Implementation Challenges of 3D-Printed Walls for Affordable Housing Projects: A Qualitative Approach

Yazid Saif[1], Yusri Yusof[1], and Ayad Mutafi[2]

[1] Advanced Materials and Manufacturing Center (AMMC) at Universiti Tun Hussein Onn Malaysia, Parit Raja, Malaysia.
[2]Faculty of Civil Engineering and Built Environment, Universiti Tun Hussein Onn Malaysia, Parit Raja, Malaysia.
Corresponding author's E-mail: Sameea@uthm.edu.my

Abstract

The advancement of 3D-printed wall technology represents a significant innovation in the construction industry, particularly in the housing sector. This technology is increasingly being discussed due to its potential to reduce construction project time and address the growing demand for affordable housing. Despite its benefits, the widespread adoption of 3D printed wall technology faces significant challenges, primarily due to the high initial costs associated with expensive 3D printing equipment and materials. This study aims to identify the main challenges and strategies for implementing 3D-printed walls in affordable housing projects. A quantitative approach was employed, involving 73 housing developers in Selangor. Data were collected through online questionnaires and physical meetings, achieving a response rate of 71.2%. Frequency and descriptive analyses were conducted to address the study's objectives. The analysis revealed that transportation is the primary challenge in implementing 3D-printed walls for affordable housing. Additionally, the main strategy for successful implementation identified was ensuring worker safety. These findings suggest that addressing transportation logistics and prioritizing worker safety are crucial for improving the adoption of 3D-printed wall technology in affordable housing projects. In short, the relationship to the construction sector is multifaceted, involving technological advancement, economic considerations, implementation challenges, safety concerns, and data-driven strategies. Integrating 3D-printed wall technology in the construction sector, particularly for affordable housing, can revolutionize building practices by improving efficiency, reducing costs, and meeting the growing demand for housing.

Keywords: *3D Printed Wall, Developer, House, Affordable.*

1. INTRODUCTION

The building industry has experienced significant changes recently, including BIM, cloud technology, drones, virtual reality, 3D printing, artificial intelligence, robotics, and advanced materials. These advancements have led to smarter construction, smart homes, and advanced materials (Sedghi, Rashidi and Hojati, 2024). The study explores the potential of new technologies like BIM, camera network systems, IoT, and digital signage in Malaysian construction safety management, emphasizing the need for technology-based policies (Yap *et al.*, 2024). As a future of BIM, the study examines how 3D printing, notably Contour Crafting and Building Information Modelling, could revolutionize construction by cutting costs, time, pollution, and injuries despite current limitations(Sakin and Kiroglu, 2017). Along with the development of the times, the potential of 3D Printed Walls has been recognized in the building construction industry, which uses this technique to change complex (conventional) building designs into reality in a short time (Holt *et al.*, 2019). 3D Printed Wall technology has impacted the construction industry worldwide. This technology is limited due to the small number of teams performing full-scale infrastructure design and construction. Most studies only speculate about 3D Printed Wall technology so that it becomes a more robust technology, including in the construction of affordable housing (Suntharalingam *et al.*, 2021). This study aimed to identify the main challenges and strategies for implementing 3D-printed walls in affordable housing projects. A quantitative approach was employed, involving 73 housing developers in Selangor, Malaysia.

2. METHODOLOGY

This section describes the research methods used by the researcher to design, collect, and analyze data to obtain evidence to support this study. It aims to identify the main challenges and main strategies of implementing a 3D Printed Wall for an affordable house and further analyze the relationship between the main challenges and the primary strategy of implementing a 3D Printed Wall for an affordable house.

2.1 Study Design

In order to fulfill the objectives and goals of the study, this study uses two methods, namely primary data and secondary data, to obtain information. The primary data used in this study is a quantitative method involving housing developers in Selangor. These data are collected through questionnaires and references to scientific sources.

2.1.1 Questionnaire Form

A set of questionnaires was used to collect research data and was made based on a literature review. Each set of questionnaires is distributed to developers online and in physical meetings. The study population is developers for housing projects in Selangor. Table 1 shows the number of house units approved by the house type category in 2022 in Selangor, which is currently running a single-house project with as many as 88 projects (National Housing Department, 2018). So, based on the determination of (Krejcie and Morgan, 1970), the developer sample size is based on the number of approved house units, which is as many as 73 projects. The distributed questionnaire contains three parts: Part A, B, and C. Part A is about the background, and Part B consists of questions about the main challenges of implementing 3D-printed Walls for an affordable house. Part C is related to the primary strategy of implementing 3D-printed Walls for an affordable house. The survey questionnaire was used with an evaluation scale that is a 5-point Likert scale consisting of five answer options that include "Strongly Disagree," "Disagree," "Not Sure," "Agree," and "Strongly Agree."

Table 1. Number of House Units Approved by House Type Category Year 2023 (National Housing Department, 2018)

House's	State
Johor	23
Kedah	85
Kelantan	91
Malacca	121
Negeri Sembilan	17
Pahang	48
Silver	43
Perlis	20
Penang Island	87
Selangor	88
Terengganu	52
W. P. Kuala Lumpur	0
W. P. Putrajaya	0
Total	675

2.2 Data Analysis

Data analysis involves quantitative methods. Content analysis is used to identify themes, concepts, and meanings.

2.2.1 Frequency Analysis

This analysis measures the frequency of data in parts A (demographics), B (the main challenge of implementing 3D Printed Walls for an affordable house), and C (the primary implementation strategy for 3D Printed Walls for an affordable home). SPSS software was used to help analyze frequencies, means, and percentages. The results of this analysis can help achieve the first and second research objectives.

2.2.2 Descriptive Analysis

Descriptive analysis means transforming data into a form that is easy to understand and explain, reorganizing and manipulating data to produce descriptive information. This study uses the same Likert scale in parts B and C. In this part, a 5-point Likert scale is used to assess the developer's level of agreement. The results of this analysis also help achieve the first and second research objectives.

2.3 Pilot Study

A pilot study was conducted before conducting a full study and distributing an online questionnaire to respondents. This pilot study was conducted on 10 respondents consisting of affordable housing developers in the state of Selangor. This is because, according to (Johnson and Christensen, 2014), the flexible number of respondents is 5 to 10 people. A pilot study is significant to ensure that the respondents understand each question the researcher gives. The results of the reliability test analysis of the set of questionnaires have an alpha value of more than 0.7, which is 0.989. Therefore, the questionnaire is reliable, and the items have relatively high internal consistency (Gliem and Rosemary R. Gliem, 2003). The Cronbach's Alpha value was"0.989" for all 109 questions, which indicates high internal consistency and reliable data measurement.

3. RESULTS AND DISCUSSION

Discussion of the analysis results of data collection from the questionnaire. A total of 73 questionnaires were distributed to housing developers, and only 52 sets of questionnaires were returned with answers and used for data analysis purposes. The percentage of respondents' responses was 71.2% of the total questionnaire distributed.

3.1 Part A: Respondent Information (Demographic profile)

Figure 1 shows the summary of the data analysis in part A. The percentage of respondents who are the majority of age are respondents who are between 20 and 30 years old, which is 67.30%, which represents 35 respondents. Next, most of the respondents with the highest qualifications for this survey are at the degree level, which is 65.40%, with 34 respondents. Followed by Civil Engineer as the position with the highest number of respondents with a percentage of 46.20% which is a total of 24 respondents. In addition, the majority have years of service in the construction industry between 1 and 5 years, with a percentage of 53.8%, representing 28 respondents.

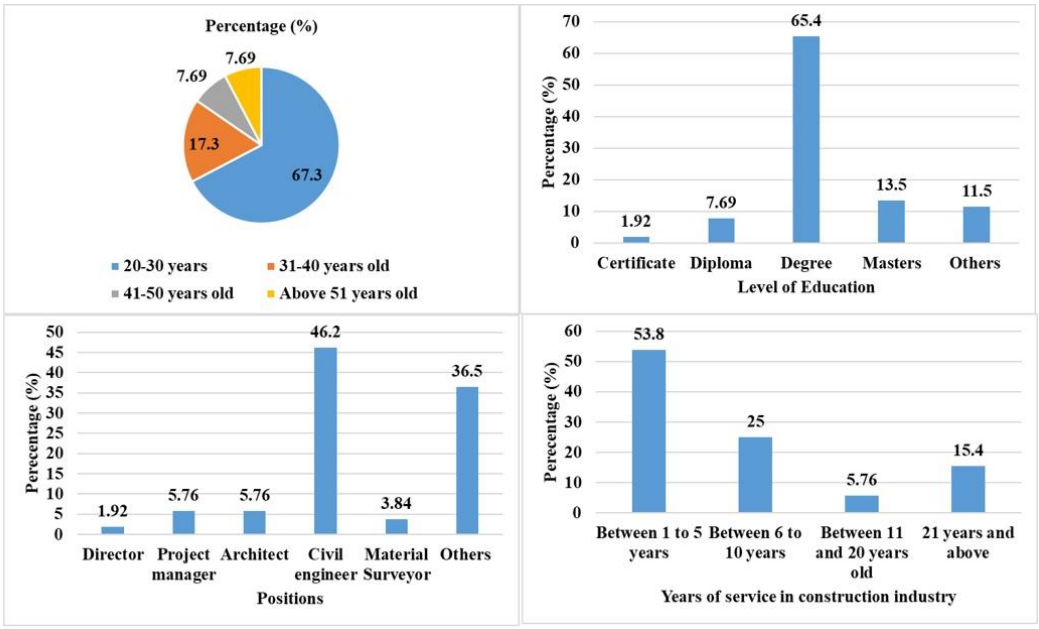

Figure 1. Percentage (%) of the demographic profile of respondents.

3.2 Part B: Identifying the main challenges of implementing 3D Printed Wall for an affordable house

The results of the analysis show the summary of the data analysis in part B. The highest average shows that transportation is at a "high" level of agreement with a mean value of 4.2600. In addition, the lowest value is a limited construct size where the mean value is 3.9519 with a "high" level of agreement and is at the level of position 9. Meanwhile, the second highest average value quality control item is 4.1268, with a "high" level of agreement. Followed by limited materials, regulations, design inaccuracy, lack of manpower, high cost, and stone structure without Mold of 4.0960, 4.0240, 4.0129, 4.0128, 4.0000, 3.9780 with a "high" level of agreement (refer to Figure 2). In Malaysian construction, "stone structure without Mold" refers to using natural or cut stones as the principal building material rather than formwork or Molds.

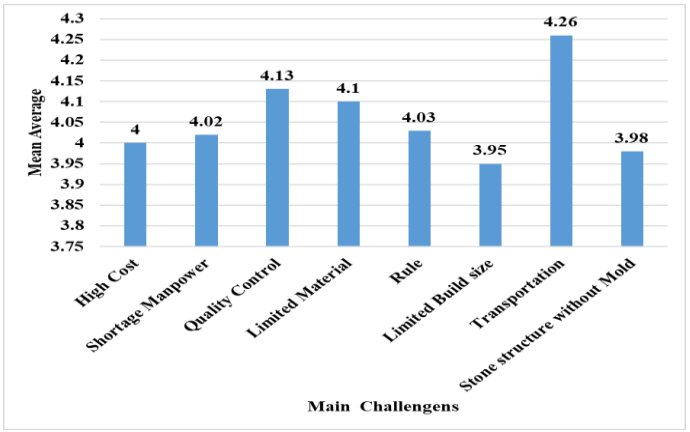

Figure 2. The mean average of the main challenges of implementing 3D Printed Walls for an affordable house

Figure 2 emphasizes the data analysis from part B, which indicates a "high" degree of consensus regarding the transportation costs of 3D-printed wall houses. The substantial expenses associated with transporting and installing these houses are the cause of this counterintuitive outcome. The transportation costs are increased by the necessity of transporting weighty materials, such as concrete, despite the rapid assembly time of a few days. Furthermore, the project's lead time is extended, and the risk of damage during transit is increased by the process of transporting and assembling the home at the site. The structure's integrity can be compromised by such damages, which can sometimes go undetected, potentially resulting in future failures.

3.3 Part C: Identifying the main strategy for the implementation of 3D Printed Wall for an affordable house

Figure 3 shows the summary of the data analysis in part B. The highest average shows that the employee safety item is at a "high" level of agreement with a mean value of as much as 4.2346. In addition, the lowest value is an adapted construct where the mean value is 4.0577 with a level of "high" agreement and is at the level of position 9. Meanwhile, the process efficiency item mean value is 4.1987 with a level of "high" agreement at the second highest position.

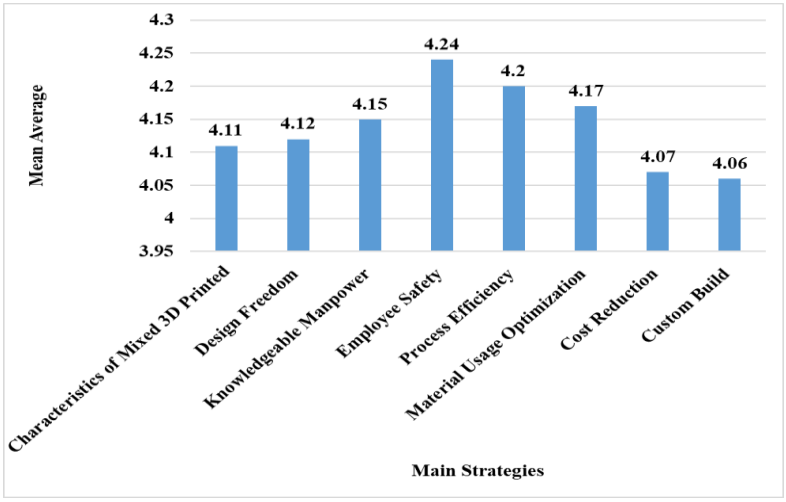

Figure 3. The mean average of the main strategy for the implementation of a 3D-printed Wall for an affordable house

In addition, Figure 3 highlights the priority of worker safety in 3D-printed wall construction. Enhancing labor safety is crucial, particularly in large-scale projects. Off-site 3D printing reduces hazards and ensures medical facilities are accessible. It also decreases health and safety risks for employees. On-site 3D printing usually requires just one or two operators, minimizing human effort and hazardous labor. Additionally, the process often includes electrical and insulation work, creating a safer environment and shortening construction time through monitored computerized equipment.

4. CONCLUSION

In short, the study determined that the developer's primary obstacle to implementing 3D Printed Walls for affordable housing is transportation. The primary obstacle in implementing a 3D Printed Wall for an affordable house is transportation, as it poses difficulties in securely managing tools at the construction site. The study's limitations include a focus on a specific region (Selangor), a limited sample size, a purely quantitative approach, potential response

bias, and a narrow exploration of challenges and strategies, limiting the generalizability and depth of its findings. This poses challenges for constructing a cost-effective dwelling utilizing this technology. Nevertheless, the researchers have identified some significant obstacles in implementing 3D Printed Walls for cost-effective housing. Moreover, implementing 3D Printed Walls for cost-effective housing prioritizes worker safety, process efficiency, and material usage to reduce energy consumption and enhance process speed. This study aims to assist developers in addressing the primary obstacles and approaches to enhance the execution of 3D Printed Walls for constructing cost-effective housing.

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