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THE SUITABILITY OF IMPLEMENTING 3D PRINTING CONSTRUCTION TOWARDS MALAYSIAN CONSTRUCTION INDUSTRY

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ABSTRACT

3D printing will change the construction industry's routine. 3D printing uses a computer to layer liquid substance to form a building's shape. Thus, this research is aimed to determine the suitability of the implementation of 3D printing construction in the Malaysian construction industry. The research's two objectives are (1) to identify the challenges; and (2) to analyse construction industry players' capabilities implementing 3D Printing construction. This quantitative method will be utilised by distributed questionnaires to Quantity Surveyors at QS firm and Contractor G7 in Petaling district, Selangor. The findings showed that they are aware of the challenges of implementing 3D printing construction in the Malaysian construction industry due to a lack of materials, machinery, skills, and environmental impact. Construction players in Malaysia recognise their inability to understand 3D Printing construction. In conclusion, Malaysian construction players are unable to comprehend the 3D Printing construction concept, so 3D Printing construction cannot be implemented yet.

Keywords: "*3D Printing", "3D Building", "IR 4.0", "Construction Industry", "Malaysia".*

INTRODUCTION

3D printing will change the construction industry's routine. 3D printing uses a computer to layer liquid substance to form a building's shape. Olsson et al. (2019) state that advanced printer technology transforms a digital 2D model into a 3D solid construction structure. Thus, it improves product quality, guarantees good materials, and has a well-developed construction method. However, several researchers revealed that in relation to traditional construction methods will arise several problem which are Khan et al. (2021) state that issues quality of final products, such as construction project products, are global and serious. Project success is most dependent on product quality. Construction projects often have quality assurance issues due to poor construction methods, raw material quality, and labour skills. Sami Ur Rehman M. et al. (2022) state that labour availability has decreased, causing a skilled worker shortage during this critical time. The client's proposed project will be hampered by a lack of field labour for dirty, dangerous, and difficult 3D work.

Construction has stopped to prevent the pandemic from spreading. Construction workers are unemployed when work stops. Bajjou, M.S. and Chafi, A. (2021) stated that construction waste had become the main issue for industry players, resulting in higher costs. Construction waste management prevents injuries and pollution. Waste transportation, labour, and disposal cost extra. Most conventional methods produce a lot of project waste, which can be an issue in the construction industry without waste management. According to Teo et al. (2021), implementing IR 4.0 may produce an unhealthy environment for future construction workers. IR 4.0 integrates physical, digital, and biological components. A.I., robotics, IoT, 3D printing, genetic engineering, and others are used to improve industry performance (CIDB, 2022). IR 4.0 can intelligently connect all building products. Modern control systems and software combine multiple platforms to create great products and performance in Industrial Revolution 4.0.

New production methods benefit from these systems' networking. Any job requires technological adaptation. Organisations use various skills to achieve a goal. Starting 3D printing construction requires new skills to operate our building's 3D printing system. 3D printing helps design teams create fast, accurate physical models, according to Greenhalgh (2016). Advanced technology improves design team skills and product quality. As related to this, research aim is to determine the suitability of the implementation of 3D printing construction in the Malaysian construction industry. In line with this aim, two research objectives were established: (1) To determine the challenges of implementing 3D Printing construction in the Malaysian construction industry. (2) To analyze the capability of construction industry players regarding implementing 3D Printing Construction in the Malaysian Construction Industry.

LITERATURE REVIEW

3D Printing and Indsutrial Revolution 4.0 (IR 4.0)

Technology is the application of scientific knowledge to improve our way of life. In the construction industry, new technology enhances performance. The Construction Industry Development Board (2020) emphasizes Industrial Revolution 4.0's role in boosting construction productivity in Malaysia. This requires key players to innovate, learn new methods, and utilize tools like 3D printing to create precise models. Malik et al. (2022) note 3D printing's potential in IR 4.0 for construction. Technological advancements reduce errors and enhance performance. In the 21st century, technology is vital across industries. Demirkesen and Tezel (2021) highlight IR 4.0's impact on construction company performance. This study evaluates Malaysia's construction industry readiness for 3D printing. IR 4.0 blends physical, digital, and biological realms using A.I., robotics, IoT, 3D printing, genetics, etc. to enhance industries (CIDB, 2022). In construction, it intelligently links building components, employing advanced software and control systems to create superior products and methods, fostering effective networking and communication. Implementing Industrial Revolution 4.0 across education could inspire tech support from the next generation. Butt et al. (2020) suggest ICT enhances adaptable learning and critical thinking. ICT drives IR 4.0. Hussain (2020) highlights its smart factory role, enabling digital integration for smart services. Disruptive tech, per Boninsegni et al. (2022), reshapes living and production. 3D printing streamlines processes for safety and efficiency (Boninsegni et al., 2022).

3D Printing Construction.

Zuo et al. (2019) state 3D printing in construction shortens supply chain time by automating component production. Steps include 3D modeling, STL file generation, slicing, and path planning. Mechtcherine et al. (2019) suggest considering machine space and weight for architecture. Shahzad et al. (2020) explain STL files instruct the printer via software, using a conveyor to feed concrete. Pham et al. (2022) describe using CAD models and slicing for layer-by-layer printing. Zhu et al. (2021) confirm material-tech fusion in 3D printing constructs quality structures quickly, without formwork, offering diverse geometries.

Challenges in the implementation of 3D Printing Construction.

Due to most people being comfortable with the traditional method, any change, development, or evolution in our standard of living will face many barriers. People are used to the traditional method and find it hard to start from scratch to produce the same product with new and improved methods.

Insufficient of Material.

According to de Schutter et al. (2018), the limited range of materials available for 3D printing in construction is a major barrier to its widespread adoption, and shrinkage cracking must be adequately controlled through good mix design and effective curing. The inability to convert readily available high-quality cementitious materials, particularly concrete materials that comply with valid structural concrete codes, into print-ready materials is hindering the transition from formwork-based technologies to more automated additive manufacturing approaches (de Shutter et al., 2018). Due to resource scarcity, Malik et al. (2022) believe construction players will struggle to choose a binder.Jagoda et al. (2020) state that bagged material mixes for 3D printing construction may be difficult, expensive, or time-consuming to purchase in remote, isolated, or expeditionary environments. 3D-printed structures are more sensitive to material rheology than traditional buildings because they must provide adequate permeability, printability, buildability, and open time (Jagoda et al., 2020).

Machinery Constraint.

Because many machines must be moved, Malik et al. (2022) say it takes a long time and lowers productivity. enforces size restrictions on printed items, limiting their versatility on the construction site, and purchasing new machinery and replacing obsolete models is expensive. De Schutter et al. (2018) state that 3D printing machinery will be expensive because there are three main subprocesses: transporting the material to the head-print, accurately positioning it, and activating the parts for the desired component to build the structure. Guamán-Rivera et al. (2022) found that 3D printing construction case studies had higher material and machinery costs. Because printing material is still more expensive than concrete or CMU (Conventional concrete masonry unit), the printing technology was expected to be expensive. that a 3D printing machine with all the extras is still rare in the construction supplies market, making it hard for established players to enter the 3D printing construction industry (Guamán-Rivera et al., 2022).

Lack of Skills and Knowledge.

Heidarnezhad, F. and Zhang, Q. (2022) state that the construction industry's lack of 3D printing skills and knowledge is a technological barrier that must be overcome to advance this technology. 3D printers are harder to control than extrusion printers. In the I4.0 era, the construction industry is struggling to find qualified workers due to the complex and ever-changing nature of projects, according to Demirkesen, S. and Tezel, A. (2022). The construction industry must overcome a labour shortage to successfully implement IR4.0, which may require new technologies and departments (Demirkesen, S. and Tezel, A.,2022). Malik et al. (2022) believe that only a few people have the comprehensive expertise and broad comprehension needed to work in 3D printing and are unable to provide in-depth information and accurate comprehension of any 3D printing methodology. A design engineer and the relevant technician will discuss a component's viability and practicability before manufacturing it because automated processes have eliminated the technician's role (Malik et al., 2022). Thus, those with knowledge lack practical experience.

Environmental Impact.

As 3D printing becomes more popular, the potential for environmental damage increases, necessitating strict controls on its pollution (Malik et al., 2022). de Schutter et al. (2018) noted that environmental emissions are produced during construction and service life, and functional hybridization may make it harder to retrofit a structure and increase the rate at which building elements need to be replaced.

Skills that are needed for implementation of 3D Printing Construction.

3D printing gives construction companies even more potential. From basic engineering and architecture to component selection technology, a high-quality product requires a variety of skills and knowledge. 3D printing construction requires a deep understanding of 3D technologies to prepare and manage the project.

Technical Skills.

This additive manufacturing requires design skills to eliminate construction defects. According to Ning et al. (2021), Building Information Modelling (BIM) and simulation skills may help quantity surveyors and contractors adapt to this advanced technology. Feasibility studies use these skills to estimate construction project life cycle costs.The design scope of 3D Printing Construction may conflict with existing standards that favour prefabrication assemblies of given geometries, where quality can be more tightly controlled when personnel can control the machine during the manufacturing process of 3D Printing machine on site (Adaloudis, M., and Bonnin Roca, J., 2021). Parisi et al. (2023) To design a 3D-printed structure, construction players must learn inputs like human perceptions, representing knowledge, reasoning, problem-solving, and planning.

Management Skills.

According to Wang, T. and Chen, H. (2023), construction project management requires specialised knowledge, skills, methodologies, and strategies to guide project activities towards desired outcomes. Adaloudis, M., and Bonnin Roca, J. (2021) stress that construction stakeholders must have sufficient decision tools to assess the cost-competitiveness of 3D printing frameworks compared to other technologies.Communication is essential for project managers to share information and complete tasks. According to Bazli et al. (2023), stakeholders should prioritise enhancing communication and local skills development in Building Information Modelling (BIM), Augmented Reality (AR), and Virtual Reality (VR) technologies to facilitate design communication with community members and provide training opportunities for community members, particularly in 3D printing, to help them better understand the design. However, a building economist or quantity surveyor must be able to take-off and prepare bills of quantities for 3D printing construction projects (Olatunji et al., 2021).

Economical Skills.

The data preparation phase, which includes schematic design and Bill of Quantities creation, requires the ability to understand the complex 3D printing process and its materials. Construction methodology determines the project site's service requirements. According to Olsson et al. (2021), 3D Printing technology has optimised the construction process, reducing material use and enabling the construction industry to produce a reasonable rate of 3D printing. A thorough understanding of the topic can help determine the total cost of building the 3D printing technology, as Ning et al. (2021) noted that each material has its own ability to support the number of loads designed for the building's structure. De Schutter et al. (2018) stated that engineering expertise is integrated into a centralised software platform like a BIM system during design. This allows the architect to use their expertise to design cost-effective 3D-printable buildings.

RESEARCH METHODOLOGY

Methodology will gather data and results for this dissertation. Researchers analysed valid data and concluded efficiently. For title-related conclusions, this research's findings will be discussed. Selangor-based quantity surveyors and builders G7 will be participate. Problem statement, research objectives, and questions come first. Second, collect trustworthy data. Quantity Surveyors and Contractor G7 companies will receive a questionnaire to evaluate Malaysia's 3D printing construction benefits, challenges, and opinions. Questionnaire respondents will answer based on their knowledge of the topics. Quantity Surveyors consultants and G7 Building Works contractors will receive full-question surveys.

Surveys gather research data, distributing questionnaires to Quantity Surveyors and G7 Building Works contractors using a quantitative methods via online medium such as Email. This study uses stratified random sampling in the Petaling, Selangor area, with 322 respondents chosen from 2,041 residents.

Percentage of Samples for each Construction Personnel

Samples = Sample size ÷ Study Population

Samples = (322 ÷ 2,041) X 100%

Samples Percentage = 16 %

The 16% will be distribute based on the strata of respondents (14 Quantity Surveyor and 308 G7 Contractor) to gain different perspectives and fulfil the balance of respondent ratio.This size aligns with Krejcie and Morgan's (1970) table. Response rates, influenced by Medway and Fulton (2012), suggest a range of 10% to 20%. Data analysis employed SPSS version 29.0, offering comprehensive descriptive statistics and complex analyses, generating reports and visual plots.

ANALYSIS OF FINDINGS

This section explains the analysis and findings from the questionnaire survey. Generally, this section will be divided into three parts for two objectives :(1) to identify the challenges; and (2) to analyse construction industry players' capabilities implementing 3D Printing construction. Before jump into the objectives, thesea are the demographic data from the repondents.

- **Analysis on Demographic respondent background.**

Table 1 : Demographic respondent background.

Item	Description	Frequencies	Percentage (%)
A	What Firm are you involved in the Construction Industry?		
	Quantity Surveyor	31	24.0
	Contractor G7	98	76.0
B	How long is your working experience within the field of expertise in the construction industry?		
	Less than 5 Years	14	10.9
	5-10 Years	33	25.6
	11-15 Years	61	47.3
	More than 15 Years.	21	16.3
C	Are you aware that the construction industry is already pursuing Industrial Revolution 4.0 (2021 – 2025) phase in Malaysia?		
	Yes	127	98.4
	No	2	1.6

Based on the table 4.1, Quantity Surveyor firms (24.0%) have fewer respondents than Contractor G7 companies (76.0%). Both companies with different backgrounds provide diverse questionnaire responses. Next, Further analysis shows that most respondents have worked in construction for 11–15 years (47.3%) and 5–10 years (25.6%). Others worked between 15 and 5 years (16.3%). Finally, 98.4% of respondents are aware that the construction industry is pursuing Industrial Revolution 4.0 (2021–2025) in Malaysia, while 1.6% are unaware.

- **Analysis on to determine the challenges of implementing 3D Printing construction in the Malaysian construction industry.**

Table 2: Challenges of implementing 3D Printing Construction.

Item	Categories.	Mean	Rank.
Challenges 1			
Insufficient Material	Availability of material near the construction	4.26	1
	Restricted range of materials that are now available	4.25	2
	Due to binder scarcity, construction players struggle to choose one.	4.23	3
Challenges 2			
Machinery constraint	cost of machinery will be extremely high	4.40	1
	availability of 3D Printing machines is low	4.30	2
	Machines need to be transferred to different locations.	4.28	3
Challenges 3			
Lack of skills and knowledge	Insufficient experience in handling	4.27	1
	the lack of available skills labour force	4.24	2
	unable to have a deep understanding on the information	4.23	3
Challenges 4			
Environmental impact	advanced technology high energy consumption	4.22	1
	potential for environmental damage.	4.09	2
	Environmental emissions occur throughout construction.	4.07	3

Overall, the analysis reveals several key challenges in the construction industry, including issues related to material availability, machinery constraints, lack of skills and knowledge, and environmental impact. These challenges can significantly impact the efficiency and sustainability of construction projects and may require specific strategies and solutions to address them effectively.

As for the Challenge 1: Insufficient Material, first variable are Insufficient Material: Availability of material near the construction (Mean: 4.26, Rank: 1) This challenge highlights the difficulty in accessing materials that are located near the construction site. Second variable are Restricted range of materials that are now available (Mean: 4.25, Rank: 2) It suggests that the range of available materials for construction is limited, which could potentially hinder the construction process. As for the third variable are Due to binder scarcity, construction players struggle to choose one (Mean: 4.23, Rank: 3) This challenge refers to the scarcity of binders, which makes it challenging for construction professionals to select an appropriate binder for their projects.

As for the Challenge 2: Machinery constraint, first variable are Cost of machinery will be extremely high (Mean: 4.40, Rank: 1) This challenge indicates that the high cost of machinery poses a constraint on construction projects. Second variable are Availability of 3D printing machines is low (Mean: 4.30, Rank: 2) It suggests that there is a limited availability of 3D printing machines, which could hinder the adoption of this technology in construction. As for the third variable are Machines need to be transferred to different locations (Mean: 4.28, Rank: 3) This challenge highlights the logistical difficulty of moving machinery to different construction sites.

As for the Challenge 3: Lack of Skills and Knowledge, first variable are Insufficient experience in handling (Mean: 4.27, Rank: 1) This challenge points out the lack of experience in handling construction-related tasks, indicating a need for more skilled workers. Second variable are The lack of available skilled labor force (Mean: 4.24, Rank: 2) It suggests that there is a shortage of skilled labor in the construction industry, which can affect project execution. As for the third variable are Unable to have a deep understanding of the information (Mean: 4.23, Rank: 3) This challenge implies that there is a difficulty in fully comprehending the information relevant to construction activities.

As for the Challenge 4: Environmental Impact, first variable are Advanced technology high energy consumption (Mean: 4.22, Rank: 1) This challenge highlights the high energy consumption associated with advanced construction technologies, which can have environmental implications. Second variable are Potential for environmental damage (Mean: 4.09, Rank: 2) It suggests that there is a risk of causing environmental damage during the construction process. As for the third variable are Environmental emissions occur throughout construction (Mean: 4.07, Rank: 3) This challenge indicates that construction activities contribute to environmental emissions throughout the project lifecycle.

Overall, the analysis reveals a number of significant obstacles in the construction industry, such as material availability issues, machinery limitations, a lack of skills and knowledge, and environmental impact. These obstacles can have a significant impact on the effectiveness and viability of construction projects and may necessitate specific strategies and solutions to effectively address them.

- **Analysis on to analyse construction industry players' capabilities implementing 3D Printing construction.**

Table 3 Capabilities in implementing 3D Printing Construction.

Item	Categories.	Mean	Rank.
Capability 1			
Technical skills	Able to control the 3D Printing Machine	1.89	1
	Able to understand the functionality of the 3D Printing software.	1.90	2
	Able to design a structure based on the 3D Printing method of construction	1.95	3
Capability 2			
Management Skills	Able to manage a 3D Printing construction project. (Pre- or Post-Contract Stages).	1.97	1
	Able to communicate and understand the 3D Printing Specialist.	1.98	2
	Able to produce complete Bills of Quantities for 3D Printing construction projects.	2.00	3
Capability 3			
Economical Skills	Able to produce a reasonable rate for 3D Printing works.	1.95	1
	Able to produce an economical design that fits with the capability of a 3D Printing plant.	2.00	2
	Able to provide an appropriate total cost of construction for a 3D Printing construction project.	2.02	3

The presented data is an analysis of the capabilities of 3D printing technology in the construction industry. The capabilities are organised into three categories, with three specific capabilities listed for each category. The abilities are ranked according to their average scores. The mean score will be evaluate based on the lowest mean score to the highest mean score due to the disagreement from the respondents answer.

As for Capability 1: Technical skills, first variable are Able to control the 3D Printing Machine (Mean: 1.89, Rank: 1) This capability indicates the proficiency in operating and controlling 3D printing machines. Second variable are Able to understand the functionality of the 3D Printing software (Mean: 1.90, Rank: 2) It suggests the ability to comprehend and work with the software used in 3D printing technology. As for the third variable are Able to design a structure based on the 3D Printing method of construction (Mean: 1.95, Rank: 3) This capability highlights the competence to create structural designs specifically tailored for 3D printing construction methods.

As for Capability 2: Management skills, first variable are Able to manage a 3D Printing construction project (Pre- or Post-Contract Stages) (Mean: 1.97, Rank: 1) This capability signifies the ability to effectively oversee and manage 3D printing construction projects at various stages, including pre-contract and post-contract. Second variable are Able to communicate and understand the 3D Printing Specialist (Mean: 1.98, Rank: 2) It suggests the skill to effectively communicate and comprehend the expertise of 3D printing specialists involved in the project. As for third variable are Able to produce complete Bills of Quantities for 3D Printing construction projects (Mean: 2.00, Rank: 3) This capability indicates the proficiency in generating accurate and comprehensive bills of quantities specific to 3D printing construction projects.

As for Capability 3: Economical skills, first variable are Able to produce a reasonable rate for 3D Printing works (Mean: 1.95, Rank: 1) This capability highlights the ability to determine competitive and reasonable pricing for 3D printing construction works. Second variable are Able to produce an economical design that fits with the capability of a 3D Printing plant (Mean: 2.00, Rank: 2) It suggests the skill to develop cost-effective designs that align with the capabilities of 3D printing plants. As for the third variable are Able to provide an appropriate total cost of construction for a 3D Printing construction project (Mean: 2.02, Rank: 3) This capability indicates the competence to accurately estimate and provide the total cost of construction for a 3D printing project.

The analysis shows that 3D printing in construction requires several key capabilities. These include machine control, software, and design skills. Project management, communication, and bill of quantities generation are also important. 3D printing construction projects require economic skills like setting fair prices, creating cost-effective designs, and estimating costs. Developing and improving these capabilities can help the construction industry adopt 3D printing technology.

DISCUSSION OF FINDINGS

Discussed questionnaire survey findings here. The discussion explains the findings in relation to the research's goals. The literature should support it. Data analysis results are discussed using research question-specific questions. Thus, assessing the study's success is crucial.

Discussion on finding for Demographic respondent background.

Sub-questions ask about firm type, years of experience, current position, and IR 4.0 awareness. Table 4.23 shows respondents' firm sizes and types. Quantity Surveying firms employed 24% of respondents, while G7 Contractors employed 76%. Participation from both companies will broaden perspectives.From the table, 47.00% of respondents have 11–15 years of experience. This question is designed to assess respondents' reliability because respondents with more experience are more likely to know more about the construction industry. 98.50% of respondents knew Malaysia's construction industry is pursuing Industrial Revolution 4.0 (2021–2025). This question helps researchers learn about respondents' background knowledge and research experiences.

Discussion on findings for to determine the challenges of implementing 3D Printing construction in the Malaysian construction industry.

Table 4 Challenges of implementing 3D Printing Construction.

Challenges	Description	Rank	Perception level	Mean
Machinery Constraints	The cost of machinery will be extremely high.	1	Agree	4.40
Machinery Constraints	The availability of 3D Printing machines is low and hard to find in the current market.	2	Agree	4.30
Machinery Constraints	machines need to be transferred to different locations.	3	Agree	4.28

Table 5 indicates this research analyzed and found that the majority of responds for the most challenges variable in implementing 3D Printing Construction with top 3 upper ranking are R1 “The cost of machinery will be extremely high.” (Mean= 4.40) supported by de Schutter et al. (2018) cost of machinery will be extremely high because there are three major sub-processes involved in the 3D Printing process such as transport material, accurately positioning the machine and activate the machine. Next, R2 “The availability of 3D Printing machines is low and hard to find in the current market.” (Mean= 4.30) reinforced by Guamán-Rivera et al. (2022) that in today's construction supplies market, a 3D printing machine that comes with all the extras is still an unavailable and unusual sight. As a result, entering the 3D printing construction industry has become difficult for established players in the construction industry. Lastly, R3 “machines need to be transferred to different locations.” (Mean= 4.28) supported by Malik et al. (2022) that significant amount of time and hurts the organization's overall productivity because many machines need to be transferred to different locations imposes size restrictions on the items that can be printed, which places limitations on their versatility within the construction site. This top 3 upper ranking has the highest mean as the challenges of implementing 3D Printing Construction towards Malaysian construction industry.

Discussion on findings for to analyze the capability of construction industry players regarding implementing 3D Printing construction in the Malaysian construction industry.

Table 5 capability of construction industry players regarding implementing 3D Printing construction

Capability	Description	Rank	Perception level	Mean
Technical Skills	Able to control the 3D Printing Machine on site.	1	Disagree	1.89
Technical Skills	Able to understand the functionality of the 3D Printing software.	2	Disagree	1.90
Technical Skills.	Able to design a structure based on the 3D Printing method of construction.	3	Disagree	1.95

Table 5 indicates this research analyzed and found that answer from most respondents is at the lowest rate of means which indicates a negative perspective among the respondents towards each individual variable. For the variable capability of construction players in implementing 3D Printing Construction, the top 3 upper rankings are R1 “Able to control the 3D Printing Machine on site.” (Mean= 1.89) contradict with Adaloudis & Bonnin Roca, (2021) that quality can be more tightly when the personnel have the ability to controlled the machine during the manufacturing process of 3D Printing machine on site, R2 “Able to understand the functionality of the 3D Printing software.”(Mean= 1.90) contradict with Ning et al. (2021) that the combination of Building Information Modelling (BIM) for the simulation skills may help the construction personnel to have ability in the design stage to provide a better understanding of design for the 3D Printing Construction and R3 “Able to design a structure based on the 3D Printing method of construction.” (Mean= 1.95) R3 contradict with Parisi et al. (2023) that construction players must be able to learn inputs such as human perceptions, representing knowledge, reasoning, problem-solving and planning to design a structure based on 3D Printing method of construction. These top 3 upper rankings have the lowest mean as the capability of construction players in implementing 3D Printing Construction towards Malaysian construction industry due to the variables does not been supported by the respondent whereby they disagree that they have the capability and ability to apprehend 3D Printing concept based on their current knowledge, skills and experience.

Therefore, based on the means of the respondent on every aspect of Section D, technical skills, management skills and Economic skills, it emphasizes that current Malaysian construction players do not have the capability and ability to apprehend the 3D Printing construction concept. This is supported by Demirkesen, S and Tezel, A. (2022) complicated and ever-changing nature of projects, the construction sector is struggling to find qualified workers in the I4.0 era and lack of skills and knowledge regarding 3D Printing in the construction industry are the current technological obstacles or knowledge gaps that need to be filled to make additional progress with this technology (Heidarnezhad, F. and Zhang, Q., 2022). Moreover, Malik et al. (2022)

stated that only a select few individuals are available who possess the comprehensive expertise and broad comprehension required to work in the field of 3D printing and they are unable to provide in-depth information and accurate comprehension of any 3D printing methodology. So, these findings also can be reinforced by Bazli et al. (2023) that the lack of experience with the technology of construction will mean the uptake of new technology in local engagement will be slow.

CONCLUSION AND RECOMMENDATIONS

A 3D Printing construction concept may provide a promising technology for overcoming construction industry challenges. However, the limitations and obstacles may undermine efforts to apply and implement a 3D printing construction framework within the Malaysian construction industry. According to the discussion, data analysis reveals that most respondents rank "Able to control the 3D Printing Machine on site" as the least capable aspect for implementing 3D Printing Construction contradicting Adaloudis & Bonnin Roca (2021) who emphasize quality control through machine handling. While respondents generally express optimism about various variables, it suggests Malaysian construction players might lack the grasp of 3D printing concepts for the industry. This is particularly evident in the third objective's variables, reflecting disagreement and suggest the Malaysian construction industry's unpreparedness for 3D Printing due to deficient Technical, Management, and Economical skills in the 3D Printing framework. This is aligned with Malik et al. (2022) and Bazli et al. (2023), indicating a limited pool of experts and slow technology uptake due to a lack of experience in construction technology.

Future research could explore methods to train national construction players as experts in cutting-edge construction technology, particularly the 3D printing framework. Consideration might be given to expanding the research scope to involve other industry stakeholders like architects and engineers in Malaysia. This broader perspective could offer a more detailed and comprehensive understanding of the design and structure of ongoing 3D printing construction frameworks.

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Sekian, terima kasih.

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