is efficiently managed by the project management team [13,36–38].

**Table 2.** BIM implementation strategies in the construction industry.

No	BIM Implementation Strategies	Basma et al., (2022) [13]	Azhar S. (2011) [21]	Eastman et al., (2011) [36]	Khosrowshahi et al., (2012) [37]	Gu N and London K (2010) [38]	Ozorhon et al., (2020) [39]	Alhumayn et al., (2017) [40]	Frequency of Appearance
1	BIM implementation guidelines to ease the construction project stakeholders.	X		X		X	X		4
2	BIM establishment of standard code of practice to smoothen the communication and integration efficiency amongst the construction project team.	X			X				2
3	Full BIM implementation for all government projects.						X	X	2
4	Full BIM implementation for all private housing projects.						X	X	2
5	Government assistance in BIM's initial capital investment, especially in the software acquisition cost.						X	X	2
6	The government enables the tax waiver for housing developers that incorporate the BIM implementation in their construction projects.						X	X	2
7	The government provides training grants to housing developers to enable them to enhance their knowledge of the BIM tools.	X	X	X	X	X	X	X	8
8	The enhancement of BIM promotion and awareness of the housing developers involved in the construction projects.	X	X	X	X	X	X	X	8



Table 2. Cont.

No	BIM Implementation Strategies	Basma et al., (2022) [13]	Azhar S. (2011) [21]	Eastman et al., (2011) [36]	Khosrowshahi et al., (2012) [37]	Gu N and London K (2010) [38]	Ozorhon et al., (2020) [39]	Alhumayn et al., (2017) [40]	Frequency of Appearance
9	Acknowledging subject matter experts (SMEs) that involves in BIM implementation and execution of the construction projects.	X					X	X	3
10	Providing sufficient support to all subject matter experts (SMEs) involved in BIM implementation and execution in the construction projects.	X					X	X	3
11	Proper identification of BIM tools in the organisation and its project needs.			X	X		X	X	4
12	The importance of facilitation of the transition change by the related implementor that involves project stakeholders in the housing developers in the construction projects.		X				X	X	3
13	The improvement of technology infrastructure within the organisation to abet the BIM process and implementation in the construction projects.		X				X	X	3
14	Development of BIM workflow that helps the senior management to understand the BIM execution process better in order to instill continuous implementation in the organisation and its construction projects.						X		1

Table 2. Cont.

No	BIM Implementation Strategies	Basma et al., (2022) [13]	Azhar S. (2011) [21]	Eastman et al., (2011) [36]	Khosrowshahi et al., (2012) [37]	Gu N and London K (2010) [38]	Ozorhon et al., (2020) [39]	Alhumayn et al., (2017) [40]	Frequency of Appearance
15	Adequate BIM training and seminar to prepare the relevant stakeholders' competency amongst the housing developers in the construction projects.	X	X	X	X	X	X	X X	8
16	Incorporated BIM syllabus in the academic curriculum, especially in the construction projects.	X	X	X	X	X	X	X	8

Source: adopted and modified from [13,21,36–40].

According to [21,39,40], the facilitation of the transition between the conventional method and the BIM method is very important in construction projects. The project stakeholder has to convince their management of the implementation to ensure its continuous execution in the projects [41]. On the other hand, [21,39,40] also stated that the improvement of technology infrastructure within the organisation should abet the BIM process and implementation in housing construction projects. Without proper infrastructure and the right execution plan, the BIM implementation in the construction project will not be a success and will be temporary. Seemingly, the way out from slow BIM implementation in the construction project is through identifying the critical strategies that can help the construction industry players implement BIM in their projects. Every measure must be taken to sustain the sustainability of the housing construction project in Malaysia to overcome the BIM challenges in the projects.

However, despite various strategies planned to help with the BIM implementation, it is critical to determine the effectiveness of BIM in the sustainability of housing construction projects in Malaysia.

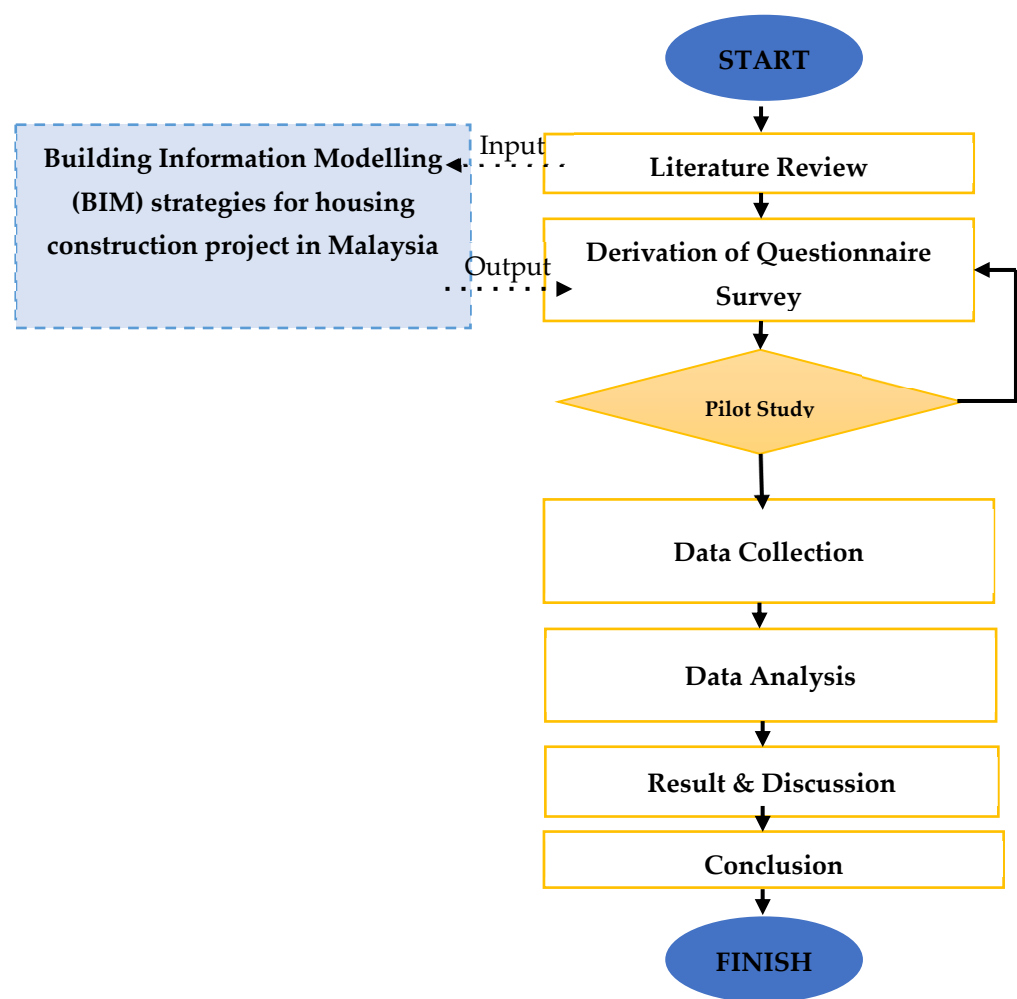
## 5. Methodology

The paper is undertaken through a thorough review of the systematic literature and questionnaire survey of fifty (50) Building Information Modelling (BIM) experts in sustainable housing construction projects in Malaysia with at least three (3) years of experience. Most of the literature review covers the overview of the housing construction project in Malaysia, the challenges in the sustainability of housing construction projects in Malaysia, and the BIM implementation strategies in sustainable housing construction projects in Malaysia. From the literature review, the questionnaire survey for the BIM experts was derived.

The pilot test was conducted to test its validity and reliability. To determine the consistency of the data, reliability analysis has to be carried out to ensure that the instrument used is suitable for the study and also reliable. This is explained by [42] on internal consistency quantification by a Cronbach's alpha ( $\alpha$ ) optimal value that ranges between 0.7 and 0.9. In addition, Cronbach's alpha value of 0.7 is acceptable while a value less than 0.6 is considered low [43].

The questionnaire survey was developed and answered by fifty (50) BIM experts from developers, consultants, and contractors involved in the sustainable housing construction project in Malaysia. The questionnaire findings were analysed using the Winstep Software (Rasch measurement models' computation) to obtain the most critical strategies that mostly affect the BIM implementation in the sustainable housing construction project in Malaysia. Two analyses were conducted in the study, namely reliability and validity analysis and person-item distribution map analysis (PIDM). The Rasch model was selected based on its theoretical unidimensional line where items and persons are measured based on their difficulties and ability using the PIDM [44,45]. Moreover, [46] delineate that Rasch analysis as a psychometric method developed based on the linearity concept to enhance the instrument's accuracy, the instrument monitoring quality, and the respondent's performance, to better understand the outcome obtained from the surveys.

Figure 2 illustrates the flow of the research beginning with the literature review that focuses on the BIM challenges and implementation strategies in the sustainable housing construction project in Malaysia. The questions are developed based on the significant variables of current challenges cross-examined against critical BIM implementation significant variables in the sustainable housing construction projects in Malaysia.



**Figure 2.** Research methodology.

The outcome of the pilot project was analysed and validated to ensure the consistency of the data collection and the data reliability. The acceptable range of Cronbach's alpha ( $\alpha$ ) is between 0.7 and 0.9 [47]. Cronbach's alpha values of less than 0.6 are deemed low [43]. The outcome from the respondent's survey generated from the completed questionnaires was analysed using WINSTEPS software. In order to evaluate the internal consistency and measure between variables, unidimensional analysis has to be conducted. Next, the reliability and validity test analysis, using the Rasch model, was conducted to ensure the quality of the instrument and respondents. Finally, the criticality of variables based on the BIM expert response was determined from the person-item distribution map (PIDM) analysis.

## 6. Result and Analysis

### 6.1. Reliability and Validity Analysis

For data analysis to outline the critical Building Information Modelling (BIM) implementation strategies, the instrument used in this study was Winstep software, which is very reliable. The Winstep software uses the Rasch measurement model to analyse data obtained from the BIM experts. One of the analyses that were conducted in the study was reliability and validity analysis. With an  $\alpha$  value of 0.97, the data proved to be reliable in this study [44]. In addition, the value of the Standard Error (SE) of 0.49, stipulated that the questionnaire survey was completed by the competent respondents [48]. Table 3 shows the summary of 50 BIM experts for BIM implementation strategies in the sustainable housing construction project in Malaysia. From the Rasch model analysis, it can be illustrated that the organisation's statistics investigation on Mean Square (OMNSQ) is 1.18 and Z-Score

(OZSTD) is  $-0.2$ . The value from the Rasch model shows that the values indicate that the survey respondents were from the most relevant and competent group that was able to reflect on all 16 items that were discussed.

**Table 3.** Summary of 50 BIM experts for BIM implementation strategies in the sustainable housing construction project in Malaysia.

		Count	Measure	Model Error	Infit MNSQ	ZSTD	Outfit MNSQ	ZSTD
Mean		50.0	0.00	0.31	1.17	0.1	1.18	$-0.2$
S.D.		0.0	1.90	0.08	0.87	3.0	1.00	3.0
Max.		50.0	3.53	0.54	3.61	7.1	3.64	5.3
Min.		50.0	$-3.68$	0.17	0.23	$-3.7$	0.13	$-4.6$
Real RMSE	0.41	TRUE SD	1.86	Separation	4.53	Item Reliability		0.95
Model RMSE	0.32	TRUE SD	1.88	Separation	5.93	Item Reliability		0.97

S.E. of Person mean = 0.49.

## 6.2. Person–Item Distribution Map (PIDM)

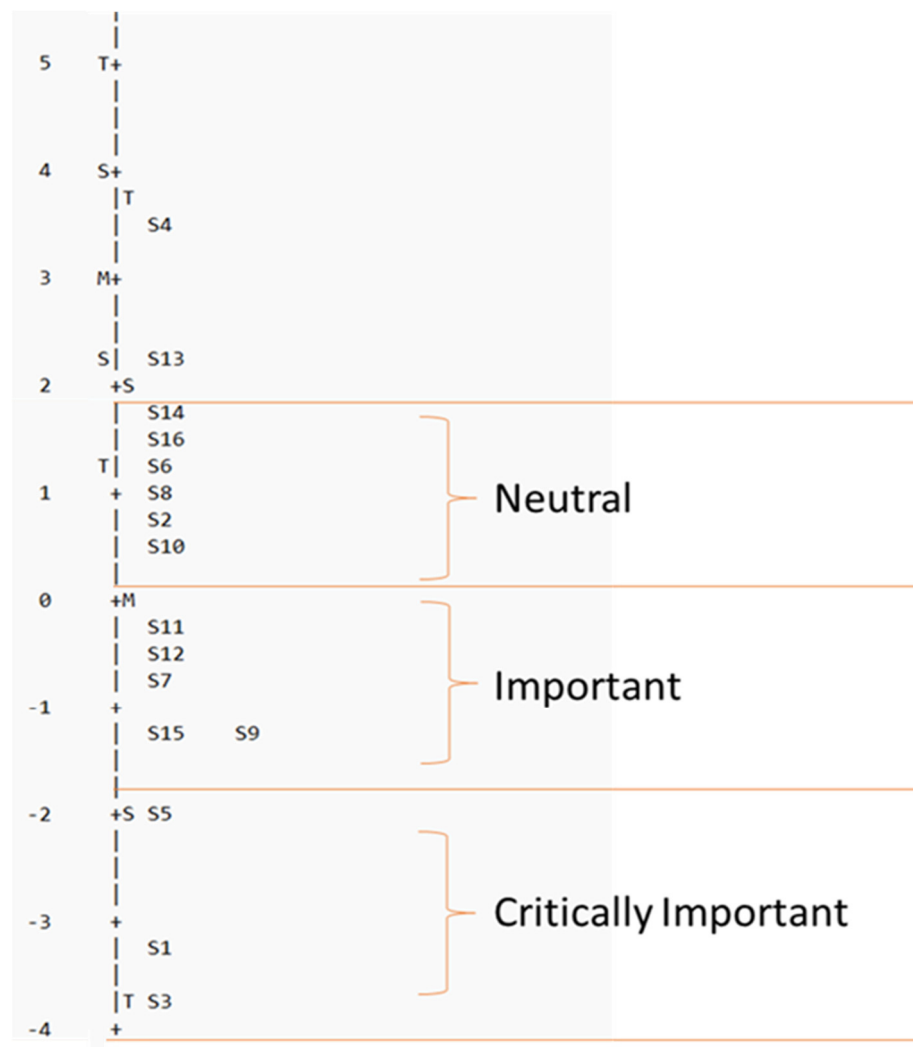
On the other hand, in the other analysis on person–item distribution analysis (PIDM), a 16-item questionnaire survey was initiated based on the existing BIM implementation strategies in the construction industry in Malaysia. Then, the questionnaire surveys were handed out to 50 BIM experts in Malaysia’s housing construction industry. Figure 3 displays the results obtained through PIDM. From the analysis shown in Figure 3, there are only three items highlighted as critically important, namely S5 (ability to encourage all project stakeholders to participate in the BIM coordination team), S1 (BIM awareness level in the housing construction projects), and S3 (sufficient government roles and supports in BIM implementation in the housing construction projects).

In addition, the five items categorised as important strategies are S11 (proposing a comprehensive BIM implementation strategy within the organisation), S12 (supportive organisational culture toward BIM implementation), S7 (introduction of BIM execution plan to the project management team for better BIM implementation in the project), S15 (availability of the financial resources to complement the BIM implementation in the housing construction projects), and S9 (ensuring sufficient BIM expert assistance to ease its implementation in the housing construction project).

The demand for sustainability in housing construction projects is increasing. The design planning phase of housing construction projects is one of the most critical phases in the project to ensure that the sustainability of the development can be achieved [49].

BIM is widely known as an important tool of sustainability methods, especially in helping the project team to help solve design problems and to assist in data integration during the construction period [21]. However, BIM implementation in Malaysia is only at 49 percent compared to other developed countries, such as the United Kingdom (UK), with BIM implementation at 69 percent [18]. Hence, it is very important to increase the awareness of BIM’s critical roles to ensure that the housing construction industry players understand the benefit of BIM and how it can help housing construction projects achieve sustainable design. Normal conventional ways of the traditional computer-aided design (CAD) cannot perform necessary sustainability analyses compared to BIM software [4]. Therefore, based on the Rasch measurement model analysis, BIM strategies must be developed to help the BIM experts achieve sustainability in the housing construction project. The final critical outcomes from the Rasch models PIDM were tabulated in Figure 4.





**Figure 3.** Person–Item Distribution Map (PIDM) for BIM implementation strategies in the sustainable housing construction project in Malaysia.



**Figure 4.** BIM implementation critical strategies for the sustainable housing construction project in Malaysia.

The data from the questionnaire survey answered by the BIM experts from the construction industry players were analysed by using the Rasch measurement model analysis. The important and critically important BIM implementation strategies are identified and gathered in Figure 4. Figure 4 shows two indicators of red box and blue box that both indicates critically important strategies and the important strategies. It is agreed by the BIM experts that the critical important strategy is the ability of the project team to encourage all of their project stakeholders to participate in the BIM coordination system. BIM can

be used to enhance the construction cost throughout the project life cycle. If the project stakeholders understand the advantage of BIM and how BIM can help their project, all project teams will open their minds to understand BIM better. By using BIM software, project stakeholders can identify the best construction material to use, the efficient ways to construct the work, and mitigate the construction problems before it even happens by initiating virtual modelling. Moreover, it can help to minimise the project risk and potentially gauge the unforeseen risk during the construction period. It is shown that using BIM can help the housing construction project to optimise its construction cost, potentially identify the construction problem, and reduce project delay throughout the construction project period.

Next, another critically important strategy shown in Figure 4 is the BIM awareness level within the sustainable housing construction project in Malaysia. The construction industry players must understand the BIM's importance and role in their projects, such as facilitating various green building analyses during the design phase, which can contribute to the sustainable and resilient building, including deciding on building orientation and form, lighting analysis, energy modelling, sustainable materials, water harvesting, and site management. Moreover, BIM can also detect the carbon footprint before proceeding with building work to support the low-carbon city initiatives set by the Malaysian government to support their sustainable agenda.

Furthermore, another critically important strategy in BIM implementation is sufficient support from the government. This can be related to the government initiatives in promoting sustainable elements for the housing construction project. Hence, the government should also promote BIM as the process of achieving sustainable efforts by encouraging the construction industry players to implement BIM by assisting them with necessary support, be it in monetary or non-monetary parts. BIM can help with the sustainable analysis for housing construction project sustainability. In addition, to support sustainability efforts for a building, BIM can help minimise the building maintenance costs upon the completion of the construction phase. It is also agreed by most of the BIM experts that it would be possible to minimise the building maintenance cost if BIM were to be implemented from the beginning of the design stage of the building construction.

Overall, the outcome shows that the critical BIM implementation strategies can be used to support the UN SDGs agenda, especially its sustainable initiatives, particularly for the housing construction projects in Malaysia. Generally, BIM experts agree that all BIM implementation strategies affect their projects and need to be executed the soonest.

## 7. Discussion

Based on the Rasch measurement model analysis result, from 16 items of Building Information Modelling (BIM) implementation strategies that were identified from the systematic literature review, only three items are critically important in the sustainable housing construction project in Malaysia. Another five items are in important categories that also play essential roles in the execution stage. This further validates that the existing stakeholders in the sustainable housing construction industry are well aware of the BIM roles in construction projects, but require immediate execution plans. Even though the BIM implementation is at a slow pace, mainly due to the several challenges in Malaysia, the construction industry's momentum is growing. Based on [40], the surveys observed that the challenges in Malaysia involve a lack of BIM-competent staff to operate the software, an unawareness of the technology features, a high cost to acquire the software, a long time to develop the model, difficulties in understanding the software, and the most importantly, there is no encouragement and enforcement from the government and related clients.

Looking at the most critical BIM implementation strategies in the sustainable housing construction project in Malaysia, one of them is the BIM awareness level amongst the housing construction project stakeholders. The surveys identifies that the awareness level is the highest priority initiative to execute. This is supported by [14,50] on the awareness level strategy. The authors clearly stated that awareness of BIM software is very important

to ensure everybody understands BIM's critical roles. The action plan that can be executed under this strategy is promoting a BIM training program for construction project stakeholders and conducting seminars and workshops related to BIM for sustainability efforts in the affected organisation. Hence, it is crucial to improve awareness in order to enable BIM implementation to run smoothly in housing construction projects.

This paper also revealed that the other most critical important strategy is the ability of the project team to encourage all of their project stakeholders to participate in the BIM coordination system. Proper modules of BIM training and courses for various levels of housing construction projects need to be imparted to ensure sufficient knowledge of BIM application. All project stakeholders are required to work together in reducing implementation costs in BIM to encourage the participation of project stakeholders in their projects [25]. Furthermore, [51] similarly found that 92.63% of the respondents, who are construction project stakeholders, believe that the government should play a vital role in BIM implementation, as suggested in this paper, which is also a critically important BIM implementation strategy in the sustainable construction project in Malaysia.

## 8. Conclusions

It is agreed by the Building Information Modelling (BIM) subject matter experts that most of the BIM implementation strategies affect the Malaysian housing construction project's sustainable initiatives. The essential BIM implementation strategies, which critically affect the sustainable housing construction projects, were identified as the ability to encourage all project stakeholders to participate in the BIM coordination team, the BIM awareness level in the housing construction industry projects, and a sufficient government role and support in BIM implementation in the housing construction projects.

The construction industry in Malaysia certainly requires an extensive BIM implementation strategy to overcome the unsustainable construction challenges that will occur throughout the project. The proactive measure will help to achieve an effective sustainable outcome. This effort doubtlessly contributes to the United Nation Sustainable Development Goal 11 (UNSDG11) objective of ensuring access for all to adequate, safe, and affordable housing for middle-income communities. From the UNSDGs perspective, the outcome of this paper will encourage the sustainability effort using BIM software that will minimise the energy, land, and clean water consumption throughout the project life cycle, specifically in the sustainable housing project. Furthermore, this paper is expected to benefit the housing construction industry players to achieve sustainable project performance and to support the BIM implementation target by Public Works Department (PWD) BIM Strategic Plan 2021–2025, the National Construction Policy 2030 agenda by the Ministry of Works Malaysia, and the UNSDG.

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