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Future-Ready Construction and Facility Management:
Driving Research and Innovation for a Smart Built Environment

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SMART DIGITAL MODULAR SCAFFOLDING (SDMS) FOR LOW-RISE BUILDING

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Abstract
Scaffolding systems are essential for the safety and efficiency of construction workers. However, the manual adjustment of the height in a traditional scaffolding system can cause delays due to time consuming and a high safety risk. Therefore, to improve efficiency and safety this study presents the Smart Digital Modular Scaffolding (SDMS) as an innovation project mainly for low rise building. The research methodologies used in this innovation project are desk study and simulation techniques. 2D and 3D modelling using Revit and SketchUp software, which enabled virtual testing prior to actual implementation. Key findings indicated that the Smart Digital Modular Scaffolding reduces the need for manual assemble and disassemble while significantly enhancing height adjustment efficiency using a hydraulic pump and remote-control system. This new idea makes the height adjustment safe and efficiency of movement in height adjustment for platform is achieved. This innovation project improves construction efficiency and safety by reducing on assembly time and improving workflow, which may have an impact on future construction industry standards. Additionally, it supports innovation and technological improvement in the building industry, which is align with Sustainable Development Goal (SDG) 9.

Keywords: modular scaffolding, smart digital, assembly, safety

1. INTRODUCTION

Scaffolding is a temporary framework used to support materials and labourers during the construction, maintenance, and repair of buildings and other structures. It is primarily used to give workers a safe working platform while preserving structural integrity and stability during different phases of construction (Southwest Scaffolding & Supply, 2024). Scaffolding safety is importance because working at heights carries inherent risks. Strict safety procedures are followed when erecting, using, and disassemble scaffolding, according to laws and standards that set by the Occupational Safety and Health Administration (OSHA) (SafetyCulture, 2024). The development of scaffolding has prompted the use of cutting-edge methods, like modular scaffolding systems, which provide labour savings, flexibility, and ease of assembly. Compared to traditional scaffolding types, it is more flexible and efficient (The Editors of Encyclopaedia Britannica, 2019). Modular scaffolding comprised of prefabricated, standardised parts that are quick to install and disassemble, such as diagonal bracing, horizontal ledgers, and vertical posts. This design makes it simple to adapt to different structural configurations, which improves on-site efficiency and safety *(Frederike Berg, 2022).* The development of innovative scaffolding technologies, like prefabricated and modular systems, improves the productivity and safety of construction projects, so that SDG 9 cane be achieved (alpine, 2020).

The significance of this study is to greatly progress the construction industry by tackling important existing modular scaffolding system-related concerns. It can help workers

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reduce time for assembly and disassembly when adjusting height of platform. It is because improve on the height adjustment do not need do manually compare to the existing modular scaffolding. Enhance the safety as there is no manual assembly and disassembly are required. It can also reduce work delays by improving work quality in the construction industry. The project intends to alleviate common issues including safety and assembly challenges by creating a scaffolding system that prioritises safety, efficiency of workflow, and structural integrity.

The inefficiency of height adjustment of the existing modular scaffolding which are manually adjusted, make it similar to the traditional scaffolding. Because existing systems usually require disassembling and reassembling components in order to change platform heights, the efficiency of movement in height adjustment is limited. The existing product is time-consuming to assemble and dissemble manually and if errors occur during that process, it may compromise safety. It also can delay the construction time (Anuar, 2023c). This had developed a research question on how advance technology of digitalisation being adopted in the innovation of existing modular scaffolding. Therefore, the aim of this study is to innovate modular scaffolding with smart digitalisation in minimizing safety risk and increase efficiency among construction workers.

2. LITERATURE REVIEW

Scaffolding is a structure that ensures worker safety while enabling high-altitude work. They are frequently employed on the job site to gain access to areas that are difficult to reach, including heights *(Pieńko & Robak, 2018).* In this study, there are several types of modular scaffolding are Cuplock Scaffolding, Ringlock Scaffolding and Kwikstage Scaffolding as shown in Table 1. Cuplock scaffolding, is made up of horizontal ledgers and vertical standards (uprights), which are joined by a special locking device called a "cuplock". Without the use of nuts, bolts, or wedges, the ledgers may be quickly and safely fastened into the uprights thanks to the cuplock system (APAC, 2023). Prefabricated components of ringlock verticals (standards), starters (base collars), ringlock ledgers, diagonal braces, truss ledgers, scaffold transoms, brackets, base jacks, scaffold planks, stairs, head jacks, lattice girders, etc. make up the flexible modular scaffold system known as ringlock scaffolding, which is primarily utilised in industrial construction (WellMade, 2023). Kwikstage scaffolding is a modular scaffolding system commonly used in construction projects. Vertical standards, horizontal ledgers, and transoms that are joined by wedge locks for easy assembly and disassembly are among the prefabricated parts that define this system (Avontus, 2021). Triangular pressings on the standards improve stability and load-bearing capability by allowing the simultaneous attachment of up to four ledgers.

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Table 1 Types of Modular Scaffolding

Criteria/Types	Cuplock Scaffolding (APAC, 2023) 	Ringlock Scaffolding (WellMade, 2023) 	Kwikstage Scaffolding (Avontus, 2021) 
Material	Mild steel	Mild steel	Mild steel
Assembly	Moderate within 30-45 minutes	Faster within 20-35 minutes	Slightly slow within 40–60 minutes
Flexibility	Moderate flexibility	High flexibility	Low to moderate flexibility
Safety	Less safe because manually height adjustment	More safer for height adjustment because of multi-angle rosette connectors	Less safe because manually height adjustment same as Cuplock Scaffolding
Efficiency of movement in height adjustment	Platform movement to adjust heights is manual	Adjust platform heights is manual but more faster than Cuplock Scaffolding	Platform movement to adjust heights is manual

Based on the literature review, the criteria such as material, assembly time constraint, limited flexibility, safety, and manual adjustment of the platform are the issues that arise when using the existing modular scaffolding. Thus, this indicates that inefficiency and high risk of safety are still occurred.

3. METHODOLOGY

The four processes of research design as a framework for innovation project were implemented. The framework consists of emphasize, define, ideate and simulation (Securitas AB, 2024). In emphasize, gathering an important information from online publications such as journals, and website were accomplished (Dam, 2024). While define indicate the problems in the existing modular scaffolding which able to recognize through literature review (Stevens, 2020). Design is a stage that important to develop creativity idea by referring to the issues and problems of existing modular scaffolding (Han, 2022). Simulation is creation in virtual of the innovation idea (Yu Siang, 2019). using Revit and Sketch Up software to form 2D and 3D modelling. This two software were also used to demonstrate the assembly and performance of the SDMS product.

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Two data collection methods were used in this innovation project such as desk study and simulation. A methodical process for examining or assessing the written and digital materials, including computer-based and website network content, is also known as desk study. The simulation was using Sketch Up for the development of the innovative idea of Smart Digital Modular Scaffolding. This software is essential for visual representation of the innovation concept so that the benefits, methods, and basic design can all be better understood. Content analysis was used to evaluate the performance of Smart Digital Modular Scaffolding in comparing with the existing modular scaffolding.

4. FINDING AND DISCUSSION

The performance of SDMS is divided into specific components, which consist of an off-road tire, a motor for movement, a hydraulic pump for an adjustable platform, a single stick controller, a remote control for platform movement, and an access platform gate. The efficiency of movement in height adjustment for the platform can be achieved as shown in Table 2. It means that to adjust the height of the platform electronically and not manually like the existing modular scaffolding. Just use the remote control that connect with hydraulic pump to control the movement of the working platform. So, the worker can adjust the work platform to the required height. If they want to move the platform upwards, just press the upwards button and if want to move downwards just press the down button. The assembly time for the proposed product is faster than the existing product (approximately within 15-20 minutes). This is applied for a 2 storey building. The delays of the work also can be prevented and the project will be completed within the given time. The safety will be more guaranteed because there is no manual height adjustment. Usually during the process of assembling and disassembling, errors can happen.

Table 2 Performance comparison of Existing Modular Scaffolding and Smart Digitalisation Modular Scaffolding

Criteria/ Types	**Cuplock Scaffolding (APAC, 2023)**	**Ringlock Scaffolding (WellMade, 2023)**	**Kwikstage Scaffolding (Avontus, 2021)**	**Smart Digitalisation Modular Scaffolding**
				
Material	Mild steel	Mild steel	Mild steel	Mild steel

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Assembly	Moderate within 30-45 minutes	Faster within 20-35 minutes	Slightly slow within 40–60 minutes	Faster than existing product (approximately within 15-20 minutes)
Flexibility	Moderate flexibility	High flexibility	Low to moderate flexibility	High flexibility
Safety	Less safe because manually height adjustment	More safer for height adjustment because of multi-angle rosette connectors	Less safe because manually height adjustment same as Cuplock Scaffolding	Safer because there is no manual height adjustment
Efficiency of movement in height adjustment	Platform movement to adjust heights is manual	Adjust platform heights is manual but more faster than Cuplock Scaffolding	Platform movement to adjust heights is manual	Automated height adjustment by remote control

5. CONCLUSION

In conclusion, this study evaluated the creation and innovation of the SDMS, a system intended to overcome the problems of the existing modular scaffolding currently used in the construction industry. The suggested innovation has been shown to greatly increase construction efficiency, safety, and adaptability, especially for low-rise buildings, after a thorough literature review, data collection, and analysis. Smart Digital Modular Scaffolding not only represents a technological advancement in the construction industry, but it also highlights how important continuous innovation in solving problems faced in construction. This project helps to improve construction work processes and productivity by offering a safer, more effective, and technologically advanced scaffolding solution. It also paves the way for the industry's wider embrace of digital tools. This study also can achieve SDG 9, the development of innovative modular scaffolding technologies improves the productivity and security of building projects.

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