

Optimising The Implementation of Building Information Modelling in 4D (Scheduling) and 5D (Cost) for Highway and Bridge Construction

A. S. A. Kassim¹, A. M. Sarman^{2*}, E. M. Mazlan¹, J. Manggi¹, Y. M. Chin¹

¹ Faculty of Engineering,
Universiti Malaysia Sabah, 88400 Kota Kinabalu, Sabah 88400, MALAYSIA

² Advanced Construction Technology (ACT) Research Unit, Faculty of Engineering,
Universiti Malaysia Sabah, 88400 Kota Kinabalu, Sabah, MALAYSIA

*Corresponding Author: asmawan@ums.edu.my
DOI: <https://doi.org/10.30880/ijie.2025.17.03.019>

Article Info

Received: 6 August 2024

Accepted: 30 April 2025

Available online: 18 September 2025

Keywords

Building information modelling,
scheduling, cost estimating,
highway, bridge, construction

Abstract

Building Information Modelling (BIM) is a shared knowledge repository for information about a facility that serves as a trustworthy foundation for decision-making throughout the facility's life cycle, which is described as "existing from inception to demise." BIM is still lacking in usage and awareness of BIM benefits in implementation in the highway and bridge construction industry. Furthermore, the disconnect between project scheduling, cost estimation, and BIM models exacerbates the complexity of construction processes, hindering the seamless integration of BIM in highway and bridge projects. Therefore, the objective of this study is to identify the current level of awareness of Building Information Modelling implementation in the highway and bridge construction industry, to produce a BIM 4D (Scheduling) and 5D (Cost Estimating) model based on the highway and bridge construction project and to recognize the benefits and challenges of implementing Building Information Modelling approaches in the highway and bridge construction industry. This research conducted an industrial survey, literature review, and 4D/5D BIM modelling focusing on the Malaysian highway and bridge construction industry. The results suggest that the industry has a moderate understanding of 4D/5D BIM but has superior scheduling and cost estimating skills. The three highest listed benefits are improved on-site cooperation, model-based cost estimation, and project visualisation in preconstruction with 3.633, 3.767 and 3.900 mean ranks respectively. The three highest-ranked challenges are technical problems, legal challenges, and reluctance to change, with 3.500, 3.467 and 3.400 mean ranks respectively. In order to replicate the 4D/5D model, modelling is constructed using Infracore, MS Project, and Navisworks.

1. Introduction

In the building industry, Building Information Modelling is a very effective tool (BIM). BIM is "a digital representation of a facility's physical and functional attributes" as defined by the United States' National Building Information Model Standard Project Committee. A BIM is a shared knowledge repository for information about a facility that serves as a trustworthy foundation for decision-making throughout the facility's life cycle, which is

This is an open access article under the CC BY-NC-SA 4.0 license.



described as "existing from inception to demise" [1]. Confusion and misunderstanding occur when BIM is seen just as a three-dimensional model of a facility enhanced with features and functions; however, BIM is about information, and the three-dimensional model is merely one technique of expressing the information. As a result of the emergence of centralised information generation, sharing, and management, a significant paradigm shift occurred in the Architecture, Engineering, Construction, and Operations (AECO) industry, with a shift away from traditional design methods toward more collaborative information-centric design. For decades, BIM has been widely accepted in the construction industry, but its acceptance and implementation in transportation infrastructure have been gradual [2]. The research gap lies in the lack of exploration into how BIM's 4D and 5D capabilities specifically address and mitigate time and cost overruns in highway and bridge projects. As mentioned, BIM is still lacking in usage and awareness of BIM benefits in implementation in the highway and bridge construction industry. BIM implementation in the private and public construction sectors is still shallow. Most of the surveyed organisations are not using BIM, and the team is not practising its concept. This results in a delay in the diffusion of BIM implementation [3]. As a result, future engineers must use BIM and devise implementation techniques to benefit society. The lack of awareness of BIM approaches benefits in the highway and bridge construction industry. In addition, majority of highway and bridge construction project lack a connection between the project scheduling, cost estimation to the generated BIM model that has been generated. This is due to the complicated and dynamic process of highway and bridge construction process. Lastly, most of the practitioners in the construction industry lack interest in implementing the 3D/4D/5D BIM in the highway and bridge construction industry. Lack of true understanding of what BIM is [4].

The purpose of this study is to provide perspectives on the optimisation and application of Building Information Modelling 4D (scheduling) and 5D (cost Estimation) in the highway and bridge building sector. The following are the study's objectives:

- (i) To identify the current level of awareness of Building Information Modelling implementation in the highway and bridge construction industry.
- (ii) To produce a BIM 4D (scheduling) and 5D (cost Estimating) model based on the highway and bridge construction project.
- (iii) To recognise the benefits and challenges of implementing Building Information Modelling approaches in the highway and bridge construction industry.

The National Building Specification in the United Kingdom has performed yearly BIM studies and surveys. The newest NBS BIM report (2015) illustrates a growing outlook, demonstrating that BIM adoption has gained momentum in the UK, going from 13% in 2010 to 40% in 2012 and continuing to 50% in 2014, a significant growth in a short time [5]. In comparison, comparable surveys performed by McGraw-Hill Construction in the United States indicate that BIM adoption for infrastructure is around three years behind that for buildings, having reached 50% adoption in 2013 [6]. These levels will continue to expand as more academic research is performed and the UK industry reaches BIM level 2 and continues to level 3 [7]. Additionally, several countries whose governments recommend BIM recognise its benefits and have taken steps to promote its adoption and implementation, including the Netherlands, Denmark, Belgium, Luxembourg, France, Germany, Italy, Malaysia, Spain, Switzerland, Ireland, Japan, China, Taiwan, and New Zealand [8].

BIM has several clear benefits. Technical superiority, interoperability, early building information capture, utilisation throughout the building lifespan, integrated procurement, improved cost control methods, reduced conflict, and project team benefits. Long-term benefits include fewer claims and lower building costs. BIM also helps retain prior clients [9]. BIM 4D schedules help phase, coordinate, and communicate scheduled work [10]. BIM systems must deliver real-time updates and adequate visualisation to enable successful team collaboration [11]. BIM is beneficial from early conceptual design [12] until demolition [13]. If any problem occurs that requires maintenance, this list of schedules can be referred to get extra information about the items [14]. BIM can also help project management [15]. Continuously collected, saved, and maintained project data simplifies tracking and evaluation [16]. BIM provides a fast and precise evaluation of design possibilities, leading to more efficient, cost-effective, and sustainable solutions. BIM can help facility managers compare energy performance choices to reduce environmental impacts and operating expenses.

The first legal challenge is to evaluate the ownership of the BIM data and how to secure it through copyright and other laws [17]. For instance, if the owner pays for the design, the owner may feel entitled to own it. However, if team members provide proprietary information for the project, that knowledge must also be secured. As cost and schedule aspects are added to a 3D model, the responsibility for the correct technological interface between programmes becomes an issue. Prior to the start of a project, many sophisticated contracting teams ask subcontractors to produce precise CPM timelines and line-item cost breakdowns. Currently, the majority of these project management tools and 3D models have been created independently. Contractual provisions must address responsibility for the accuracy and coordination of cost and schedule data [18].

2. Methodology

A combined methodology consisting of a literature review followed by both a qualitative and quantitative technique is utilised for comparable studies, including BIM deployment and integration soon. All such research attempted to determine the value and degree of application of BIM before delving further into the benefits of BIM, including improved building performance, decreased financial risk, and shortened project schedules. The following Fig. 1 portrays how the research aim and objective were achieved through different data collection and analysis.

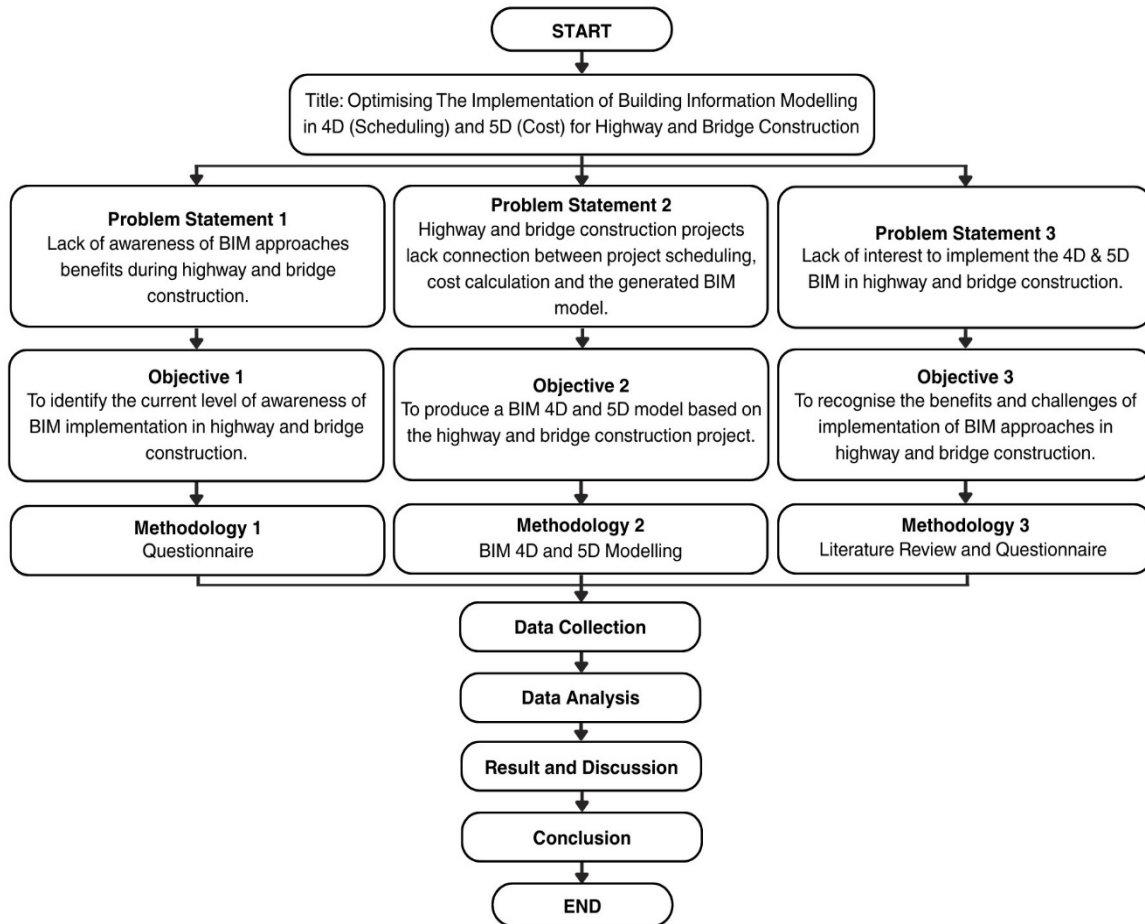


Fig. 1 Research methodology flowchart

2.1 Literature Review

The literature review methodology involved a thorough analysis of previous research, using academic journals and online historical resources to explore various facets of Building Information Modelling (BIM). This included investigating its definition, tracing its evolution, examining its dimensions, elucidating its benefits throughout the life cycles of highway and bridge construction projects, and scrutinising various modelling techniques associated with BIM. Through this systematic approach, the chapter aims to illuminate the research gaps in BIM literature, thereby providing readers with a more nuanced and comprehensive understanding of the subject matter.

2.2 Industrial Survey

The industrial survey is a field survey in which statistical data on economic activities in the industry field are collected from a sample of selected industrial establishments according to the establishments framework in the Establishments Economic Survey [19]. This industrial survey will be distributed to a total of 30 respondents who are construction industry practitioners, and their responses will be recorded. Relatively small sample size minimises the potential influence of numerous variables on the study's conclusions. By narrowing the focus to a specific group of practitioners, the study can better control for extraneous factors, ensuring that the analysis remains more targeted and accurate. This study will assess their demographic data, skills, and knowledge with BIM software. The survey will also determine their opinion on the benefits and challenges of BIM implementation. The survey results will be statistically analysed using SPSS version 22. The Pearson Chi-Square, Cross Tabulation,

and Frequencies Tests were used to examine the connection between the independent variable (IV) and the dependent variable (DV).

2.3 Modelling

Increasing automation of quantification and the development of BIM models necessitates a shift in the role of the project cost manager to provide more sophisticated cost management services that include 4D time and 5D cost modelling and sharing cost information/data with the project team [20]. As quantification becomes increasingly automated, and BIM models evolve, the role of the project cost manager will need to develop to provide more sophisticated cost management services that incorporate 4D time and 5D cost modelling, as well as the sharing of cost information/data with the project team, as part of the BIM integrated project delivery approach [21]. For the development of the 3D model, the schedule and cost estimation, data were collected from project reports, 2D paper drawings, and interviews with project participants from an ongoing highway and bridge construction project. The 3D model will be developed using Infracore 360, the 4D/5D model will be developed using MS Project, and finally, all three models will be combined using Navisworks Manage. Once the BIM model was developed, a simulation was run to visualise the project construction.

3. Results and Discussion

3.1 Demographic Data of Respondents

According to the pie chart in Fig. 2, half of the respondents (15 respondents) are between the ages of 26 and 30. After that, 20% (6 respondents) of those surveyed were between the ages of 20 and 25. Meanwhile, respondents aged 41 - 45 and 36 - 40 account for 10% (3 respondents) and 13% (4 respondents) of the total. Finally, just 7% (2 respondents) are members of the generation between the ages of 31 and 34. Based on Fig. 3, from the total of 30 respondents answering the questionnaire, 73% (22 respondents) are male and 27% (8 respondents) are female.

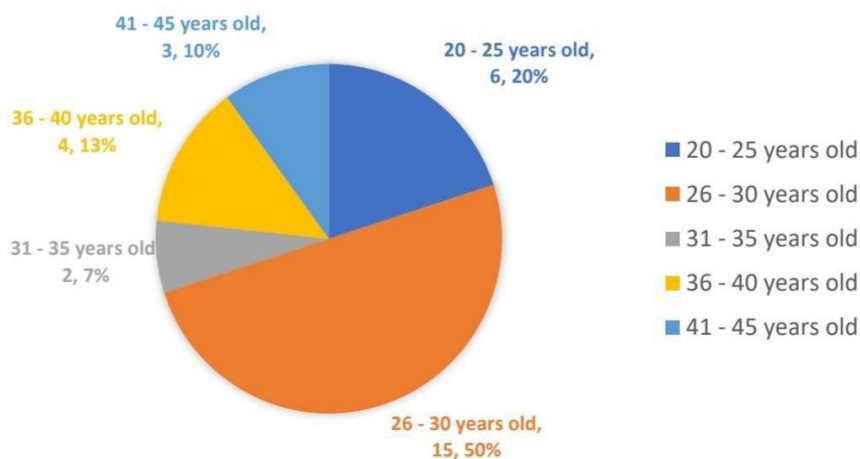


Fig. 2 Age group of respondents



Fig. 3 Gender of respondents

Table 1 shows the level of education of 30 respondents for this questionnaire. The highest percentage level of education is the respondents who have a bachelor's degree at 63% (19 respondents) and a diploma at 37% (11 respondents). Meanwhile, the level of education, such as a certificate, master's degree and PhD, is at zero percentage.

The result from Table 2 shows that the respondents currently working in the highway construction field are the highest at 46.7% (14 respondents), followed by other fields such as dam safety, infrastructure, network, slope rectification and hydro dam at 20% (6 respondents). Then, the building construction field and electrical and mechanical fields are both at 10% each (3 respondents). Lastly, bridges construction field and the oil and gas field are the lowest fields of work for respondents at 6.7% each (2 respondents).

Table 1 Level of education of respondent

Level of Education	Frequencies	Percentage
Certificate	0	0
Diploma	11	37
Bachelor's degree	19	63
Master's degree	0	0
PhD	0	0
Total	30	100

Table 2 Field of work respondents

Field of Work	Frequencies	Percentage
Highway construction	14	46.7
Bridges construction	2	6.7
Building construction	3	10
Electrical and mechanical	3	10
Oil and gas	2	6.7
Others	6	20
Total	30	100

The pie chart in Fig. 4 shows the years of experience in the industry of the 30 respondents. The highest respondents are 1-2 years of experience at 43% (13 respondents). Followed by 3-4 years of experience at 27% (8 respondents). Then, 8 years and above experiences at 20% (6 respondents). The respondent that has 7-8 years and 5-6 years of experience has 7% (2 respondents) and 3% (1 respondent) respectively.

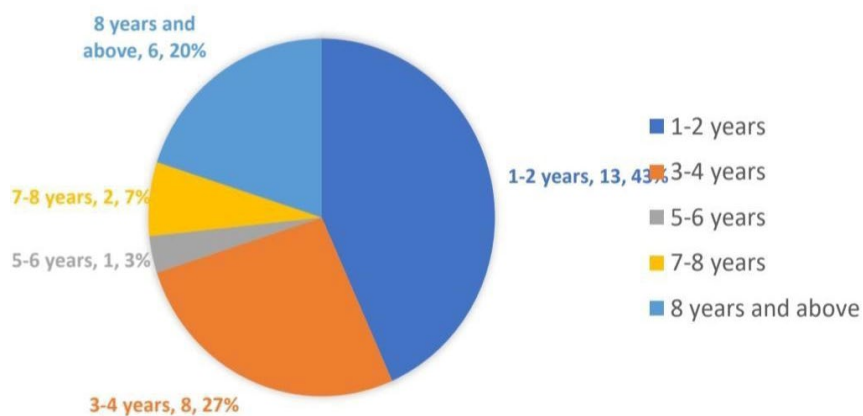


Fig. 4 Year of experience in the industry of the respondent

3.2 Industrial Survey

A total of 30 replies were analysed using IBM SPSS. The data has been collected and analysed using the SPSS statistical software. For this reason, both parametric and nonparametric comparison analyses may be performed with relative ease using the SPSS statistical program.

Based on the cross tabulation in Table 3, the number of respondents who are not familiar with BIM 4D is very high, which is 11 respondents; thus, the number of respondents who are moderately skilled and knowledgeable

in scheduling is 11 respondents. Meanwhile, only 1 respondent is very familiar with BIM 4D, and only 2 respondents are very skilled and knowledgeable in scheduling.

Table 3 Cross tabulation of knowledge and skill in scheduling and familiarity with BIM 4D

How do you rate your knowledge and skill in scheduling?	How familiar are you with BIM 4D Scheduling					Total
	Extremely Not Familiar	Not Familiar	Familiar	Very Familiar	Extremely Familiar	
Not Knowledgeable	5	1	0	0	0	6
Slightly Knowledgeable	0	4	0	0	0	4
Moderately Knowledgeable	3	5	3	0	0	11
Knowledgeable	0	1	5	1	0	7
Very Knowledgeable	0	0	0	0	2	2
Total	8	11	8	1	2	30

The null hypothesis is rejected based on Table 4, which shows that scheduling knowledge and experience and familiarity with BIM 4D are correlated, as the p-value is less than our predefined significance level of = 0.05.

Table 4 Chi Chi-square test of knowledge and skill in scheduling and familiarity with BIM 4D

	Value	df	Asymptotic. Significance. (2-sided)
Pearson Chi-Square	57.392 ^a	16	.000
Likelihood Ratio	41.972	16	.000
Linear-by-Linear Association	17.643	1	.000
N of Valid Cases	30		

a. 25 cells (100.0%) have expected count less than 5. The minimum expected count is .07.

Based on the cross-tabulation Table 5, the respondents who are extremely not familiar with BIM 5D are very high, which is 13 respondents, and the respondents who are moderately skilled and knowledgeable in cost estimating are the highest, with 12 respondents. Meanwhile, the number of respondents who are very familiar with BIM 5D is the lowest, with only 1 respondent, and the number of respondents who are not skilled and knowledgeable in cost estimating is only 2. The null hypothesis is not rejected since the p-value is higher than the chosen significance level (= 0.05). Rather, discovered that there is not enough information to demonstrate a relationship between BIM 5D familiarity and cost estimation knowledge and skill.

Table 5 Cross tabulation of knowledge and skill in cost estimating and familiarity with 5D

How do you rate your knowledge and skill in scheduling?	How familiar are you with BIM 4D Scheduling					Total
	Extremely Not Familiar	Not Familiar	Familiar	Very Familiar	Extremely Familiar	
Not Knowledgeable	2	0	0	0	0	2
Slightly Knowledgeable	4	2	0	0	0	6
Moderately Knowledgeable	5	4	3	0	0	12
Knowledgeable	1	2	3	1	0	7
Very Knowledgeable	1	0	0	0	2	3
Total	13	8	6	1	2	30

Based on Table 6, the Chi-square test was conducted to examine the association between knowledge and skill in cost estimating and familiarity with 5D. The Pearson Chi-Square value is 30.783 with 16 degrees of freedom (df) and a significance level (p-value) of 0.014, which is less than the conventional alpha level of 0.05. This indicates a statistically significant relationship between the two variables, suggesting that knowledge and skill in cost estimating are associated with familiarity with 5D. However, the Likelihood Ratio value of 24.641 yields a p-value of 0.076, which is slightly above the 0.05 threshold, indicating a marginal or non-significant association by this measure. Interestingly, the Linear-by-Linear Association value of 10.383 with a p-value of 0.001 shows a strong and significant linear trend between the variables, implying that as familiarity with 5D increases, the knowledge and skill in cost estimating also tend to increase. It is important to note that 96% of the cells (24 cells) had an expected count of less than 5, and the minimum expected count is 0.07, which may violate the assumption

of the Chi-square test and could affect the reliability of the results.

A question was asked about their opinion on the benefits and challenges of BIM 4D/5D, and they will have the opportunity to choose whether or not they agree with these statements. The benefits and challenges selected have been carefully observed in a past study that has been conducted. According to Fig. 5, the top three highest percentages of BIM 4D/5D benefits are better coordination and clash detection (3.933), better visualisation in preconstruction (3.900) and overall better build. Fig. 6 shows the technical challenges of BIM 4D/5D; the top three challenges are the requirement of a sophisticated laptop or computer (3.733), lack of experience in BIM (3.667) and lack of exposure to BIM (3.633).

Table 6 Chi Chi-square test of knowledge and skill in cost estimating and familiarity with 5D

	Value	df	Asymptotic. Significance. (2-sided)
Pearson Chi-Square	30.783 ^a	16	.014
Likelihood Ratio	24.641	16	.076
Linear-by-Linear Association	10.383	1	.001
N of Valid Cases	30		

a. 24 cells (96.0%) have expected count less than 5. The minimum expected count is .07.

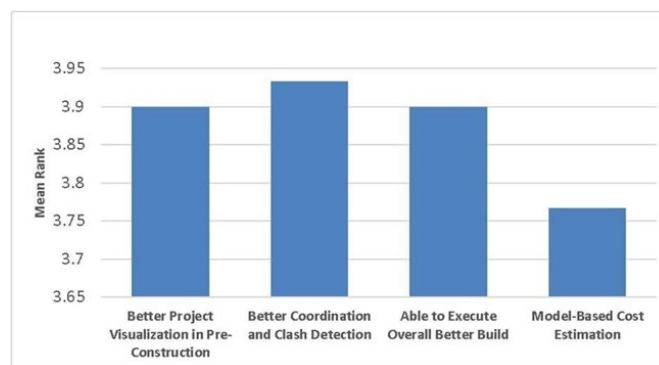


Fig. 5 Benefits of BIM 4D/5D

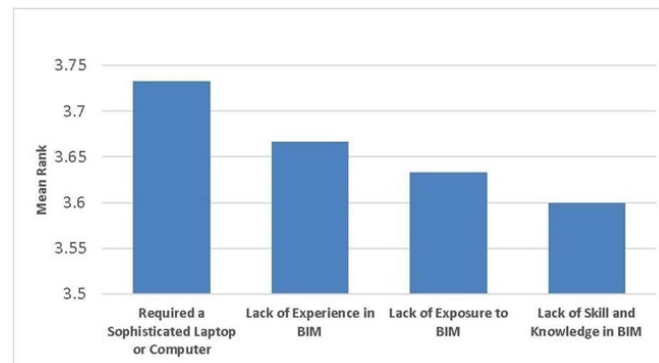


Fig. 6 Technical challenges of BIM 4D/5D

3.3 Modelling

Microsoft Project, Navisworks Manage, and Autodesk Infracore 360 are used to create 4D and 5D BIM modelling. The purpose of this model is to provide a more accurate preconstruction visual representation of the construction project.

3.3.1 3D Modelling

Autodesk Infracore 360 provides a powerful platform for creating realistic, data-rich 3D visualizations of infrastructure projects such as the Muara Lassa Bridge as shown in Fig. 7. One of the primary benefits is ease of use—the software allows engineers, planners, and designers to rapidly model and visualize large-scale bridge projects using intuitive tools. The speed of rendering and processing in Infracore 360 is another advantage, enabling users to develop complex models with multiple structural components such as piers, decks, and supports in a short time frame. The display clarity in the image is evident through the precise alignment and spacing of

piers, highlighting the bridge's structural rhythm and engineering intent. Furthermore, InfraWorks 360 supports detailed view management, allowing users to assess the bridge from various angles and perspectives, which is critical for stakeholder presentations. The use of data integration ensures that geospatial and topographical data are accurately embedded into the model, supporting realistic environmental context and facilitating design decision-making. Overall, the Muara Lassa Bridge rendering illustrates how InfraWorks enhances understanding of bridge scale, layout, and interaction with the natural environment, ultimately improving communication and confidence in project feasibility.



Fig. 7 Muara Lassa Bridge

The rendering of Junction 2 at Road C and Road A using Autodesk InfraWorks 360 demonstrates the software's strength in visualising transportation and roadway networks with high clarity and detail, as shown in Fig. 8. The software enables the integration of real-world terrain data and road geometry, which is essential for accurate junction design. The model shows a smooth merge of Road A and Road C with proper curvature and elevation changes, providing a realistic representation of what the construction might look like on site. The display quality highlights important features such as road boundaries, lane demarcations, and surrounding topography. This level of detail supports engineers in conducting visibility analysis, safety checks, and traffic flow simulations. The user-friendly interface and speed of modelling allow rapid adjustments to road layouts, junction designs, and intersection treatments, enhancing productivity and reducing design turnaround time. Moreover, InfraWorks 360's ability to overlay topographic lines and elevation data directly on the model ensures precise planning and grading. The visualisation helps stakeholders—engineers, authorities, and the public better understand the project scope and its alignment with the landscape. In short, InfraWorks transforms raw survey and GIS data into an intelligent, interactive visual, improving decision-making and project coordination.



Fig. 8 Junction 2 at Road C and Road A

3.3.2 4D/5D Modelling

BIM 4D or work schedules, as shown in Fig. 9, are carried out for a better understanding of the constructive dynamics involved by comparing the work status to the estimated completion times, and for each activity and constructive element of the work, to complete the construction job. Furthermore, a rigorous cost and resource usage analysis can lead to a timely check of the expenses to be borne and the profit margins, which can be referred to as BIM 5D. Both BIM 4D and 5D BIM must be constructed first in MS Project before combining in Navisworks software.

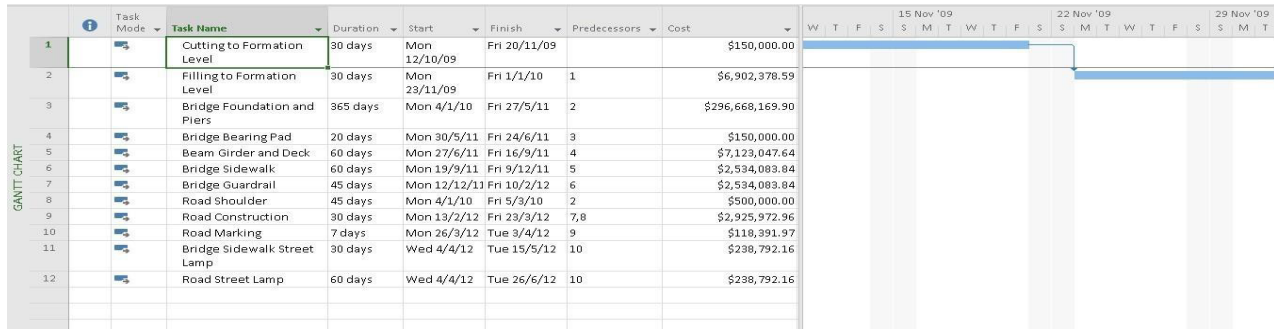


Fig. 9 Scheduling and cost estimation done in MS Project

Before working with Navisworks, a model must be generated first using many kinds of BIM software. In the real world, each design team member will produce a different 3D, 4D and 5D model. So, what Navisworks does is take all the various designs and formats and combine them into one model. Therefore, it can be viewed, navigated, measured, and analysed in one environment. That is why Navisworks is very critical in clash detection, as shown in Fig. 10.

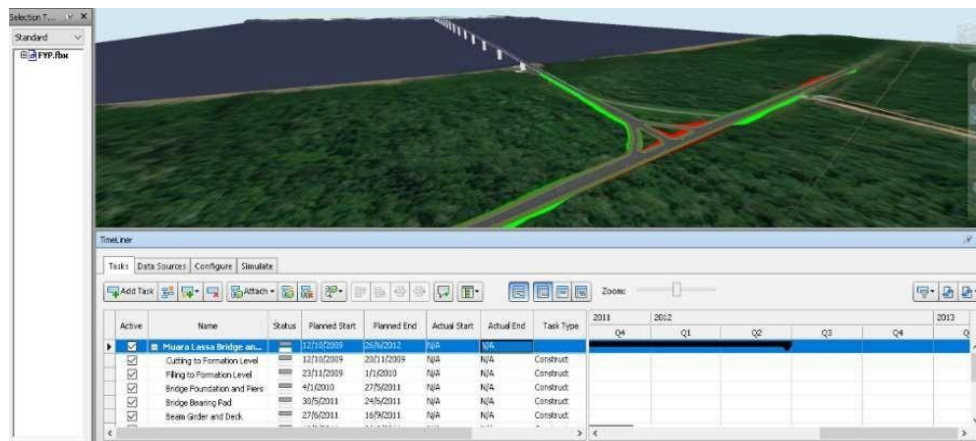


Fig. 10 3D, 4D and 5D model combination in Navisworks

3.4 Discussion

BIM, which consists mainly of a 3D model of the project, enables project simulation that contains all essential information during the planning, design, construction, and operation phases. The 3D model objects in this study are enhanced with cost and time information to construct 4D and 5D model simulations, as illustrated in the preceding section.

Building Information Modelling (BIM) has emerged as a transformative approach in the construction industry, offering numerous advantages that enhance project delivery and performance. Table 7 presents one of the key benefits is the improvement of onsite collaboration and communication, as BIM facilitates real-time information sharing among stakeholders, ensuring better coordination and reduced errors. Its ability to provide visualisation during preconstruction stages enables stakeholders to understand design intent and foresee potential issues. Furthermore, BIM supports model-based cost estimation, which enhances budgeting accuracy and financial planning. The integration of clash detection tools helps identify conflicts before construction begins, thus mitigating risks, reducing rework, and ultimately lowering project costs. Additionally, BIM contributes to safer construction sites by identifying hazards during planning. However, despite these advantages, several disadvantages hinder widespread adoption. Legal and technical challenges, such as issues with data ownership and interoperability, can complicate implementation. Resistance to change remains a significant barrier, particularly among professionals accustomed to traditional methods. High initial costs, including software,

hardware, and training, may deter smaller firms. Moreover, a general lack of knowledge and expertise in BIM usage can compromise its effectiveness. Finally, the complexity of BIM software and the need for standardisation across platforms create further obstacles. Overall, while BIM offers substantial benefits, addressing its challenges is essential for successful integration.

The findings summarised in Fig. 11 illustrate the current landscape and practical challenges of Building Information Modelling (BIM) implementation within the highway and bridge construction industry. Firstly, the research highlights a significant gap in awareness, as only 50% of respondents are familiar with BIM, with most relying heavily on conventional software like AutoCAD. This limited adoption rate underscores the necessity for targeted industry-wide standardisation and systematic training to bridge knowledge gaps and enhance interoperability across different disciplines. Furthermore, the study successfully demonstrates the feasibility of producing BIM 4D (scheduling) and 5D (cost estimation) models using tools such as Navisworks Manage, showcasing tangible benefits like improved coordination and clash detection. However, it also points out notable challenges, particularly the high initial cost of BIM implementation, which may deter smaller firms. The recommended utilisation strategies, including encouraging companies to establish small BIM departments and ensuring staff are adequately trained, aim to mitigate these barriers and promote wider adoption. These strategies emphasise that true value from BIM is realised when supported by comprehensive organisational commitment and standardised processes. Ultimately, this study not only maps the current state of BIM application but also provides actionable steps to advance its integration in complex infrastructure projects.

Table 7 Advantages and disadvantages of BIM

Advantages	Disadvantages
<ul style="list-style-type: none"> Improving onsite collaboration and communication Model-Based Cost Estimation Visualise Projects in Preconstruction Better Coordination and Clash Detection Mitigate Risk and Reduce Cost Better Safety on Construction Sites 	<ul style="list-style-type: none"> Legal challenges Technical challenges Resistance to change High initial cost of implementation Lack of knowledge BIM software complexity and standardisation

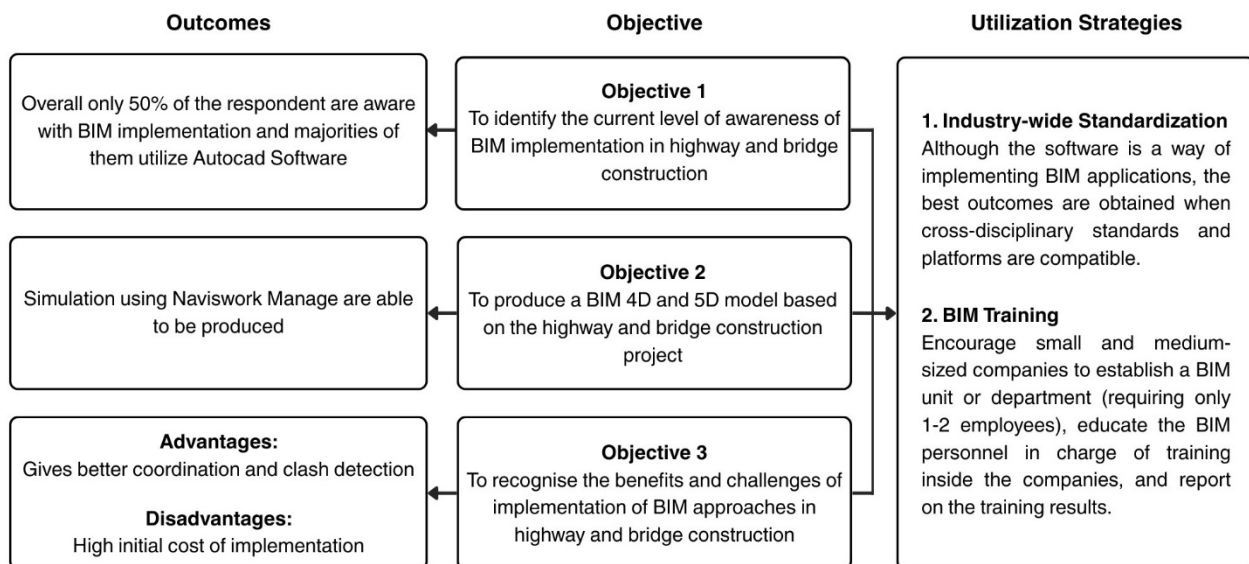


Fig. 11 Summary of study objective, outcomes and utilisation strategies

4. Conclusion and Future Work

BIM technology and tools are still evolving quickly. BIM implementation necessitates the urgent development of reliable tools for information exchange between various software tools while enabling effective and direct coordination and monitoring processes between project participants and team members employed for the project from different companies and using multiple software sets. For BIM deployment to be more acceptable, the acceptable degree of interoperability and standardisation of the work procedures must be presented to project participants and team members. AEC firms must invest in software, hardware, training, and other prerequisites for BIM adoption. BIM involves process investments, such as internal collaborative BIM procedures and business investments for future BIM capabilities [9]. The study achieved its objectives by assessing awareness levels,

creating BIM 4D and 5D models, and identifying implementation challenges in highway and bridge construction. Through surveys and analysis, it pinpointed knowledge gaps among practitioners. Utilising software tools such as Infracore 360 and MS Project, it developed comprehensive models, improving visualisation and cost estimation. Despite challenges like equipment requirements, the study highlights BIM's potential to enhance project management efficiency in this sector. Some restrictions apply to this study since this study is only conducted by questionnaire and 3D/4D/5D modelling. The recommendation is to interview the construction industry's engineering practitioners and produce a 6D (Sustainability) and 7D (Facility Management) model to expound more on the findings.

Acknowledgement

The author wishes to express their appreciation to Green Materials and Advanced Construction Technology (GMACT) Research Unit and Faculty of Engineering, Universiti Malaysia Sabah, for their unending support and for providing good facilities to conduct this research.

Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

*The authors confirm contribution to the paper as follows: **Study conception and design:** Ag. Shafiee Adzmey Ag. Kassim, Asmawan Mohd Sarman, Elis Mardzianah Mazlan; **Data collection:** Jimmyson Anak Manggi; **Analysis and interpretation of results:** Asmawan Mohd Sarman, Elis Mardzianah Mazlan; **Draft manuscript preparation:** Ag. Shafiee Adzmey Ag. Kassim, Chin You Mui. All authors reviewed the results and approved the final version of the manuscript.*

References

- [1] Moynihan, G. P., & Harsh (2015). Current state of construction project delivery methods. Proceeding of the IIE Annual Conference 2015, Institute of Industrial & Systems Engineers, pp. 174.
- [2] Kim, U., Kim, Y., Ok, H., & Yang, S. (2015). A study on the status of infrastructure BIM and BIM library development. Proceeding of the International Conference on Computational Science and Computational Intelligence, IEEE Xplore. <https://doi.org/10.1109/CSCI.2015.52>
- [3] Alex, B., Haijiang, L., Robert, L., & Simon, D. (2016). BIM for infrastructure: An overall review and constructor perspective. *Automation in Construction*, 71, 139-152. <https://doi.org/10.1016/j.autcon.2016.08.019>
- [4] Alhumayn, S., Chinyio, E & Ndekugri, I. (2017). The barriers and strategies of implementing BIM in Saudi Arabia. *WIT Transactions on The Built Environment*, 169, 55-67. <https://doi.org/10.2495/BIM170061>
- [5] National Institute of Building Science (2011). United States National Building Information Modeling Standard Version 1 - Part 1: Overview, Principles, and Methodologies. The Northern American Chapter of Building SMART International.
- [6] Bernstein, H. M., Jones, S. A., & Gudgel, J. E. (2010). *The Business Value of BIM in Europe: Getting BIM to the bottom line in the United Kingdom, France and Germany*. McGraw-Hill.
- [7] Nor, J. M., Sarman, A. M., Che-Ani, A. I., Latiff, R. A., & Wahi, W. (2019). Identifying the critical components to extend concrete flat roof service life in equatorial climates: *International Journal of Recent Technology and Engineering*, 7, 281-284.
- [8] Succar, B. (2009). Building information modelling framework: A research and delivery foundation for industry stakeholders. *Automation in Construction*, 18, 357-375, <https://doi.org/10.1016/j.autcon.2008.10.003>
- [9] Bernstein, H. M., Jones, S., & Russo, M. (2012). *The Business Value of BIM in North America: Multi-Year Trend Analysis and User Rating (2007-2012)*. SmartMark Rep.
- [10] Kymmell, W. (2007). *Building Information Modeling: Planning and Managing Construction Projects with 4D CAD and Simulations*. McGraw-Hill.
- [11] Johansson, M., Roupé, M., & Bosch-Sijtsema, P. (2015). Real-time visualization of building information models (BIM). *Automation in Construction*, 54, 69-82. <https://doi.org/10.1016/j.autcon.2015.03.018>
- [12] Kovacic, I., & Zoller, V. (2015). Building Life Cycle Optimization Tools for Early Design Phases. *Energy*, 92, 409-419. <https://doi.org/10.1016/j.energy.2015.03.027>

- [13] Langenhan, C., Weber, M., Liwicki, M., Petzold, F., & Dengel, A. (2013). Graph-based retrieval of building information models for supporting the early design stages. *Advanced Engineering Informatics*, 27, 413–426. <https://doi.org/10.1016/j.aei.2013.04.005>
- [14] Sarman, A. M., Jaison, C., Mazlan, E. M., & Nazeri, N. N. (2021). Potential and opportunities of building information modeling (BIM) for housing maintenance. *IOP Conference Series: Materials Science and Engineering*, 1176, 012041. <https://doi.org/10.1088/1757-899X/1176/1/012041>
- [15] Bryde, D., Broquetas, M., & Volm, J. M. (2013). The project benefits of building information modelling (BIM). *International Journal of Project Management*, 31, 971–980. <https://doi.org/10.1016/j.ijproman.2012.12.001>
- [16] Qian, A. Y. (2012). Benefits and ROI of BIM for Multi-Disciplinary Project Management. National University of Singapore.
- [17] Azhar, S., Hein, M., & Sketo, B. (2008). Building information modeling (BIM): Benefits, risks and challenges. *Proceedings of the 44th ASC Annual Conference*, pp. 2-5.
- [18] Thompson, D. B., & Miner, R. G. (2007). Building Information Modeling - BIM: Contractual Risks are Changing with Technology. <http://www.aepronet.org/ge/no35.html>
- [19] General Authority for Statistics (GASTAT). (2017). Industrial Activity Survey, 2017. Statistical Report, Riyadh, Saudi Arabia.
- [20] Shen, J. (2020). The application of BIM technology in road and bridge construction management. *IOP Conference Series: Earth and Environmental Science*, 587, 012002. <https://doi.org/10.1088/1755-1315/587/1/012002>
- [21] Smith, P. V. (2014). BIM & the 5D project cost manager. *Procedia – Social and Behavioral Sciences*, 119, 475–484. <https://doi.org/10.1016/j.sbspro.2014.03.053>