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Smart Construction Implementation in The Malaysian Construction Industry

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ABSTRACT

Smart construction involves the entire process of advancing digitisation, connectivity, visualisation, automation, and intelligence. Malaysia has recently started implementing smart construction, particularly in line with Industrial Revolution (IR) 4.0. Therefore, this research aims to investigate the implementation of smart construction in the Malaysian construction industry. Two (2) objectives were outlined: to identify the components of smart construction and to determine the benefits of smart construction in the Malaysian construction industry. An extensive literature review was done to obtain general information related to the components of smart construction and its benefits at large. A 254 questionnaire surveys were distributed to the G7 contractors in Johor via an online platform to learn in-depth about the components and benefits of smart construction in the Malaysian context. 31% of responses were obtained and analysed using Statistical Package for Social Sciences (SPSS) software. Findings revealed two (2) main components of smart construction: digital technologies and manufacturing, and five (5) core benefits have been identified. Thus, the emergence of smart construction will lead to better construction site management, proper construction monitoring, enhanced resource and asset management, and improved workplace safety. This research acts as a continuous source of information for the ongoing research undertaken by the author on the need to establish smart construction concepts in the Malaysian construction industry.

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INTRODUCTION

The construction industry has experienced a major transformation in recent years due to the emergence of smart construction technology. Integrating modern technology and data analytics into the construction process significantly transforms the design, construction, and management of buildings and infrastructure (Beale & Co., 2023). However, similar to any revolutionary undertaking, the implementation of smart construction entails a range of advantageous and disadvantageous consequences, as a result, requiring a comprehensive analysis of its effects.

Although the government has made efforts to assist with the implementation of smart construction in the Malaysian construction industry, there is still a lack of a comprehensive study, such as the article specifically on the adoption of smart construction in the Malaysian construction industry. The majority of the existing articles focus on the topics of smart construction technology, such as Building Information Modelling (BIM), Artificial Intelligence (AI), and Augmented Reality (AR). Overall, the studies on implementing the smart construction concept in Malaysia are almost non-existent and very limited. Therefore, this study aims to investigate the implementation of smart construction in the Malaysian construction industry.

Fundamental of Smart Construction in the Construction Industry

The smart building is a typical example of a perfect combination of traditional and high-tech industries, which has opened up new fields of development and application for information technology while encouraging the development of the construction sector (Ejidike & Mewomo, 2023). Since then, smart buildings have required enterprises to change the construction method, the operation model, and the management involved in the design, construction, equipment, raw material supply, operation and maintenance, and property management.

The high-tech nature and complexity of smart buildings require smart construction to systematically update and comprehensively transform technology, talents, equipment, projects, development plans, operating modes, and management philosophy (Baghchesaraei & Baghchesaraei, 2016). These advancements in technology allow for a more exact production process, which in turn results in less waste and fewer delays. Malaysia has also established frameworks, such as the Construction Industry Digitalisation Framework (CIDF), to help with digital transformation in construction. Furthermore, Malaysia's Construction Industry Development Board (CIDB) has identified the twelve critical construction industry technologies (CCIT) that align with the principles of smart construction (CIDB, 2021). These ,

The Concept

Smart construction concepts broadly encompass implementing digital technologies in the construction industry. It covers the use of hardware, such as robotics, sensors, and controllers, and various software solutions, including those powered by big data, AI, and Machine Learning (ML) technologies (Cisco, 2023). Smart construction aims to streamline construction processes by imparting various beneficial effects, such as improving productivity, minimising whole-life costs, enhancing sustainability, and maximising user benefits. Smart construction involves the development and use of processes and applications that improve construction planning and the management of projects. It goes beyond basic business efficiency and collaboration tools, incorporating technologies such as drones for site monitoring, programmable cement, self-healing concrete, and autonomous and robotic machinery for construction projects.

The concept of smart construction offers a transition from the traditional methods of construction to manufacturing through the increased use of standardised components and offsite fabrication. The application of smart construction technology has the potential to facilitate faster, safer and more sustainable construction processes, contributing to increased productivity and reduced costs in the construction industry

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(Wee, 2023). The term smart construction encompasses various interpretations and applications. It involves the design, construction, and operation of assets through collaborative partnerships that make full use of digital technologies and industrialised manufacturing techniques, which are the two (2) main components, used in the smart construction concept to enhance productivity, reduce overall costs over the lifespan, promote sustainability, and optimise user benefits.

The Components

According to Ayob & Janipha (2024), there were two (2) main components of smart construction: digital technologies and manufacturing. Digital technologies play a pivotal role in revolutionising the construction industry, particularly in the context of smart construction. These technologies are the instruments for transforming construction projects, including those designed, managed, and executed. They improve communication, enhance decision-making, and optimise construction processes.

The use of digital technologies and accompanying processes, such as simulations, testing, and predictive analytics, can indeed facilitate getting the design, planning, and execution right (Koeleman et al., 2019). It emphasises the practical application of digital tools to optimise the build phase and enhance asset utilisation. The current reality for digital software in the construction industry is that it is used not only to record the performance of projects but also to empower organisations to make informed and intelligent decisions right from the project's inception. This aligns with the broader theme of leveraging digital tools for enhanced efficiency and effectiveness in construction processes.

Manufacturing component refers to the proportion of building components manufactured off-site before being brought to the construction site for assembly (Lu et al., 2023). Increasing the proportion of pre-manufactured components radically improves the speed of delivery, with groundwork and construction occurring in parallel to the major build phase and main elements built in a quality-controlled environment. Manufacturing can be categorised into panelised construction (Orlowski, 2020), structurally insulated panels, volumetric construction (Lu et al., 2023), and sub-assembly manufacturing (Anvari et al., 2016; Sola et al., 2023).

The Benefits

The smart construction concept broadly encompasses digital technology implementation in the construction industry. Cisco (2023) highlighted that the smart construction concept included the use of hardware; robotics, sensors, and controllers, and various software solutions, such as big data, AI, and ML technologies. Smart construction aims to increase precision and quality, and process control while minimising waste. This is achieved through pre-delivery inspection, factory-controlled installation conditions, traceability of components for maintenance and modification, and properly planned interfaces, which all of it contribute to reducing defects in the final building.

Smart construction involves the development and use of processes and their applications that can improve construction planning and the management of projects. It goes beyond basic business efficiency and collaboration tools, incorporating technologies such as drones for site monitoring, programmable cement, self-healing concrete, and autonomous and robotic machinery for construction projects.

METHODOLOGY

For this research, the primary data is gathered from a questionnaire given to the respondents, specifically G7 contractors, on the implementation of smart construction, and secondary data is gathered from reviewing articles and books from libraries, academic journals, scholarly articles, and online searches such as the Construction 4.0 Strategic Plan (2021-2025) by CIDB to transform the construction industry in Malaysia. The concept of "smart construction" is central to the Construction 4.0 Strategic Plan. It involves

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leveraging emerging technologies like BIM, prefabrication, Internet of Thing (IoT), AI, and 3-dimensional (3D) printing to enhance productivity, safety, and sustainability in the construction industry.

Probability sampling was used to gather the data, which involved randomly selecting a small group of people (a sample) from a larger population and then predicting the characteristics of the whole population based on the characteristics of the sample. Probability sampling is ideal for quantitative studies where the goal is to use statistical analysis to conclude a large population. The participants for this research were contractors, classified as grade G7 in Johor areas, registered under CIDB. The main objective was to obtain their perceptions regarding the implementation of smart construction in the Malaysian construction industry. Johor is known as one of the developed states in Malaysia.

To identify the sampling size, the overall population size needs to be analysed. The population numbers represented by contractor G7 were taken from the Construction Industry Development Board (CIDB) website, and only active licenses with building projects were available for selection. According to Krejcie and Morgan (1970), the target population size of G7 contractors for this research was 750, and the sample size was determined to be 254 numbers. The total sample size for this research, as described by Krejcie and Morgan (1970), was 254. The distribution period was one (1) month, from May to June. Due to face-to-face distribution limitations, the response rate only reaches 31%. According to Pandya (2019), the acceptable response rate for online surveys is between 30% and 40%, and this research achieves a 31% response rate, which is adequate for data collection.

The data utilised in this research were analysed through the Statistical Package for Social Sciences (SPSS), which is employed to generate frequency tables. These tables subsequently present the data tables and figures, which aid understanding by illustrating the frequency and percentage of agreement expressed by each respondent. Later, the findings will be concisely summarised through recommendations and conclusions. The primary objective of the research is to identify the problems and difficulties associated with smart construction. Data analysis will be conducted to produce the research findings.

FINDINGS AND DISCUSSIONS

This section outlined the outcomes for the smart construction components that have been implemented in the construction projects and their benefits to the Malaysian construction industry. The findings and analysis were analysed using the Statistical Package for Social Sciences (SPSS) version 26. The mean score, perception level and rank for each component and benefits factors were analysed and shown in this section.

The Components

Table 1 shows the breakdown of the implementation of smart construction components in the construction project. Smart construction components are divided into two (2) components: digital and manufacturing. Digital components are separated into two (2) types: digital design software and digital information tools. From the table, the highest rank for digital design software components was AutoCAD software (mean value = 4.40, standard deviation = 0.880), followed by ArchiCAD software (mean value = 4.34, standard deviation = 0.526).

Next, Autodesk Revit software placed third, with a mean value of 4.19 and a standard deviation of 0.813. This software was primarily used by engineers (civil, mechanical, and electrical) for technical drawings and also by architects for various design tasks. For the digital information tools components, the highest rank was data gathering technology (mean value = 4.59, standard deviation = 0.592), followed by smart site technology (mean value = 4.56, standard deviation = 0.592). Both technologies were indicated as highly important based on respondents' perceptions of their level of significance. The last rank was delivery tracking and management, with a mean value of 3.59 and a standard deviation of 0.688. Project managers are the primary users of these technologies because they are in charge of project coordination, timeline management, and ensuring that every part of the project operates smoothly.

For the manufacturing components, the first rank voted was panelised manufacturing (mean value = 4.31, standard deviation = 0.565). The second rank was structurally insulated panels (SIPS) manufacturing (mean value = 4.21, standard deviation = 0.589). Next, volumetric construction (mean value = 4.05, standard deviation = 0.778). The last rank of manufacturing technology was delivery sub-assemblies and components, with a mean value of 4.00 and a standard deviation of 0.842.

Table 1. The Smart Construction Components in the Malaysian Construction Industry

Smart Construction Components	Mean	Standard Deviation	Perception Level	Rank
DIGITAL				
Digital Design Software				
AutoCAD	4.40	0.880	Important	1
ArchiCAD	4.34	0.526	Important	2
Autodesk Revit	4.19	0.813	Important	3
Digital Transformation Tools				
Smart Site	4.56	0.592	Highly Important	21
Data Gathering	4.59	0.567	Highly Important	3
Delivery Tracking and Management	3.59	0.688	Important	
MANUFACTURING				
Panelised	4.31	0.565	Important	1
Structural Insulated Panels (SIPS)	4.21	0.589	Important	2
Volumetric Construction	4.05	0.778	Important	3
Sub-Assemblies and Components	4.00	0.842	Important	4

Source: Ayob, et al. (2024)

The literature review has identified that smart construction is divided into two (2) components, which are 'digital' and manufacturing'. Digital components were divided into two (2) more categories, which were 'digital design software' and 'digital information tools'. Apart from that, the respondents were asked regarding their perspective on the components of smart construction and the extent to which these elements are being applied in Malaysia.

According to the data research, AutoCAD software was the technology that ranks first in terms of importance among digital design software components. This was owing to its adaptability, solid features, and widespread application across industries. This finding was supported by the literature, which shows that AutoCAD is utilised in architecture, engineering, and manufacturing, making everyone in the construction industry familiar with this software. Its broad applicability makes it an essential tool for experts in various industries, increasing productivity and precision in their design processes. AutoCAD's ability to work easily with a selection of software and file formats allows it to be integrated into a wide range of workflows, allowing for smooth cooperation among different teams.

The second type of digital component was digital information tools. According to respondents, smart sites and data-gathering technology were two (2) of the most crucial components. These tools are digital information tools that are part of the smart construction system. Previous research stated that smart sites and data-gathering technology were critical in construction projects because they improve efficiency, safety, cost savings, project planning, sustainability, and real-time decision-making. Data allows for quick workflow adjustment, reducing delays and ensuring smooth project progression. Leveraging this technology will improve overall project outcomes.

The last component that will be discussed was manufacturing components. Based on the findings and analysis, panelised manufacturing was ranked highest among these components. The literature review highlighted that panelised systems often provide more design flexibility than other components. Panels can be modified to match architectural styles and project needs, including complex geometries and unique building shapes, making this a popular manufacturing option for building development. This study's data analysis and findings are consistent with those of other research on the components of smart construction.

The Benefits

Table 2 shows the benefits of implementing smart construction components. The first benefit was to raise the quality of the project. Quality control occupies the highest ranking among the factors contributing to this benefit, with a mean value of 4.66. Subsequently, precision and accuracy were at the second rank, with a mean value of 4.65. The respondents "strongly agree" that the implementation of smart construction components in the project has a positive effect on the control of the project's quality and gives precision and accuracy to the work carried out. Meanwhile, real-time monitoring and feedback are ranked third, with a mean value of 3.87.

Besides, the table also provides data on the factors that can influence the overall lifespan of the project when implementing smart construction components. The research indicated that the first-ranked result was the reduction of on-site costs, with a mean value of 4.65. The element "minimise waste" ranked second with a mean score of 4.58. The respondents express a high level of agreement about the factors that suggest that the use of smart construction components in the project will lead to a reduction in on-site costs and a minimisation of waste. This, in turn, has a beneficial impact on the overall lifespan of the building. On the other hand, the category of reducing the risks of error' has the lowest rank, with a mean value of 4.51.

Incorporating smart construction components into the project will enhance the design and contribute to the overall well-being of the project. The table also depicts various variables that contribute to the design's well-being in the project. The first rank voted was 'health and safety monitoring', with a mean score of 4.38, followed by achieving 'occupant comfort' with a mean value of 4.10, ranking second in the design for well-being benefits. Meanwhile, the last rank score for the aspect that promotes the project's well-being is 'optimal work environments', with a mean value of 4.08. Overall, all respondents acknowledged and agreed that this element had resulted in the project's well-being.

Furthermore, smart construction components in the project result in enhanced flexibility. The table shows some factors that contribute to these benefits. The project's flexibility is enhanced by accuracy and efficiency in the design process. This aspect was ranked highest with a mean score of 4.61, and the respondents strongly agree that it can significantly enhance the flexibility of the project. The aspect of versatility in design' was ranked second with a mean value of 4.39. 'Predictive analytics for risk mitigation' came last with a mean value of 3.90.

The last benefit of implementing smart construction can be obtained through environmental performance. Factors that contribute to these benefits were also outlined. Environmental monitoring was among the factors that contributed to environmental performance. This factor was placed at the highest rank with a mean value of 4.59, and the respondent's feedback strongly agrees that this factor could deliver environmental performance in the project. Carbon emission reduction was placed at the second rank with a mean value of 4.18. The ‘waste reduction’ was last ranked with a mean value of 3.99. The mean score for the indicated benefits of incorporating smart construction components into the project is calculated by analysing the breakdown of factors within each category.

Refer to the table, the category benefit of 'overall lifespan of the building' (mean value = 4.51) ranks top among all others. Raising quality has the second-highest mean score in the benefit category, at 4.39. Following that, 'boost flexibility' (mean value = 4.30), 'deliver environmental performance' (mean value =

4.25), and 'design for well-being' (mean value = 4.19) ranked lowest. Overall, all respondents provided favourable feedback for the benefits listed, with some elements reaching ' strongly agree' and others reaching 'agree' on their perception level of all the items indicated in each area.

Table 2. The Benefits of Smart Construction Implementation in the Malaysian Construction Industry

Item	Benefits	Mean	Perception Level	Rank
A	**Raise Quality**			
1	Quality Control	4.66	Strongly Agreed	1
2	Precision and Accuracy	4.65	Strongly Agreed	2
3	Real-time Monitoring and Feedback	3.87	Agreed	3
	Total Average	**4.39**		**2**
B	**Overall Lifespan of the Building**			
1	Reduced Life Cycle Costs	4.65	Strongly Agreed	1
2	Minimised Waste	4.58	Strongly Agreed	2
3	Reducing the Risk of Error	4.31	Agreed	3
	Total Average	**4.51**		**1**
C	**Design for Wellbeing**			
1	Occupant Comfort	4.10	Agreed	2
2	Optimised Work Environment	4.08	Agreed	3
3	Health and Safety Monitoring	4.38	Agreed	1
	Total Average	**4.19**		**5**
D	**Enhanced Flexibility**			
1	Accuracy and Efficiency in the Design Process	4.61	Strongly Agreed	1
2	Versatility in Design	4.39	Agreed	2
3	Predictive Analytics for Risk Mitigation	3.90	Agreed	3
	Total Average	**4.30**		**3**
E	**Deliver Environmental Performance**			
1	Waste Reduction	3.99	Agreed	3
2	Environmental Monitoring	4.59	Strongly Agreed	1
3	Carbon Emission Reduction	4.18	Agreed	2
	Total Average	**4.25**		**4**

Source: Ayob, et al. (2024)

Based on the questionnaire survey that was carried out, the results indicate that the implementation of smart construction concepts in the Malaysian construction industry is moderate. Even though the smart construction concept was introduced in Malaysia in the early 2010s, the response to the implementation of smart construction among stakeholders in Malaysia, especially contractors, is not encouraging compared to other countries. Previous research indicates that the adoption of smart construction technologies (SCTs) in overseas countries, particularly in the United States, Australia, and Japan, has been more advanced compared to Malaysia. These countries have been at the forefront of leveraging technologies like Building Information Modeling (BIM), the Internet of Things (IoT), augmented reality (AR), and construction robotics to improve productivity, quality, and efficiency in construction.

Furthermore, respondents were asked about their perspective on the benefits of smart construction implementation to know the benefits that respondents obtained from applying smart construction technology to their construction projects. Overall, the perception level of agreement analysed was rated at strongly agree and agree levels of agreement. This research was also achieved by calculating the mean score and rank for each benefit category listed. Among the benefits that will be gained when implementing this concept are raising the quality of the project, having a positive impact on the overall lifespan of the building, designing for well-being, enhancing flexibility, and delivering environmental performance.

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This study also discovered the three (3) most important benefits of implementing smart construction in the project. Among the benefits is that it has a positive effect on the overall lifespan of the building. This is the main benefit of implementing this concept. According to the findings of this survey, respondents strongly agree that these benefits will reduce life cycle cost expenditures. Smart construction approaches generally result in structures that require less maintenance and repair during their lifetime. Smart construction reduces long-term operational costs by incorporating predictive maintenance like the Internet of Things (IoT), efficient energy management systems, and durable materials. Predictive maintenance, for example, enables timely repairs before serious difficulties arise, potentially saving money on future repairs or replacements. This proactive maintenance technique may improve the lifespan of building components. Implementing smart construction concepts in the project will improve its overall quality.

Based on the findings and analysis, the respondents express a high level of agreement that smart construction technologies will control quality and ensure precise and accurate work. For instance, components are produced in controlled industrial environments where conditions can be precisely monitored. The process results in higher-quality components than those built on-site, where environmental factors can affect the quality of materials and workmanship. It also improves the precision and accuracy of the work, as fewer mistakes mean less rework and material waste, contributing to overall project efficiency and sustainability.

The last benefit of incorporating smart construction into the project is enhanced flexibility. According to the data and analysis, respondents strongly agree that implementing smart construction technologies will improve the accuracy and efficiency of the design process. Smart construction technologies such as laser scanning and drones give precise site measurements and topographical data for accurate design and planning. Technologies can increase site survey accuracy by 20–30%, resulting in more efficient and successful project execution. Furthermore, Internet of Things (IoT) devices monitor various parameters in real time and provide precise data that informs design adjustments to ensure optimal performance, security, and efficiency in construction projects.

CONCLUSION

The Malaysian construction industry is at a critical juncture where adopting smart construction practices are no longer a choice but a requirement for future growth and sustainability. According to the research, there are plenty of benefits to integrating smart construction concepts or practices into project development. Thus, the industry must continue smart construction technology integration to improve production, efficiency, and worker safety on the construction site. However, there are obstacles to implementation that must be addressed to enhance the overall implementation of smart construction in the Malaysian construction industry.

There are two (2) major components, which are digital and manufacturing. The digital component divided into two (2) categories, the digital design software and digital information tools. Based on the findings, AutoCAD software is the most important digital design software, while the data-gathering tool is the most important in digital information tools. Respondents identified the panelised component as the most crucial manufacturing component. The integration of smart construction principles within the Malaysian construction sector is currently at the reasonable level. Even though the smart construction concepts was introduced in Malaysia in the early 2010s, the response to its implementation among stakeholders in Malaysia, particularly contractors, is not encouraging compared to other countries.

The implementation of smart construction revealed benefits from several components, which often result in buildings that require less maintenance and repair during their life spans. Smart construction reduces long-term operating costs by incorporating technology, such as predictive maintenance, efficient energy management systems, and durable materials. This proactive approach uses data analytics and

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machine learning to identify potential equipment failures before they occur, reducing downtime and maintenance expenses. Smart construction integrates sustainable materials that minimise the amount of carbon dioxide emitted throughout the production process. The components consist of recycled materials, low-carbon concrete, and locally obtained products that reduce transportation emissions.

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CONFLICT OF INTEREST STATEMENT

As the authors of this research, we acknowledge that completing scholarly work requires transparency and integrity. We also agreed that none of the authors have benefited financially from any organisations and companies that were involved to this research. Furthermore, none of the authors have any connection that would prejudice the results of the research study. Although few of the authors have affiliation to a construction company in Malaysia, this did not influence the study's integrity. Consequently, we believe that there was no possibility of bias during the research process, ensuring the study's credibility.

AUTHORS' CONTRIBUTIONS

Yazira Ayob carried out the research process and wrote the research. Nurul Afida Isnaini Janipha conceptualised the research idea, supervised the research progress, revised the research content and provided the articles. Izza Izzati Norazwan Booi anchored the review, revisions and approved the article submission.

REFERENCES

Anvari, B., Angeloudis, P., & Ochieng, W. Y. (2016). A multi-objective GA-based optimisation for holistic Manufacturing, transportation and Assembly of precast construction. Automation in Construction, 71(Part 2), 226–241. https://doi.org/10.1016/j.autcon.2016.08.007

Ayob, Y. & Janipha, N.A.I. (2024). Conceptualisation of Smart Construction in the Construction Industry: A Review. *Quantity Surveying Research & Innovation Presentation Proceeding*. Pp26-30. Available online at: https://drive.google.com/file/d/1UmURV3ZWYzyB_L1K4SogpIiOF2tgCd3d/view?usp=sharing

Beale & Co. (2023). The Impact of Innovative Technology in The Construction Industry. Available online at: https://beale-law.com/article/the-impact-of-innovative-technology-in-the- construction-industry-staying-ahead-of-the-curve/

Baghchesaraei, O. R., & Baghchesaraei, A. (2016). Smart buildings: Design and construction process. *Journal of Engineering and Applied Sciences*, *11*(4), 783–787. Available online at: https://www.researchgate.net/publication/307591059_Smart_buildings_Design_and_construction_process

CIDB (2021). Technologies Defining Malaysias Construction. Available online at: https://smart.cidb.gov.my/article/12-technologies-defining-malaysias-construction-40-79

Cisco (2023). Work Smarter with AI/ML. Available online at: https://www.cisco.com/c/en/us/solutions/artificial-intelligence/what-is-aiops.html

Ejidike, C. C., & Mewomo, M. C. (2023). Benefits of adopting smart building technologies in building construction of developing countries: review of literature. In *SN Applied Sciences* (Vol. 5, Issue 2). Springer Nature. https://doi.org/10.1007/s42452-022-05262-y

Koeleman, J., Ribeirinho, M. J., Rockhill, D., Sjödin, E., & Strube, G. (2019). Decoding digital transformation in construction. *Capital Projects & Infrastructure Practice*. Mckinsey & Company. Available online at: https://www.mckinsey.com/capabilities/operations/our-insights/decoding-digital-transformation-in-construction

Krejcie, R. V., & Morgan, D. W. (1970). Determining sample size for research activities. *Educational and Psychological Measurement, 30*(3), 607–610. https://doi.org/10.1177/001316447003000308

Lu, W., Yang, Z., & Kong, L. (2023). Identification of Learning Effects in Modular Construction Manufacturing. Automation in Construction, 154. https://doi.org/10.1016/j.autcon.2023.105010

Orlowski, K. (2020). Automated manufacturing for timber-based panelised wall systems. In Automation in Construction (Vol. 109). Elsevier B.V. https://doi.org/10.1016/j.autcon.2019.102988

Pandya, C. (2019). What is an Acceptable Response Rate for Online Survey?. Available online at: https://www.appjetty.com/blog/acceptable-response-rate-for-online-surveys/

Sola, A., Trinchi, A., & Hill, A. J. (2023). Self-assembly meets additive manufacturing: Bridging the gap between nanoscale arrangement of matter and macroscale fabrication. Smart Materials in Manufacturing, 1, 100013. https://doi.org/10.1016/j.smmf.2022.100013

Wee, X. R. (2023) Exploring the Implementation of Smart Technologies In The Construction Industry Wee Xin Rhu. Available online at: http://eprints.utar.edu.my/5812/