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# Challenges of Integrating Building Information Modelling (BIM) into Sustainable Design for Green Highway Construction

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The integration of Building Information Modelling (BIM) into sustainable design has become a popular trend in the construction industry. However, the application of BIM in green highway construction poses several challenges. This paper examines the challenges of integrating BIM into sustainable design for green highway construction. The research employs a qualitative approach of interviews with professionals in the construction industry, and the results are analyzed using content analysis. The study reveals that integrating BIM into a sustainable design for green highway construction challenges include high cost, insufficient data, limited collaboration among stakeholders, the need for specialized skills, and inadequate software. The study recommends adopting a collaborative approach to overcome these challenges. The paper concludes by emphasizing the importance of addressing these challenges to achieve sustainable construction practices in the highway sector.

## 1. Introduction

The building sector is under intense pressure to stop such harm and take additional steps to compensate for such losses because it significantly contributes to global warming (Tryggestad, 2013). A system that supports human civilization and activities is infrastructure. Transport systems, viewed as the cornerstone of a thriving economy and social development, are included in the broad scope of infrastructure development (Costin et al., 2018). According to Laali et al. (2022), creating and planning infrastructures environmentally is essential, especially while developing green highways. The multiple aspects and considerations in infrastructure design, which establish substantial restrictions and strictly condition their design, make it typically complicated (Bongiorno et al., 2019). Decision-makers and stakeholders may not be aware of this during the early design phase because sustainability is frequently considered and studied in terms of the balance between various sustainability factors (Shahtaheri et al., 2018). Creating new infrastructure services and frequently replacing outdated transport infrastructure call for efficient and cutting-edge technologies (Adshead et al., 2019).

The development of Building Information Modelling (BIM) technology has significantly improved the supply of construction domains across the project lifecycle (He et al., 2017). Using BIM throughout the project enables concurrent building (Succar, 2009). BIM also helps evaluate and analyze green structures (Lu et al., 2017). Wong and Zhou (2015) summarised previous research on the definition of green BIM as a model-based method of generating and managing coordinated and consistent building data throughout a project's lifecycle that enhances a building's energy-efficiency performance and makes it easier to achieve predetermined sustainability goals.

McLennan (2004) states that sustainable design is "a design philosophy that seeks to maximize the quality of the built environment while minimizing or eliminating negative impacts on the natural environment." According to system theory, a green highway is a road project that integrates planning, design, building, operation, and management procedures for the duration of the road's service life that must be able to coordinate the interaction between the quality of highway construction, resource utilization, energy consumption, pollution discharge,

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environmental effect, and operational efficiency. It should achieve the highest operational efficiency while utilizing the fewest resources, consuming the least energy, emitting the least pollution, and having a negligible environmental impact. (Stern, 2002). Cai et al. (2020) analyzed the construction of the Puyan motorways, where the project's goal is to improve the structure's level of standardization management while also maintaining quality and safety. The development of the Puyan Motorway is effectively promoted by strengthening management, technology, equipment, image, environmental protection, and information technology applications.

Experts are increasingly searching for efficient solutions to lower energy use and environmental impact due to the need to be more sustainable. BIM and its companion technologies for sustainability design, implementation, and evaluation have recently received much attention (Xie et al., 2022). To promote the use of renewable energy sources and include passive design to lower operational energy use in buildings, several green building assessment systems, including BREAM, LEED, CASBEE, Green Star, and GBI, have been established (Neardey et al., 2020). Building Research Establishment Environmental Evaluation Method (BREEAM), Sustainable Building Tool (SBTool), and Leadership in Energy and Environmental Design (LEED) are three methodologies used to evaluate the sustainability of a building. Carvalho et al. (2020) looked at the influence of BIM in these three methods. Based on the research, it was determined that the SBTool was the most alluring method for enhancing future building sustainability. Carvalho et al. (2019) studied about SBTool PT-H optimized building sustainability assessment (BSA) methodologies using BIM technology. BIM may offer designers a wealth of information to compare the effectiveness of different sustainable solutions and assess the structure's sustainability throughout its life cycle. The construction industry will benefit from technology, sustainability, green initiatives, and Multi-Criteria Decision Making (MCDM), which results in a superior performance combination. Despite these benefits, some BIM limitations for sustainability and greener highway building must still be addressed, such as the expense of training senior employees in BIM and hiring new BIM specialists. Changing the procedure and the tools, obtaining licenses, and training the staff on BIM technology might be expensive and time-consuming. Farouk et al. (2023) add that there is no assurance that BIM investments would pay off as there is no assurance that BIM projects for sustainable highway construction will materialize in the future. Therefore, this study examines the difficulties associated with BIM and sustainable design in developing the green highway.

## 2. Literature Review

### 2.1 Challenges of Integrating BIM and Sustainable Design for Green Highway Construction

Numerous Green BIM programs lack specific industry norms or guidelines for developing green highways, one of the major problems and research gaps outlined by Santos et al. (2019). The intricacy of the BIM models and the lack of suitable software to assess the requirements for green highways hinder the deployment of Green BIM. Although BIM for sustainability is being developed, it is still mainly concentrated on one specific element. For illustration, a comprehensive BIM-based digital procurement system was proposed to give project stakeholders a new way to collaborate compatible with social sustainability (Grilo and Goncalves, 2011). Given that many enterprises will continue to lack BIM expertise and execution of the development of the green highway, the problem may become more circular (Ghaffarianhoseini et al., 2017). To point out the environmental sustainability that may be used in developing the green highway, Wong and Zhou (2015) in-depth examined Green BIM, and Chong and Wang (2016) outlined the BIM initial model for further sustainable green highway construction. Furthermore, BIM regulations, rules, and utilization for sustainability for developing the green highway have not yet been adequately explored, claim Chong et al. (2017). These policies, norms, and utilization will affect BIM and the green highway. Full sustainability analyses inside BIM applications are not yet available, and the transition from building information modelling to building energy modelling (BEM) is currently a main priority, according to Rahman et al. (2013).

Due to competing interests in the supply chain for AEC projects, the construction team may hesitate to employ BIM for green roadways (Redmond et al., 2012). Antón and Díaz (2014) claim that stakeholders' decisions about green highway development are impacted by their ignorance of BIM tools and the variables to consider when evaluating sustainability. The top risks for BIM at all levels are a lack of project experience and a lack of competent staff with the skills to handle the requirements of green highway development (Chien et al., 2014). According to Zahrizan et al. (2013), a major obstacle to implementing BIM is the lack of BIM understanding, particularly regarding developing the green highway. According to Liu et al. (2015), the two implementation challenges that are most frequently mentioned are the implementation of sustainable highway projects and the shortage of technical BIM knowledge. The degree of implementation is still low due to a lack of adequate training and understanding of how BIM works and the development of the green highway.

Technology and the BIM framework's accessibility for green highway construction were also highlighted as additional challenges in previous studies (Rahim et al., 2022). Rahim et al. (2022) also noted that because construction industry players are still hesitant to implement BIM, developing green motorways incorporating BIM

would go slowly. The BIM framework accessibility for green highway construction impacted how the construction industry applied BIM to developing green highways. Zahrizan et al. (2013) asserted that in the absence of permission from the required foundation, a firm would not be able to maintain improvements made to a new process for building green highways.

The move to technology methods, including BIM and sustainable highways, has a significant capital cost, according to Memon et al.'s (2014) argument. When it comes to developing the green highway, clients are hesitant to use BIM, except the client ties it to endless benefits for their specific companies and a significant reduction in training costs. BIM technologies are also the most pricey to purchase and challenging to set up, according to Ezeokoli et al. (2016), who claimed that this impacts the entire cost of building green highways. Purchasing BIM computer gear and applications, its infrastructure, and the costly nature of staff training will all require significant initial capital outlays for implementing BIM with sustainable highway construction (Memon et al. 2014). As a result, project stakeholders may spend more than they should (Niewoehner, 2010). Many actors in the construction industry lacked confidence in their ability to apply BIM in sustainable highway projects without appropriate financial support from the government, especially given the present BIM implementation attempts.

### 2.2 Overcoming the Green Highway Construction Incorporating BIM-Sustainable Design Challenges

Impediments include a lack of interest from the client or top management, legal requirements or government commitment, a lack of understanding of sustainable design and green highways, unwillingness to change, and a lack of training. These significant hurdles must be removed to help the built environment achieve its sustainability objectives of building green highways (Mellado, 2020). It can be accomplished by reaffirming policies to promote the implementation of BIM for environmentally friendly highway construction (Onososen and Musonda, 2022). The construction sector has demands to be met by the government authorities; therefore, it is recommended that the ministry develop a guideline requiring 100 percent integration of BIM for green highway construction to promote more BIM and green in infrastructure projects (Rahim et al., 2022). The government should be able to assist in promoting BIM and sustainable highways to participants in the building sector (Rahim et al., 2022). Due to the government's capacity to raise the level of knowledge among actors in the development sector, such efforts have a vital influence on the industry (Rahim et al., 2022). Another crucial tactic is to make sure that the relevant project stakeholders receive enough BIM training, seminars, and information about green highway development so that everyone can better understand how to use BIM and green highways, causing the construction further effective and sustainable in the long run (Rahim et al., 2022). Due to the expensive cost of BIM software, the government might promote its use in all public and commercial projects, particularly those including green roadways, by offering incentives and financial support (Zaini et al., 2020). Any construction company that wishes to use BIM in the construction of green highways may receive an interactive package from the government (Zaini et al., 2020).

## 3. Methodology

This paper adopted a qualitative method approach by using semi-structured interviews. The interviews were conducted with the experts to get information on the challenges of BIM and sustainable design for green road development. The interviews took place around Kajang, Selangor, and engaged three people specializing in highway construction. The overall interview duration was 1 hour and 49 minutes and was recorded prior to the interviewees' consent.

Table 1 shows the interviewees' code IDs and positions. The interviews using the recorded audio were transcribed into text documents (Microsoft Word) before being analyzed using the content analysis method.

*Table 1: Interviewees code*

| Interviewees' IDs | Interviewees' positions | Years of Experience |
|---|---|---|
| P1 | Engineer | 17 Years |
| P2 | Engineer | 15 Years |
| P3 | Designer | 10 Years |

## 4. Findings and Discussions

This section discusses the challenges of BIM integrated into sustainable design for green highway construction. The discussion is based on content analysis. Three main challenges are highlighted, namely policy and guidelines, people, and resources.

*Table 2: The Challenges of Integrating BIM into Sustainable Design for Green Highway Construction*

| Type of challenges | Elaboration on the challenges |
|---|---|
| Policy and guidelines | *It is hard to amend with the concessionaire company…* (P1)<br>*It is due to many challenges, such as it depends on concessionaire companies that they able to catch up with the current technology and sustainable green in highway construction…* (P1)<br>*Not only that, the policy and the guidelines of BIM, sustainable design, and green highway construction must be strong enough to ensure all the construction industry players take the next step and follow the legal policy and mandates that the government has highlighted…* (P1)<br>*The government applies the Public Expenditure Savings policy but encourages the construction industry to use expensive technology that is BIM, which violates the Public Expenditure Savings policy…* (P2) |
| People | *Malaysia is still in the stage of encouraging the construction industry and the people to adopt BIM, sustainable design, and green highway construction…* (P1)<br>*The BIM or the system has no shortcomings, whereas humans have shortcomings in identifying problems with managing and transferring data into the BIM…* (P1)<br>*The readiness of the company to handle ample storage…* (P2)<br>*The readiness of staff to manage and insert all the data into BIM…* (P2) |
| Resources | *Difficulties to insert the thirty years of hardcopy data that must be found first to include in BIM data management and model…* (P1)<br>*BIM and green sustainability did not fully impose on concessionaire companies because of high capital costs…* (P1)<br>*It takes a long time or duration to make amendments with the concessionaire company…* (P2)<br>*Before BIM arrives, the cost of the project is not high, but when BIM is a must in the project, the cost of the project will increase…* (P2)<br>*In Malaysia, BIM has a problem with facilities management…* (P3) |

The first main challenge is regarding policy and guidelines. P2 mentioned that the government applies the Public Expenditure Savings policy but encourages the construction industry to use expensive BIM technology, which violates the policy. Therefore, the policies and guidelines of the government are not strong enough to fully utilize BIM for green highway construction in Malaysia. It aligns with Chong et al. (2017) that informed BIM policies, guidelines, and usage for sustainability towards green highway construction as a whole have not yet been thoroughly examined.

The second main challenge involves people. P1 stated that Malaysia still encourages the construction industry and the people to adopt BIM, sustainable design, and green highway construction. P1 mentioned that BIM or the system has no shortcomings; otherwise, humans have shortcomings in identifying problems with managing and transferring data into BIM. It shows that the lack of knowledge and expertise in BIM and sustainable highway design is still not solved in the Malaysian construction industry. The challenge involves people, referred to the study by Antón and Díaz (2014), which stated that stakeholders' decision-making in green highway construction is influenced by their lack of understanding of how to use BIM software and the factors to consider for sustainability evaluation. Liu et al. (2015) mentioned that the lack of technical BIM knowledge and execution in green highway projects are the two most frequently reported implementation obstacles. It is clear that without sufficient training and comprehension of the BIM process and green highway construction, the implementation can still be at a low level.

The third challenge is related to resources. P1 stated that BIM and green sustainability are not fully imposed on concessionaire companies because of high capital costs. While P2 mentioned that before the presence of BIM, the project cost was not too expensive, but when BIM was established, the project cost skyrocketed. The capital cost aligns with Memon et al. (2014), who argued that moving to technology methods, including BIM and sustainable highways, has a significant capital cost. Clients are hesitant to use BIM, except they can tie it to endless benefits for their specific companies and a significant reduction in training costs. Ezeokoli et al. (2016) also reported that BIM technologies are the most pricey to purchase and challenging to set up, impacting the entire cost of developing the green highway. Many actors in the construction industry lacked confidence in their ability to apply BIM in sustainable highway projects without appropriate financial support from the government, especially given the present BIM implementation attempts.

## 5. Conclusion

In a nutshell, this study has addressed several challenges of BIM integrated into the sustainable design for green highway construction. Highways play a vital role in transportation infrastructure, connecting cities, regions, and countries. The main challenges of integrating BIM into the sustainable design for green highway construction are policy and guidelines, people, and resources. All these obstacles will cause the slow implementation of BIM for sustainable design for green highway construction in Malaysia. It will cause the highway environment to be affected due to the lack of use of BIM in sustainable design for green highway construction. The importance of addressing these challenges is ensuring that Malaysia's construction industry takes note and shows an effort to utilize BIM and sustainable design for green road development more efficiently. It is to prevent the environment from being destroyed because the construction industry does not consider sustainable design, protect flora and fauna, and reduce pollution. Other importance of green highways in their projects also addresses the challenges aligned with the Construction Industry Transformation Programme (CITP) 2016-2020 and the latest Construction 4.0 Strategic Plan 2021-2025 under the thrust of Technology Clustering-Simulation and Modelling. The limitation of this study is the qualitative approach, which is an interview, is not enough; the quantitative method, which is a survey, must be done to get enough information from the construction industry, especially BIM expertise and specialized in highway construction. The different positions of interviewees, Engineers, and Designers to gather the current scenario of the topic and the preliminary interview to gather initial findings for future research are also included in the limitation of this study. A future recommendation is to study subsidies by the government that can lead to ease in implementing BIM in the Malaysian construction industry and the policies that can enhance BIM utilization more widely. Recommendations for future studies include the level of adaptiveness among highway construction teams towards the new BIM technology and sustainable design for green highways in the Malaysian construction industry.

### References


Adshead D., Thacker S., Fuldauer L.I., Hall J.W., 2019, Delivering on the Sustainable Development Goals through long-term infrastructure planning, Global Environmental Change, 59.

Antón L.Á., Díaz J., 2014, Integration of LCA and BIM for sustainable construction, International Journal of Civil and Environmental Engineering, 8(5), 1378-1382.

Bongiorno N., Bosurgi G., Carbone F., Pellegrino O., Sollazzo G., 2019, Potentialities of a highway alignment optimization method in an I-BIM environment, Periodica Polytechnica Civil Engineering, 63(2), 352-361.

Cai J., Liao F., Lin J., Zhong H., Shang X., Wang D., 2020, Discussion on technical system and practice of green highway construction, In Web of Conferences, 145.

Carvalho J.P., Bragança L., Mateus R., 2019, Optimising building sustainability assessment using BIM, Automation in Construction, 102, 170-182.

Carvalho J.P., Bragança L., Mateus R., 2020, A systematic review of the role of BIM in building sustainability assessment methods, Applied Sciences, 10(13).

Chien K.F., Wu Z.H., Huang S.C., 2014, Identifying and assessing critical risk factors for BIM projects: Empirical study, Automation in construction, 45, 1-15.

Chong H.Y., Lee C.Y., Wang X., 2017, A mixed review of the adoption of Building Information Modelling (BIM) for sustainability, Journal of Cleaner Production, 142, 4114-4126.

Chong H.Y., Wang X., 2016, The outlook of building information modeling for sustainable development, Clean Technologies and Environmental Policy, 18(6), 1877-1887.

Costin A., Adibfar A., Hu H., Chen S.S., 2018, Building Information Modeling (BIM) for transportation infrastructure–Literature review, applications, challenges, and recommendations, Automation in Construction, 94, 257-281.

Ezeokoli F., Okoye P., Nkeleme E., 2016, Factors affecting the adaptability of building information modelling (BIM) for construction projects in Anambra State Nigeria, Journal of Scientific Research and Reports, 11(5), 1-10.

Farouk A.M., Zulhisham A.Z., Lee Y.S., Rajabi M.S., Rahman R.A., 2023, Factors, challenges and strategies of trust in BIM-Based construction projects: A case study in Malaysia, Infrastructures, 8(1), 13.

Ghaffarianhoseini A., Tookey J., Ghaffarianhoseini A., Naismith N., Azhar S., Efimova O., Raahemifar K., 2017, Building Information Modelling (BIM) uptake: Clear benefits, understanding its implementation, risks and challenges, Renewable and Sustainable Energy Reviews, 75, 1046-1053.

Grilo A., Jardim-Goncalves R., 2011, Challenging electronic procurement in the AEC sector: A BIM-based integrated perspective, Automation in Construction, 20(2), 107-114.

He Q., Wang G., Luo L., Shi Q., Xie J., Meng X., 2017, Mapping the managerial areas of Building Information Modeling (BIM) using scientometric analysis, International Journal of Project Management, 35(4), 670-685.

Laali A., Nourzad S.H.H., Faghihi V., 2022, Optimizing sustainability of infrastructure projects through the integration of building information modeling and envision rating system at the design stage, Sustainable Cities and Society, 84.

Liu S., Xie B., Tivendale L., Liu C., 2015, Critical barriers to BIM implementation in the AEC industry, International Journal of Marketing Studies, 7(6), 162-171.

Lu Y., Wu Z., Chang R., Li Y., 2017, Building Information Modeling (BIM) for green buildings: A critical review and future directions, Automation in Construction, 83, 134-148.

McLennan J.F., 2004, The philosophy of sustainable design: The future of architecture, Ecotone publishing, Missouri, US.

Mellado F., Lou E.C., 2020, Building information modelling, lean and sustainability: An integration framework to promote performance improvements in the construction industry, Sustainable Cities and Society, 61.

Memon A.H., Rahman I.A., Memon I., Azman N.I.A., 2014, BIM in Malaysian construction industry: status, advantages, barriers and strategies to enhance the implementation level, Research Journal of Applied Sciences, Engineering and Technology, 8(5), 606-614.

Neardey M., Aminudin E., Chung L.P., Zin R.M., Zakaria R., Wahid C.C., Noor Z.Z.N., 2020, Simulation on lighting energy consumption based on building information modelling for energy efficiency at highway rest and service areas Malaysia, In IOP conference series: Materials Science and Engineering, 943(1).

Niewoehner D., 2010, BIM and life-cycle analysis help determine value of green strategies, Laboratory Design, 15(2), 3-7.

Onososen A., Musonda I., 2022, Barriers to BIM-based life cycle sustainability assessment for buildings: An interpretive structural modelling approach, Buildings, 12(3), 324.

Rahim N.S.A., Ismail S., Md Yusof A., 2022, Implementation Strategies of Building Information Modelling towards Sustainable Residential Construction Project in Malaysia, Architecture, 10(4), 1556-1563.

Rahman A., Suwal S., Jäväjä P., Lic T., 2013, Diverse approach of BIM in AEC industry: a study on current knowledge and practice, Proceedings of the 30th CIB W78 International Conference, October 9-12, 2013, Beijing, China, sn, 79-88.

Redmond A., Hore A., Alshawi M., West R., 2012, Exploring how information exchanges can be enhanced through Cloud BIM, Automation in Construction, 24, 175-183.

Santos R., Costa A.A., Silvestre J.D., Pyl L., 2019, Informetric analysis and review of literature on the role of BIM in sustainable construction, Automation in Construction, 103, 221-234.

Shahtaheri Y., Flint M.M., De la Garza J.M., 2018, Sustainable infrastructure multi-criteria preference assessment of alternatives for early design, Automation in Construction, 96, 16-28.

Stern D.I., 2002, Explaining changes in global sulfur emissions: an econometric decomposition approach, Ecological Economics, 42(1-2), 201-220.

Succar B., 2009, Building information modelling framework: A research and delivery foundation for industry stakeholders, Automation in construction, 18(3), 357-375.

Tryggestad K., 2013, Sustainable Buildings and Infrastructure: Paths to the, Improving Schools, 15(1), 45-60.

Wong J.K.W., Zhou J., 2015, Enhancing environmental sustainability over building life cycles through green BIM: A review, Automation in Construction, 57, 156-165.

Xie M., Qiu Y., Liang Y., Zhou Y., Liu Z., Zhang G., 2022, Policies, applications, barriers and future trends of building information modeling technology for building sustainability and informatization in China, Energy Reports, 8, 7107-7126.

Zahrizan Z., Ali N.M., Haron A.T., Marshall-Ponting A., Hamid Z.A., 2013, Exploring the adoption of Building Information Modelling (BIM) in the Malaysian construction industry: A qualitative approach, International Journal of Research in Engineering and Technology, 2(8), 384-395.

Zaini A.A., Razali A.W., Gui H.C., Zaini N., Tamjehi S.D., 2020, Assessing strategies of building information modeling (BIM) implementation in Sarawak Construction Industry, In IOP Conference Series: Earth and Environmental Science, 498(1).