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Integrative Assessment Framework of Building Information Modelling (BIM) and Sustainable Design for Green Highway Construction: A Review

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The development of infrastructure based on the global demand for services across the entire sector has caused numerous unfavourable environmental implications. Those development implications should be dealt with the sustainability opportunities lied in the planning phase, and sustainable design can be the critical success factor. Sustainable infrastructure rating systems are claimed as the most suitable tools for assessing infrastructure's environmental performance, especially in green highways. Subsequently, Building Information Modelling (BIM) is one of the technologies that can improve the green design of infrastructure. The approaches of both BIM and green highways are still fragmented. It is necessary to integrate BIM criteria in green highways' sustainable design to assess the performances' infrastructure rating systems better. The main objectives of this paper are to review the need for an integrative assessment framework of building information modeling (BIM) and sustainable design for green highway construction. This paper had a critical review of the related issues of BIM and green highway construction. This paper is in line with the recent Malaysian government initiative in the Construction 4.0 Strategic Plan (2021-2025) agenda (under Strategic Thrust 3) to transform the Malaysian construction industry by empowering innovative construction for the future society. This strategic plan aspiration is also supported by Malaysia's National Policy on Industry 4.0 and Sustainable Development Goal (SDG 17).

1. Building Information Modelling

The definition of BIM has been adopted from Eastman et al. (2011) as a modeling technology and associated set of processes to produce, communicate, and analyze building models. Building models are characterized by building components represented with digital representations that include data describing how they behave. The data are consistent, non-redundant, and coordinated such that all views of a model are represented in a coordinated way. As reported internationally, BIM of many interests has driven the increasing adoption of the technology amongst the construction players in most of their building projects. As described by many authors, BIM benefits include cost and time saving, reduced human resources, quality and performance improvement, clash detection, improved accuracy, increased profitability, enhanced collaboration and communication, and many more. BIM brings design and documentation to the third dimension and connects the whole structure and documentation process with the time and cost as the fourth and fifth dimensions (Sharma et al., 2017). BIM is increasingly in demand within the construction industry internationally in recent years. The technology application reconciles several problems within the project teams, such as delays, rework, miscommunication, and other related inefficiencies that affect project success. While most developed countries actively employ it, BIM is not as advanced in most developing countries (Ismail et al., 2017). In Malaysia's case, the BIM development is urged through the Construction Industry Transformation Programme (CITP) 2016-2020 agenda and has been further strengthened in the latest Construction 4.0 Strategic Plan 2021-2025 of Malaysia under the thrust of Technology Clustering - Simulation & Modelling.

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2. Sustainable design and green highway

In earlier decades, sustainable development idea has grown from numerous environmental movements. Sustainable issues have recently been widely discussed, mainly in the construction industry. Sustainable development is vital in meeting the environmental objectives and fulfilling the demand for large infrastructure projects due to an increasing population and urban density. Embodied energy evaluation is frequently completed at the point when the design has either been done or created to a moderate detail level when there is a minor extension to explore distinctive design choices for decreasing the building's total energy consumption. Sahamir et al. (2017) agreed that sustainability implementations had become important initiatives discussed and undertaken by private and public sectors, especially in construction development. Pollution that causes habitat disturbance, land usage, and climate change affects construction emissions, as Griffith and Bhutto (2009) stated. The impacts can be caused by the design, construction, and management of roads, parking, and other facilities.

Sustainable design can be one factor to minimize the effects of highway damages/construction on the environment. Fernández-Sánchez and Rodríguez-López (2010) stated that it is necessary to have new techniques and tools that will allow the environmental, social, and economic commitment to be met in the building and civil engineering sector. Bryce (2008) described that most of the sustainable assessment tools were focused on building construction rather than its infrastructure, especially in highway development. Nikumbh and Aher (2017) mentioned that assessment tools would be benchmarking, identifying areas of success, and identifying areas of opportunity for improvement for sustainable choices or practices, and according to that certification awarded. Balubaid et al., (2015) mentioned that there were several sustainable assessment tools for highway development in the United States but not in the tropical region, especially Malaysia. In 2014, Malaysia Highway Authority had developed Malaysia Green Highway Index (MyGHI) as assessment tools for promoting sustainable highway development in planning, design, construction and operation and maintenance of highway (Rooshdi et al., 2018). The recent Malaysian Government agenda on sustainability-related highway construction has been highlighted in the CITP review (2019-2020). Its key outcomes by 2020 under the Focus Area 4: Sustainability has outlined the sustainable infrastructure, 50 % of new infrastructure projects more than MYR 100 million to be certified in Sustainable INFRASTAR or any proper sustainable infrastructure tool from December 2020 onwards. The data in Figure 1 also had shown that 33 % of the criteria were categorized under the planning and design stages, while 60 % were under the construction stage. Only 7 % were under the operation and maintenance stage. Therefore, it shows that the design and construction stages are important for greening the highway. Figure 2 had shown the criteria distribution for design and construction stages for green highway. Those criteria had been developed by analysed nine assessment tools of infrastructure which related to highway development.

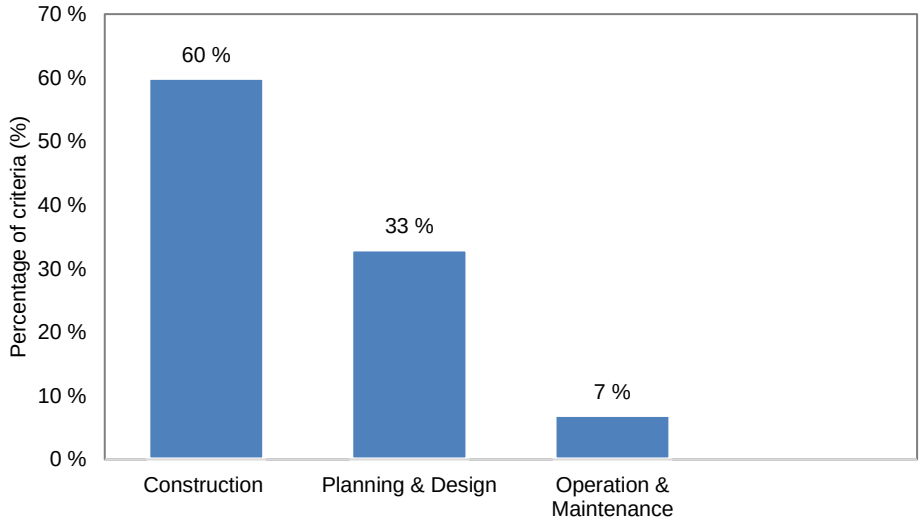

Figure 1: Main criteria in assessment tools of infrastructure (Raja Muhammad Rooshdi, 2019)

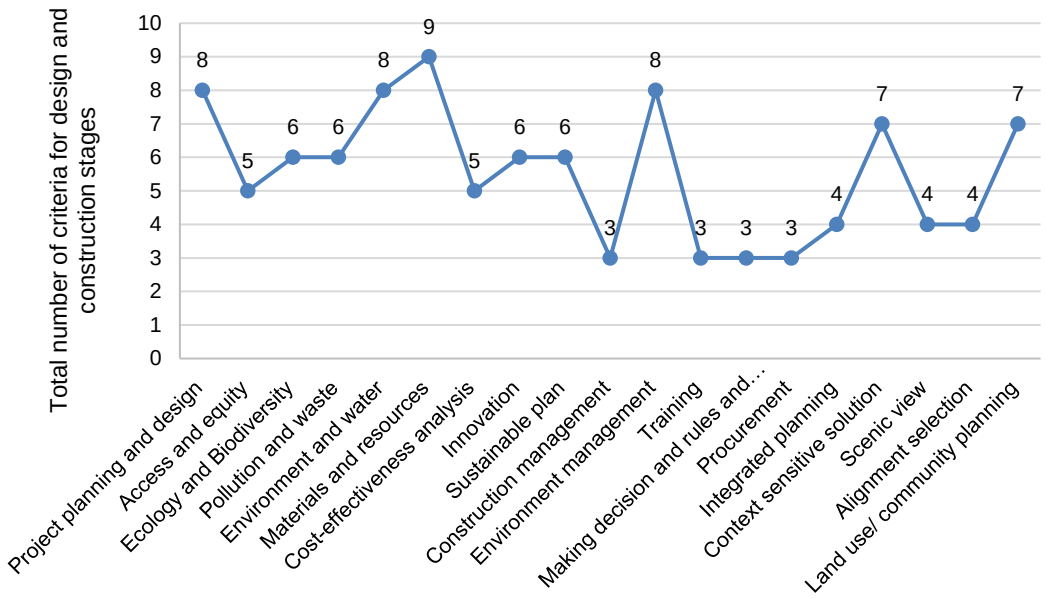

Figure 2: Criteria distribution for design construction stages for green highway (Raja Muhammad Rooshdi, 2019)

3. Building Information Modelling and sustainable design of green highway assessment tool

In the past few years, the use of BIM applications make design decisions more sustainable supporting the sustainable construction in the planning and design phases were identified and classified in several areas which were evaluation of the direction of construction, analysis of the building structure and improvement of the building envelope in equal transparency ratio manner, analysis of daylight, water harvesting assessment, renewable energy options, the requirements of sustainable materials and reduce waste and carbon footprints through appropriate site design and logistics management. BIM systems can increase productivity, efficiency, infrastructural value, quality, and sustainability besides enhancing coordination between design disciplines (Haruna el at., 2020). BIM has rapidly progressed over the past decade and has been used in architecture and traditional construction. BIM is composed of integrated facilities commonly used by the project team to monitor and manage construction work and design buildings and infrastructure, making it an effective communication platform. Given the concern for the effects of the depletion of non-renewable resources, BIM has been increasingly applied and adapted to monitor the impact of construction on the environment. Green rating system becomes a popular tool to confirm the green credential of building and infrastructure (Liu et al., 2018). Most countries have developed their green building rating systems, including the United States, Canada, Australia, United Kingdom, Hong Kong, Japan, Taiwan, Singapore, Philippines, Europe, Korea, India, and Australia. Malaysia also owns the green building rating system, namely the Green Building Index (GBI). With the successful implementation of this GBI, the rating system has been widened into Malaysia's highway developments. BIM applications are claimed to have facilitated the stakeholders, such as clients and designers, to share standard information from one single source when faced with a decision-making problem at an early design stage of construction (Månsson et al., 2017).

Green assessment related with BIM application, LEED, BEAM Plus, and Green Star are among green building rating systems, which feature their respective criteria and allocation of points and credits. BIM may be integrated with the green building certification process as summarized in Table 1. This mechanism is a strong reason for driving several countries to implement BIM in most construction phases. The BIM model helps project stakeholders, including designers, contractors, and clients, calculate, document, and measure the green building rating system scores based on those assessment tools (Abdirad, 2017). It should help the design team and construction approaches to meet the green highway accreditation requirements. Some research had shown reliability for the data and indicated that BIM alternatives efficiently achieve sustainability by integrating BIM and assessment tools such as multicriteria decision-making tools (Haruna et al., 2020). As supported by Carbonari et al. (2018), the result of decision support for the management of large building stock became more reliable with developing a BIM-based decision support system. Assessment tools and BIM can continuously strengthen each other's attributes and roles in the process of deep interaction, with forming a positive synergy for decision-making (Tan et al., 2021).

Table 1: Summary of Integration BIM and Green Assessment tools research

Author	Integration BIM and Green Assessment tools research
Haruna et al, (2020)	BIM alternatives are efficient in achieving sustainability by integrating BIM and assessment tools such as multicriteria decision-making tools
Carbonari et al. (2018)	Decision support for the management of large building stock became more reliable with the development of a BIM-based decision support system
Tan et al, (2021)	Assessment tools and BIM can continuously strengthen each other's attributes and roles in the process of deep interaction, thus forming a positive synergy for decision-making
Abdirad, (2017)	The BIM model helps project stakeholders, including designers, contractors, and clients, calculate, document, and measure the green building rating system scores based on those assessment tools

The integration of green building had been developed much earlier. Several researchers have investigated the application of BIM for green building assessment. Khoshdelnezamiha et al. (2019) summarized previous studies related to BIM application for green building assessment as presented in Table 2. It is shown that Revit had widely used as a BIM authoring tool. It had been explored and evaluated as tools that could optimize the existing methods. An alternative approach is proposed to gain direct access to the building data and process the information rapidly without any external tools. Maltese et al., (2017) had concluded that integrated a tool like BIM would be able to manage criteria in the early design stages for a better sustainable design because the data from BIM tools could give more accuracy in calculation the rating for sustainable assessment tools. Solla et al., (2017) also had analyzed that by integrated BIM in green assessment tool had increased the certification level for the project.

Table 2: Summary of previous studies related to BIM application for green building assessment (Sources from Khoshdelnezamiha et al. (2019)

Rating System	Region	Points	Tool Used
LEED	USA	17 points and two prerequisites	Revit and IES-VE
BEAM-Plus	Hong Kong	26 points	Revit
BREEAM	UK	14 points	ArchiCAD and GBAT
GBI	Malaysia	28 points	Revit, Excel and BEIT

4. The needs for Building Information Modelling integration in green highway construction assessment tool

Integrated strategies needed to stimulate further innovation and improve the process of assessing highway performance for sustainable infrastructure development. Sustainable construction development is a global concern. Different concepts and approaches have been developed over the past decades to solve environmental problems, including assessment tools and BIM. An integrated strategy must stimulate further innovation and improve it (Ghandi and Jupp, 2013). Sustainability assessment is proven to help evaluate construction systems' sustainability related to the economy, environment, and social. Using these variables and criteria in the evaluation way, construction systems' selection and application will be viable with more compatibility with the environment (Liu et al., 2018). As targeted in the Construction Industry Transformation Programme (CITP) (2016-2020), under the thrust of Environmental Sustainability, more rating tools need to be developed to promote sustainable development, especially infrastructure development. Sustainable rating tools alone are not enough to ensure that 50 % of government projects and 20 % of private projects achieve green certification. By combining BIM features into that sustainable development of infrastructure element, it probably can impact accuracy and various aspects to reach green-certified in line with IR 4.0 under the thrust of sustainable and resilient core value and BIM technology. These integrated strategies between sustainable rating tools and BIM features can be interpreted as an opportunity to improve the process of assessing highway performance for sustainable infrastructure development.

Green highway construction assessment tools is one of the decision making tools that use to measure the level of sustainability of highway development. There were a lot of research that relate BIM and decision making tools. Pavlovkis (2016) had been used BIM in his research about decision making by integrated BIM. The research had been shown that by integrated BIM would ensure the success of information management with control of the project implementation quality. Hope and Alwan (2017) suggested that integrating BIM with the assessment tools can be clearly understood by all involved in the building’s specification and construction. Chen

and Pan (2015) researched shown that by integrated BIM and decision-making model, the result would be more efficient. The importance of aligning decision-making process goals to allow more effective and efficient green highway certifications BIM has been implemented by some architecture, engineering, and construction (AEC) firms because of the long-term benefits of productivity gains (Ismail, 2017). By allowing system integration and optimization, BIM facilitates effective collaboration, which plays an essential role in this transformation. Haruna (2021) mentioned that BIM application can help significantly in achieving sustainable construction via design optimization which led to improve the solution and widen knowledge about design pace. When applied to green highway design, BIM can align the decision-making process goals and those of the project stakeholders; in some cases, the process allows for more effective and efficient green highway certification. The comprehensive data could be obtained by effectively assessing highway performance during the design and preconstruction phases (Rojas et al., 2019). BIM also allows multi-disciplinary data to be superimposed for one model, and creating the opportunity for the sustainability of the measures to be incorporated into the entire design process (Abdirad, 2017). Hussain and Erzaij (2020) mentioned that BIM integration in rating tools would provide rapid and reliable design decision support which helped stakeholders and designers to make more informed decisions at the design stage.

Malaysian CITP 2016-2020 agenda under Focus Area 6: Technology has emphasized that BIM technology should be more used in construction projects. The BIM implementation has been further strengthened in the latest Construction 4.0 Strategic Plan 2021-2025 of Malaysia (under Technology Clustering - Simulation & Modelling). It is outlined in the strategic plan that the construction industry's future will be highly dependent on the adaptation of new technologies and innovations to current processes. Adopting new technologies with new innovative methods such as BIM will shift how buildings and infrastructure projects are delivered.

There was lacking in the development of green highway rating systems and the needs of BIM sustainable criteria verification. Certification awarded in assessment tools would gauge importance in pinpointing success and opportunities for improvement in making sustainable choices or practices Nikumbh and Aher (2017). Malaysia lacks green highway rating systems to evaluate its sustainable design performance (Rooshdi et al., 2018). Integrating BIM features in sustainability assessment criteria in highway construction systems is analytical and necessary for more specific criteria verification. This is also in line with the government policy in relation to green building and rating tools addressed in the latest Construction Industry Transformation Programme (CITP) review – 2019-2020. The CITP key outcomes by 2020 under the Focus Area 4: Sustainability specifically underlined that for the sustainable infrastructure, 50 % of new infrastructure projects more than MYR 100 million to be certified in Sustainable INFRASTAR or any proper sustainable infrastructure tool from December 2020 onwards.

5. Conclusion

As outlined in the Construction Industry Transformation Programme (CITP) (2016-2020), under the thrust of Environmental Sustainability, more rating tools need to be developed to promote sustainable development, mainly infrastructure development in the Malaysian Construction Industry. The CITP review (2019-2020) key outcomes by 2020 under the Focus Area 4: Sustainability specifically underlined that for the sustainable infrastructure, 50 % of new infrastructure projects more than MYR 100 million to be certified in Sustainable INFRASTAR or any proper sustainable infrastructure tool from December 2020 onwards. As for BIM technology, its implementation has been strengthened in the latest Construction 4.0 Strategic Plan 2021-2025 of Malaysia (under Technology Clustering - Simulation & Modelling), outlining that adoption of new technologies with new innovative methods such as BIM will see a shift in how buildings and infrastructure projects being delivered in the Malaysian construction industry. In conclusion, there is a high priority need for an integrated assessment tool integrative assessment framework of building information modeling (BIM) and sustainable green highway construction. Further research would be done based on this paper review.

References

Abdirad H., 2017, Metric-based BIM implementation assessment: A review of research and practice, Architectural Engineering and Design Management, 13(1), 52-78.

Bryce J., 2008, Developing Sustainable Transportation Infrastructure Exploring the Development and Implementation of a Green Highway Rating System, Washington Internship for Student of Engineering, University of Missouri, United State of America.

Balubaid S., Bujang M., Aifa W.N., Seng F.K., Rooshdi R.R.R.M., Hamzah N., Ismail H.H., 2015, Assessment index tool for green highway in Malaysia, Jurnal Teknologi, 77(16), 99–104.

Carbonari A., Corneli G., Di Giuda L., Ridolfi V., Villa, 2018, BIM-Based Decision Support System for The Management of Large Building Stocks, ISARC, IAARC Publications, 1-8

Chen, L., and Pan, W., 2015, A BIM-integrated fuzzy multi-criteria decision making model for selecting low-carbon building measures. Procedia Engineering, 118, 606-613.

Eastman C., Teicholz P., Sacks R., Liston K., 2011, BIM handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors, John Wiley and Sons Inc, New Jersey, United States.

Fernández-Sánchez G., Rodríguez-López F., 2010, A methodology to identify sustainability indicators in construction project management - Application to infrastructure projects in Spain, Ecological Indicators, 10(6), 1193–1201.

Gandhi S. and Jupp J.R., 2013, Characteristics of Green BIM: process and information management requirements. In IFIP International Conference on Product Lifecycle Management, 1st July, 596-605. Springer, Berlin, Germany.

Griffith A., Bhutto K., 2009, Better environmental performance: A framework for integrated management systems (IMS), Management of Environmental Quality, 20(5), 566–580.

Haruna A., Shafiq N., Montasir O.A., 2021, Building information modelling application for developing sustainable building (Multi criteria decision making approach), Ain Shams Engineering Journal, 12(1), 293-302.

Hope A., Alwan Z., 2012, Building the future: Integrating building information management and environmental assessment methodologies, In: First UK Academic Conference on BIM, 5 -7 September 2012, Northumbria University, United Kingdom.

Hussain M. H., Erzaij K. R., 2020, Sustainability Assessment System for Highrise Buildings in Iraq, In International Conference on Geotechnical Engineering-Iraq, 19 - 20 February 2020, Baghdad, Iraq.

Ismail N.A.A., Chiozzi M., Drogemuller R., 2017, An overview of BIM uptake in Asian developing countries, In Proceedings of the 3rd International Conference on Construction and Building Engineering (ICONBUILD) 2017: Smart Construction Towards Global Challenges, 14 – 17 August 2017, Palembang, Indonesia.

Ismail N.A.A., 2017, Construction Cost Estimating Incorporating Building Information Modelling (BIM) in the Malaysian Construction Industry, PhD Thesis, Queensland University of Technology, Australia.

Krejcie R.V, Morgan D.W.,1970, Determining sample size for research activities, Educational and Psychological Measurement, 30, 607–610.

Khoshdelnezamiha G., Liew S.C., Bong V.N.S., Ong D.E.L., 2019, BIM-based approach for green buildings in Malaysia, IOP Conference Series: Earth and Environmental Science, 268(1).

Liu Y., van Nederveen S., Wu C., Hertogh M., 2018, Sustainable infrastructure design framework through integration of rating systems and building information modeling, Advances in Civil Engineering, 2018, 1-13.

Malaysia Highway Authority, 2010, Preliminary Guide to Nurture Green Highway in Malaysia (1st ed.), Lembaga Lebuhraya Malaysia, Malaysia.

Maltese S., Tagliabue L.C., Cecconi F.R., Pasini D., Manfren M., Ciribini A.L.C., 2017, Sustainability assessment through green BIM for environmental, social and economic efficiency, Procedia Engineering, 180, 520–530.

Mansson D., Hampson K., Lindahl G., 2017, Assessing BIM performance in building management organisations, The 9th Nordic Conference on Construction Economics and Organisation. Polyteknisk Forlag, Denmark, 375-387.

Nikumbh K., Aher P.D., 2017, A review paper - Study of green highway rating system, International Research Journal of Engineering and Technology, 4(5), 2104–2108.

Pavlovskis M., Antucheviciene J., Migilinskas D., 2016, Application of MCDM and BIM for evaluation of asset redevelopment solutions, Studies in Informatics and Control, 25(3), 293–302.

Raja Muhammad Rooshdi R.R., 2019, An assessment tool of sustainable design and construction activities for green highway, PhD Thesis, Universiti Teknologi Malaysia, Johor Bahru, Malaysia.

Rooshdi R.R.R.M., Majid M.Z.A., Sahamir S.R., Ismail N.A.A., 2018, Relative importance index of sustainable design and construction activities criteria for green highway, Chemical Engineering Transactions, 63, 151–156.

Rojas M.J., Herrera R.F., Mourgues C., Ponz-Tienda J.L., Alarcón L.F., Pellicer E., 2019, BIM use assessment (BUA) tool for characterizing the application levels of BIM uses for the planning and design of construction projects, Advances in Civil Engineering, 2019, 1-6.

Sahamir S.R., Zakaria, R., Alqaifi G., Abidin N.I., Rooshdi R.R.R.M., 2017, Investigation of green assessment criteria & sub-criteria for public hospital building development in Malaysia, Chemical Engineering Transactions, 56, 307–312.

Sharma S., Sawhney A., Arif M., 2017, Parametric modelling for designing offsite construction, Procedia Engineering, 196, 1114-1121.

Solla M., Ismail L.H., Yunus R., 2016, Investigation on the potential of integrating BIM into green building assessment tools, ARPN Journal of Engineering and Applied Sciences, 11(4), 2412–2418.

Tan T., Mills G., Papadonikolaki E., 2021, Combining multicriteria decision making (MCDM) methods with building information modelling (BIM): A review, Automation in Construction, 121, 103451.