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# THE INTEGRATION OF BIM AND IBS: A CASE STUDY OF HARMONI ELMINA 1, SELANGOR, MALAYSIA

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## ABSTRACT

*Innovative construction practices drive progress in the development of sustainable, efficient, and high-quality residential buildings. Yet, this practice in residential buildings remains limited. This study investigates the innovative construction practices applied in the development of Harmoni Elmina 1, with a focus on the integration of Industrialised Building Systems (IBS) and Building Information Modelling (BIM). Through a case study approach, key innovations were explored through interviews and project documentation analysis. BIM played a crucial role in the planning, design, and construction stages, reducing error, waste, and risk while enhancing cost efficiency and project progress. Moreover, 10 IBS components, including precast concrete, bubble deck systems, precast reinforced concrete, and prefabricated components, were utilized, further enhancing construction efficiency and quality. The findings demonstrate that integrating BIM and IBS significantly improved project performance, conserve project duration by 28-33%, preliminary cost by 30%, and achieving near zero construction waste. Inclusively, this case study offers valuable insights for industry* *professionals by showcasing best practices in BIM and IBS integration, providing a model for improving project outcomes, resource efficiency, and sustainability in the built environment. Projects like Harmoni Elmina 1 highlight the transformative potential of innovation in improving living standards, and promoting more sustainable built construction industry.*

**Keywords**: *Building Information Modelling (BIM), Industrialised Building System (IBS), Case Study, Sustainable Development, Residential Building*

## INTRODUCTION

Innovation in the construction sector significantly contributes to domestic economic growth, enhancing global competitiveness, and improving the quality of life. Theoretically, innovation is built to help the industry enhance productivity, efficiency, and sustainability. Various definitions have been proposed to describe the innovation in construction. According to Gann, (2000), innovation in construction involves the introduction and application of new technologies, materials, techniques, processes, and organizational practices with the purpose of improving efficiency, quality, and sustainability. In line with that, Liu, Sepasgozar, Shirowzhan, & Mohammadi, (2022) further indicate that innovation in construction integrates emerging technologies and processes to enhance project planning, design, monitoring, and project management.

The Fourth Industrial Revolution (4IR) has transformed the industry into modern construction and technology, resulting in more complex building designs and functions, which some of the development cannot be managed through the conventional construction method (Ajugiya et al., 2016). Consequently, the industry has embraced innovations and digitalization, leading to the implementation of Construction 4.0 (C4.0). The core concept of C4.0 particularly mirrors emerging trends of digitalization, automation, and more extensive use of Information and Communications Technology (ICT) (Alaloul et al., 2020). It aims to overcome the limitations of the conventional method, efficiently manage and control the entire construction process, and improve project performance and productivity (Ahmad Latiffi et al., 2013; Alaloul et al., 2020; Tahir, Haron, Alias, Al-Jumaa, et al., 2018). The key component of C4.0 is the implementation of the Building Information Modelling (BIM) and Industrialised Building System (IBS) (Ahmad Latiffi et al., 2013).

In Malaysia, the adoption of Building Information Modelling (BIM) and Industrialised Building Systems (IBS) has been increasing, spurred by the government initiatives outlined the significance of these technologies in several government five-year plans for the construction industry, particularly in Construction 4.0 Strategic Plan 2021-2025. Typically, these technologies have been implemented separately. However, the Construction Research Institute of Malaysia (CREAM) in collaboration with Sime Darby Property and G&A Architects, has pioneered a project by merging both technologies. This pilot project, Harmoni Elmina 1 utilizes the Divergent Dwelling Design (D3) concept. Additionally, recognized by the National Affordable Housing Policy (NAHP) and National Housing Standard (CIS 26) as an "Affordable and Sustainable Homes", this project serves as an exemplary case study for a successful D3 concept using the integration of BIM and IBS (Ministry of Housing and Local Government, 2019).

The Divergent Dwelling Design (D3) concept is an innovation in which the key of the construction method is IBS. From the study conducted by CREAM, this concept aims to increase the building performance, specifically enhancing the building quality, and site safety, shortening the construction duration, and reducing the project cost (Mohd Zain, 2023). Besides, at the initial stage of the project development, BIM was implemented to ensure the project planning was aligned with the project requirement, maintaining a good track to achieve the project goals.

The integration of these technologies is unique and brings the industry to the next level. Yet, this integration has not been critically explored by the scholars. To address the limitation, this paper aims to investigate the implementation of BIM and IBS integration in the Harmoni Elmina 1 project. This study will shed light on the integration process, impact, and best practices, serving as a guide for the construction players to implement this concept for future projects.

## STUDY AREA

Harmoni Elmina 1 is a three-block apartment building nestled in the City of Elmina, Selangor, Malaysia. The project is categorized as an affordable housing initiative, developed under the Selangor government housing project scheme, called “Rumah Selangorku”. The construction project began in 2019 and was completed in 2023. This development spans a 7.33-acre land area, strategically ensconced amidst the connectivity of five major highways: Guthrie Corridor Expressway (GCE), North Klang Valley Expressway (NKVE), North-South Expressway (PLUS), Kuala Lumpur-Kuala Selangor Expressway (LATAR), and Federal Highway.

Comprises 562 apartment units spread across two 19-storey blocks (Block A and Block B) and one 20-storey block (Block C). Furthermore, Harmoni Elmina 1 offered two different layouts (Type C and Type D), each featuring three bedrooms and two bathrooms within a range of 900 sq ft and 1,000 sq ft. Other than that, this development also complimented the shop offices and a multi-story car park, with provisions for six specially adapted units for disabled individuals across Block A and Block B, located on level 1. The pricing spectrum for this development is between RM 200,000 for 900sq. ft unit and RM 250,000 for a 1,000 sq. ft unit. Figure 1 illustrates the location and the site layout of the Harmoni Elmina 1.

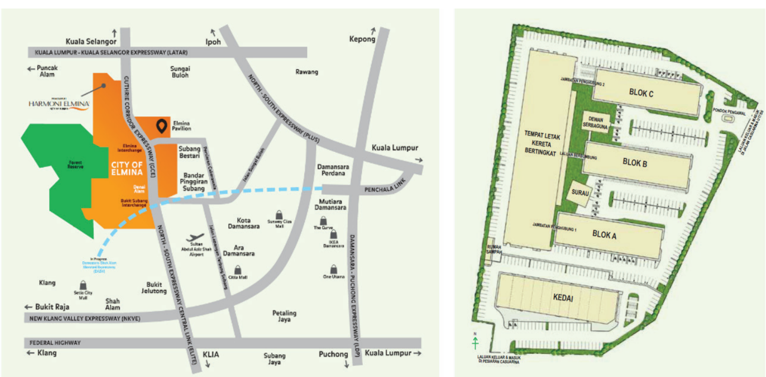


**Figure 1. Location and Site Layout Harmoni Elmina 1**

Sources: (Sime Darby Property, 2019)

Giving a nod to tradition, Harmoni Elmina 1 draws inspiration from the quintessential “Traditional Malay House” architecture. The design comprised the elements such as the Rumah Ibu (main house), attached to rooms at the side, a serambi (verandah) and an anjung (porch) at the front house, a pelantar in the middle, and a kitchen at the back of the house (Mohd Sahabuddin, 2012). This concept ethos is good in providing natural daylighting and also optimizes thermal efficiency, and air ventilation, underscoring its commitment to environmental sustainability. Based on the concept of a traditional Malay house above, Harmoni Elmina 1 replicates the same concept and applies it to the high-rise building. Each apartment features three bedrooms, a living room, and a dining room. Additionally, the design includes three separate open spaces or courtyard areas: a garden, a private space, and a laundry area. These spaces, along with an open kitchen and two bathrooms, are separated from the main house (bedrooms, living hall, and dining room) by doors and sliding doors. Figure 2 illustrates the concept of the original traditional Malay house adopted by Harmoni Elmina 1.

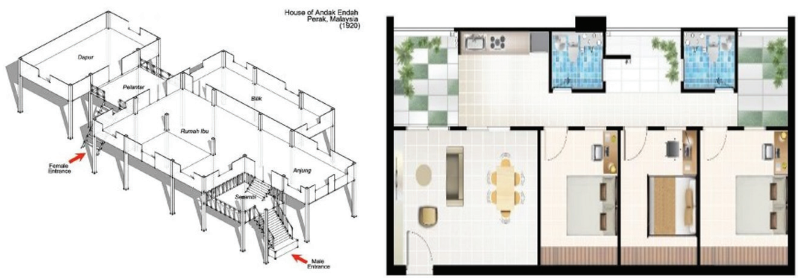


**Figure 2. The Concept of Traditional Malay House and Replication in Harmoni Elmina 1**

Source: Andak Endah House, 1920 (Mohd Sahabuddin, 2012) and Harmoni Elmina 1 Site Layout (Sime Darby Property, 2019)

Interestingly, the development of Harmoni Elmina 1 is notable for its utilization of ten components of Industrialised building systems (IBS), each IBS component used in this project is shown in Figure 3. Additionally, for the type D layout, this unit was installed with a drywall between the living room and bedroom 2, which can be removed to extend the space if needed. Conversely, in the type C layout, the wall is a prefabricated element and cannot be removed.

This housing project is unique due to its construction method, which integrates BIM and IBS components in a project. The integration of these technologies in the Harmoni Elmina 1 has had a positive impact on overall project cost, quality, time, site safety, and near zero construction waste. Initially, the timeline for this project was estimated to be around 24 to 30 months to complete, which is shorter than similar conventional construction projects that require 48 months. However, due to the unexpected COVID-19 global pandemic, this project duration was extended to approximately 42 months, still the duration is lower than the conventional method.

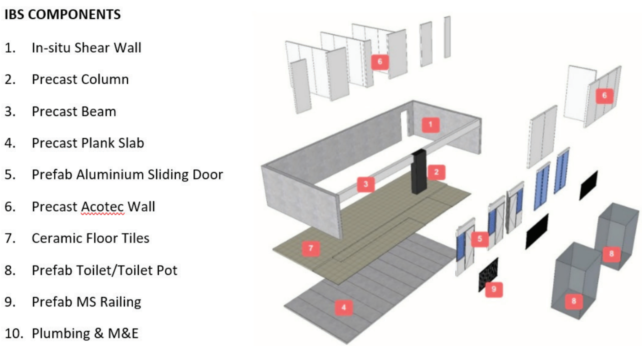


**Figure 3. IBS Components in Harmoni Elmina 1**

Source: Author

## METHODOLOGY

A qualitative research approach was adopted in this study, as it is commonly used to explore and acquire an in-depth understanding of an issue as well as to develop a better interpretation of the issue at hand from the perspective of the people who are involved and understood by them (Creswell & Creswell, 2018; Saunders et al., 2019). Then, to achieve the objectives of this study, a case study strategy was employed. According to Yin, (2018), a case study is typically used when the boundaries between the phenomenon being studied and the context in which they are studied are blurred. Thus, it is rational for this study to use this strategy in order to have a broad overview of the innovative construction practices applied in the development of Harmoni Elmina 1 by having an in-depth study of a real-life case in terms of the implementation, impact, and the best practice of this project through two key entities involved in this project development.

### Data Collection

The primary data was collected through semi-structured interviews and secondary data was sourced from official documentation where access was granted. The interview invitation was sent to five participants, but only two of them agreed to be interviewed. The interviews were conducted with two key entities: the representative from the Construction Research Institute of Malaysia (CREAM) and Sime Darby Property, both of which are directly involved in the development of the Harmoni Elmina 1 project and at the same time conducted a brief study regarding this project. BIM was implemented by the BIM team from Sime Darby Property, while, the concept and idea are from CREAM and G&A Architects. These interviews took place in early May 2024 through telephone conversation and the results were analyzed. To maintain the confidentiality, the full identity of the participants was concealed. Each interview lasts between 40 to 60 minutes. During the interviews, participants were provided with the chance to expand their discussion and exchange whatever information they had to get productive feedback. The interviews were recorded, transcribed, and analyzed using thematic analysis.

### Data Analysis

The thematic analysis was utilized to identify recurring themes in the interview transcript. This method is advantageous due to its flexibility and applicability to a wide range of theoretical frameworks and research interests (Clarke & Braun, 2013). Additionally, through this analysis, the frequency and significance of themes that related to the innovative construction practices at Harmoni Elmina 1 were identified. This approach highlights the integration, impact, and best practices based on the emerging themes. Next, all the findings were then compared to the trend identified deductively during the literature review, ensuring a comprehensive understanding of the case study.

## RESULT AND DISCUSSION

This section describes and presents the results from the analysis of the integration of BIM and IBS in the Harmoni Elmina 1. Four themes have been identified and analyzed. The themes are the integration process of

BIM and IBS, the impact, and the best practices that can be adopted for future projects.

## The Integration Process of BIM and IBS

In Harmoni Elmina 1, the integration of BIM and IBS was implemented at the initial stage of the development process, which is in the conceptual, design, and planning stages. This stage plays a pivotal role in enhancing the project efficiency and productivity through streamlined the construction process. This was explained by the participant as follows:

*"For the integration, we are focusing on the initial stage, because this stage is important in determining your project success or not"-P1*

*"We apply the integration at the earlier stage of the project to reduce the potential errors and to make sure the project planning is smooth and according to the requirement" – P2*

As affirmed by several scholars, the implementation of BIM at the initial stage of the project has a pivotal role in determining the accuracy of the building design and planning that would enhance the project design and planning efficiency (Babič et al., 2010; Eadie et al., 2013; Li, 2022; R. Yahya & A. Hatem, 2023; Salleh et al., 2023).

Furthermore, the integration has facilitated better planning and coordination throughout the project. IBS itself minimized the revision and rework due to IBS components have been designed and manufactured according to the specifications needed and assembled on-site, while BIM provides detailed and precise digital representations. Thus, it contributes to the high-quality, consistency, smoother workflows, and efficient project management. Below is the statement from the participant regarding the findings:

*"You know that IBS is manufactured in the factory and then assembled on-site, right? So, we have already minimized errors and the duration of the project. From that, we were able to manage our project management efficiently. For BIM, we used to monitor the design and provide details, both physical and digital. So, I would say it is easier than the common construction method when integrating these technologies, and we are able to control the quality of our*

*project"- P1*

*"When we started this integration, we did not 100% believe the outcome would be this great because it is a new technology. But, Alhamdulillah, this project is successfully delivered, and the progress is smooth and on track. So far, the quality is better than the conventional method" – P2*

This finding is in line with Ang Soon Ern et al., (2022) who explored the benefits and challenges of BIM and IBS integration in construction projects. In his findings, BIM implementation in the IBS project was able to visualize the design, improve the project efficiency, and improve the project quality.

In addition, the integration contributes to the improvement in communication and collaboration among the project team. This is because BIM provides a platform for effective communication and coordination. Due to that, the miscommunication can be reduced. Furthermore, through this platform, the project team is also able to detect errors, make instant decisions to resolve the issues, and instantly update the project. The specification of the IBS component is also presented and decided in this platform to ensure the IBS component is aligned with the project specifications. This was agreed by the participants in their statement below:

*"All the IBS component information and project details are gathered in our BIM platform, so it will give us updates from time to time. We share our opinion there, discuss, make instant corrections, and update all the team on the latest information" – P1*

*"Ya, through this integration, many things can be done in a great way. We optimized the function of these two technologies to deliver this project. So far, BIM has played a significant role for us in making sure the development process is always on track and minimizing the conflict in the planning stage. For the IBS component, we control the quality and make a strict selection". – P2*

Ahuja, Yang, & Shankar, (2009) and Sebastian, (2011) corroborate that BIM offers a platform that effectively manages bundles of information, to improve project collaboration and coordination. Thus, it significantly reduces the risk of miscommunication in transcribing project information.

Other than that, the interoperability of BIM with the IBS system is also highly considered during the project planning. This is also agreed by Shirowzhan, Sepasgozar, Edwards, Li, & Wang, (2020) that interoperability is a key barrier in integrating those technologies, and it must be highly considered before it can be implemented. Since the concept of integration is newly introduced in the industry, the try-and-error concept based on lessons learned from the expertise's experience and research & development (R&D) is adopted until the interoperability is matched. This was explained by the participants as follows;

*"In this integration, the most important thing is to look at their interoperability. In the process of BIM, we need to understand each software, and platform of data sharing that we use and decide which one can work together right? So, the same concept applies here. We need to understand and decide which BIM are able to integrate in this project" – P2*

Besides, at the earlier stage of the Harmoni Elmina 1, the project team discussed the best option that can be utilized in this project including the process, the best IBS component that can be adopted, the advantages and disadvantages of each IBS component, the prevention and maintenance, timeline of IBS delivery, the potential supplier, and many other projects detail. Each finding has been recorded and updated to the project team for other detailed discussion and agreement. Thus, all the procedures have given a great performance in project planning, cost management, and material selection (Ang Soon Ern et al., 2022). This was corroborated by the participants in their statement below;

*"You know, from the start all the IBS component is properly selected, we are very choosy and strict on this because once you select unsuitable IBS components, then it is unmatched with other IBS components, and your project is rubbish". – P2*

## The Impact

Through this study, several significant impacts have been identified based on the integration of BIM and IBS in Harmoni Elmina 1. Most of the impacts were from a positive viewpoint, which can be classified as the advantages of the integration between BIM and IBS. Table 1 below shows themes collected from the interview to describe the impact of the integration on the Harmoni Elmina 1 project development.

**Table 1. Themes Generated from Interviews**

| Themes | Participants | |
|---|---|---|
| | P1 | P2 |
| Enhance project efficiency | √ | √ |
| Streamlined the process | √ | √ |
| Enhance productivity | √ | √ |
| Reduce cost | √ | √ |
| Time-saving | √ | √ |
| Improved quality | √ | √ |
| Accurate design | √ | √ |
| Improve safety | √ | √ |
| Enhanced collaboration and communication | √ | √ |
| Better project monitoring | √ | √ |
| Real-time updates | √ | √ |
| Efficient project management | √ | √ |
| Sustainability | √ | √ |
| Reduce wastage up to 0% | √ | √ |
| Flexible and adaptability | √ | √ |
| Conflict detection | √ | √ |

Source: Author

Throughout the 16 themes identified in this study, the author has summarized them into 5 main categories of impact which are (i) Enhancing project efficiency and productivity; (ii) Cost saving; (iii) Improved quality and precision; (iv) Enhanced collaboration and communication.; (v) Sustainable and environmental impact.

In enhancing the project efficiency and productivity, the authors classified the integration of BIM and IBS contributes a positive impact on the project, particularly in streamlining the development process, enhancing productivity through systematic workflows, time-saving, accuration in design, efficiency in project management from monitoring to controlling, and early detection of conflict or issue in the project. All these processes are considered by several scholars as the factors that enhance the project's efficiency and productivity (Li, 2022; R. Yahya & A. Hatem, 2023; Salleh et al., 2023). As mentioned by the participant frequently in the interview session.

> *"The simple way to understand the impact of the integration in this project is that the workflow is smooth, the timeline is near to perfect, and the final product that we get is also good. What I can say, is this project is efficiently managed" - P1*

In addition, integrating these technologies aligns with the D3 concept and has led to cost reduction due to the full adoption of IBS and the use of BIM in project planning. The reduction in project errors, reworks, and waste during construction development has contributed to lower overall costs. This finding is supported by studies by Arayici, Egbu, & Coates, (2012); Haron, Raja Soh, Harun, Raja Soh, & Harun, (2017); Tahir, Haron, Alias, Harun, et al., (2018); Zhang & Gao, (2013). As explained by the participant below;

> *"After the project is completed, we can breathe a sigh of relief, because our targets to reduce the cost for this project were achieved, even though not much, it is proven that this integration can be successful when it is done correctly. For our project, the cost rate should have decreased more, but due to the COVID-19 situation during the construction period, it slightly decreased but it was still a victory for us" – P2*

Thirdly, the improvement in quality and precision. Since the project planning and specification were efficiently managed, and material selection was strictly chosen, thus, the quality of the project will be of a higher standard. This agreed by the participants as follows;

> *"The selection of IBS component and its vendors is strictly chosen; we properly checked and considered many criteria. So, for the quality, it is at a high standard. Same with the installation process, we monitor most of the process to make sure the quality is excellent" - P1*

Similar to the previous findings, the integration has improved the collaboration and communication between the project team and the client itself. Discussions can be done by considering the opinion of the project team before decision-making. Last but not least, the fifth impact is on sustainability and environmental impact. By using IBS, this project reduces near to zero waste, and the utilization of BIM is able to manage the energy efficiency in the building including the use of natural ventilation, thermal efficiency, and natural daylighting.

*"With the design concept of Traditional Malay House", the natural ventilation and lighting can be utilized in this project. So, the sustainability is there" - P2*

*"We consider sustainability impact when we design this project because the SDG elements always be our aims" – P1*

## Best Practice for Industry Adoption

The key strategies and methods used in integrating BIM and IBS in the Harmoni Elmina 1 project serve as best practices that can be adopted for future projects. The participants have concluded this best practice as below;

*"What can I describe today, the integration of BIM and IBS teaches us how important comprehensive planning is at the earlier stage of the integration in a project if you want your project to become successful, another thing BIM and IBS utilization in a project is a token to improve your project, and also for sustainability" – P1*

*"As agreed by the government, we will implement this integration to our next affordable housing project. This is good for your project to have better planning throughout the project development process and to urge the industry to implement BIM and IBS. At the same time, to increase awareness of the benefits of using these technologies. Also, for the sustainable construction" – P2*

From these points, the authors have summarized four best practices factors that need to be considered in future projects, which is also pointed out by studies conducted by Ang Soon Ern et al., (2022); R. Yahya & A. Hatem, (2023); Salleh et al., (2023); Xue, Zhang, Yang, & Dai, (2014).

## Comprehensive Planning and Early Integration

The early involvement of the project team in developing ideas, providing critiques, and offering opinions during the conceptual and planning stage has significantly contributed to comprehensive planning. Additionally, integrating BIM and IBS from the start has further enhanced project planning. Therefore, for delivering a successful project, best practices should include early integration of BIM and IBS to ensure that comprehensive planning is achieved.

### Effective use of BIM for Design and Coordination

BIM is effective in a project because it helps to improve the project development from the project conceptual planning until the operation stage. The effective use of BIM is to detect construction errors and resolve the issue, optimize the cost, reduce time, improve quality, and also improve collaboration as well as coordination in the project.

### Utilization of Prefabricated IBS Components

The utilization of IBS components in the Harmoni Elmina 1 project has simplified the construction process and improved efficiency. The quality of the IBS component is ensured by stringent quality control measures during the manufacturing process. This is to ensure the quality IBS component meets the project design specification.

### Sustainability and Environmental Consideration

The material and construction method selection are pivotal factors in determining the sustainability of a project. Due to that, the utilization of IBS in this project reduces the environmental impact such as construction waste, and contributes to a more sustainable building process. Additionally, BIM acts to simulate and analyze the environmental performance of different materials and design, thermal, and energy efficiency in the overall project.

## CONCLUSIONS AND RECOMMENDATIONS

BIM and IBS are two different perspectives that have been considered to have the potential to solve the long-standing difficulties in the construction industry, particularly in monitoring, managing, and controlling the project development process. The integration of these two technologies is known as a process of complementary each technology by maximizing the strengths and minimizing the weaknesses. The integration of BIM and IBS in the Harmoni Elmina 1 project demonstrates substantial benefits for the construction project. This integration was employed at the initial stage of the project development where the conceptual, design, and project planning were taking place. In this stage, the project team strictly monitored, managed, coordinated, and controlled the project's progress, and made decisions, which led to comprehensive project planning. Enhanced the project planning efficiency and productivity, achieved cost savings, improved project quality and precision, and fostered efficient collaboration and communication among the project team. Additionally, the integration also has contributed to sustainable and positive environmental impacts, marking a potential for a new era for Malaysia's construction industry in the future.

From the perspective of best practice for industry adoption, the integration can be employed by other projects by considering the comprehensive planning and early integration of both systems, optimizing the utilization of BIM and IBS in the project by exploring the benefits and various components in the IBS field, also considering the benefit to the environmental impact for sustainable construction.

Overall, the integration of BIM and IBS has been successfully implemented in the Harmoni Elmina 1. Even though the integration was focused at the initial stage of project development, the project goal was achieved. Additionally, the project has been recognized by the government as an Affordable and Sustainable Home under the National Affordable Housing Policy (NAHP), and the concept is expected to be widely implemented in the next affordable housing development.

For future research, the author recommends a comprehensive study by comparing the integration of BIM and IBS project with the project using the system individually. Then, another suggestion is to investigate the challenges faced by this project during the entire project development process. Another idea that can be used to improve this study is to assess the long-term impact of this pilot project and also covered the limitation from this study.

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## AUTHOR CONTRIBUTIONS

Farah Salwati Ibrahim: Worked on all aspects of the paper, involving the writing, literature, data collection, and analysis of the paper. Muneera Esa: Worked on the final review and proofreading of the paper. Wan Nursyazwani Wan Mohammad: Worked on the final review of the paper. Wan Hanani Wan Abdullah: Worked with authors for data collection and review of the paper. Raja Nurulhaiza Raja Nhari: Worked on the review of the paper and formatting.

## CONFLICT OF INTEREST

The authors declare no conflict of interest.

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