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MODULAR CONSTRUCTION FOR SUSTAINABLE SOCIAL HOUSING IN VIETNAM: INSIGHTS FROM A MULTI-STAKEHOLDER PERSPECTIVE

To Thi Huong Quynh[a,*], Ta Dang Bach[b]

[a]*Faculty of Construction Economics and Management, Hanoi University of Civil Engineering, 55 Giai Phong road, Hai Ba Trung district, Hanoi, Vietnam*
[b]*Construction Engineering Management, NTU-HUCE Joint Master Program, National Taiwan University, Taiwan*

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Abstract

Modular construction (MC) is increasingly recognised as a viable solution to the growing need for affordable, sustainable social housing, especially in rapidly urbanising countries like Vietnam. Despite its potential benefits in terms of construction speed, waste reduction, and quality control, the uptake of MC in Vietnam remains limited. This study identifies and evaluates 22 barriers and 12 drivers of MC adoption in the Vietnamese social housing sector, drawing on survey data from 256 construction professionals representing five key stakeholder groups: clients, contractors, consultants, policymakers, and academics. Statistical analyses, including reliability testing, mean score ranking, and ANOVA, reveal significant divergence in stakeholder perceptions. The results indicate that the most critical barriers, including the lack of experience among suppliers and designers, inflexible design processes, and high upfront investment costs. In addition, key drivers identified, including early design finalisation, dimensional standardisation, pilot projects, and international knowledge transfer. Based on the findings, the study proposes tailored policy implications for key stakeholders. Policymakers should mandate BIM for MC projects, offer financial incentives, and establish R&D centres to foster innovation. Contractors and consultants are encouraged to adopt BIM comprehensively and engage in pilot MC projects to strengthen technical capacity. Clients and developers would benefit from access to benchmarking data and international partnerships to reduce perceived risks. Educational and research institutions should introduce targeted training and innovation hubs to bridge skill gaps. These recommendations offer a practical roadmap for advancing MC in sustainable social housing development in Vietnam and similar contexts.

Keywords: modular construction; social housing; sustainable development; stakeholders; Vietnam.

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1. Introduction

In recent years, the significant expansion of industrial parks in Vietnam has contributed to boosting the economy and creating millions of job opportunities for workers. However, a prominent problem that is directly affecting the lives of workers is the serious shortage of affordable, quality housing. In many industrial parks, workers have to live in temporary housing areas, with poor living conditions, which affect their health and work efficiency [1]. The project of 1 million social housing apartments for workers has been strongly implemented recently, showing the Government's interest in the above issue [2]. As approved by the Government in this project, approximately 428,000 social housing units are planned for the 2021-2025 period, and 634,200 units for 2025-2030 [2]. However, on average nationwide, the supply of social housing for industrial park workers and low-income urban residents only meets about 56% of the demand. The development target volumes are small compared

*Corresponding author. *E-mail address:* quynhtth@huce.edu.vn (Quynh, T. T. Q.)

to demand in large cities (e.g., Hanoi, Ho Chi Minh City) or cities with many industrial parks (e.g., Bac Giang province, Bac Ninh province, Binh Duong province) (Fig. 1). A combination of financial, regulatory, and practical challenges in both quantity and quality recently of the development of social housing in general, and the ones for workers [2–4].

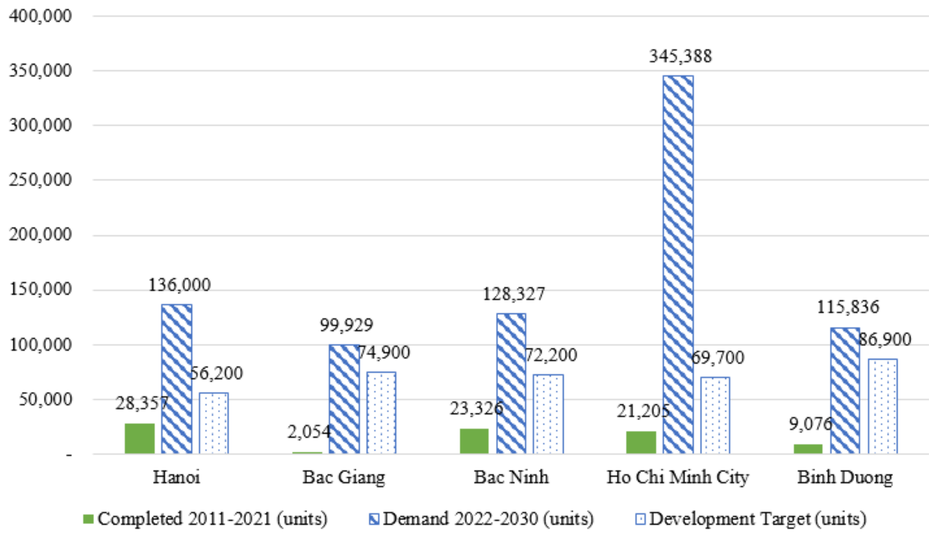


Figure 1. Existing social housing, demand and development targets for low-income people and industrial park workers in the period 2022 - 2030 in large cities in Vietnam [2]

In many countries around the world, modular construction (MC) technology has emerged as a potential solution toward sustainable development goals [5–9]. This technology not only helps to reduce construction costs and construction time, but also optimises the use of materials, minimises waste, and improves the quality of the building. The application of modular technology in the construction of housing for workers will not only help solve the housing problem for workers but also contribute to promoting sustainable development in the construction industry [10–12]. Although modular technology has been applied in many developed countries [11], in Vietnam, the implementation of this technology in housing construction for workers still has many limitations, from awareness to knowledge and cost challenges [13]. Therefore, it is imperative to research and understand the factors that promote the application of modular technology in the construction of housing for workers in industrial parks, in order to improve living conditions for workers and create a sustainable housing model in the future.

This paper aims to provide a analysis of the major barriers and drivers of MC within the Vietnamese built environment from a multi-stakeholder perspective. To do so, the study seeks to deeper understanding of MC applications in social housing development and to highlight its broader implications for the construction sector and the national economy. Understanding the specific barriers and drivers of MC in the Vietnamese construction sector is crucial for policymakers, industry stakeholders, and society at large. The findings of this research will contribute to the existing literature on MC, particularly within the context of social housing projects. It will help formulates insights and recommendations that can assist policymakers and industry stakeholders in promoting MC practices not only in Vietnam but also in other countries with the same socio-economic or cultural circumstances.

2. Literature review

2.1. Modular construction for social housing development toward sustainable development goals

MC is a modern construction method in which the components of a building, or modules, are designed and manufactured according to factory standards, and then transported to the construction site for assembly into a complete building. This method not only minimises construction time [14], but also improves efficiency, quality and sustainability in construction [15]. In the world, the concept of MC is defined and applied differently depending on the local context.

According to the Modular Building Institute (MBI), MC is a manufacturing process in which building components are fabricated off-site, usually in factories, and are strictly controlled in terms of process, sequence, quality, etc. These modules are made up of materials and standards equivalent to traditional construction, but may take only half the time to complete. When assembled on site, the modules perfectly reproduce the design concept and technical standards of traditional construction without compromising on quality [16–18].

MC technology, with its outstanding economic, environmental, and efficiency benefits, has proven its high application potential in the development of worker housing in industrial parks. This is a suitable solution to meet the increasing demand for housing in the context of urbanisation and industrialisation in Vietnam, especially in industrial parks with large labour density. MC allows for a significant reduction in construction time compared to traditional methods, often reducing construction time by 30% to 50%. For industrial parks with fast labour growth, this ensures the timely supply of high-quality housing for workers, thereby contributing to improving living conditions and working efficiency [14].

Additionally, the MC method helps reduce overall construction costs by using efficient labour at the factory, minimising wasted materials, and optimising logistics. With the characteristic that worker housing areas often require low cost but guaranteed quality, modular technology can provide an economical solution, especially in large-scale projects in industrial parks [19]. MC technology is also suitable for flexible and expansive requirements in worker housing design. The modules can be mass-produced with a standard design, then assembled on-site to form residential areas that meet the specific needs of each industrial park. In particular, the modules can be easily dismantled and moved, helping to optimise the use of space in industrial parks with limited space.

Modular technology ensures the quality of the building due to a strict quality control process at the factory. Worker housing areas built by this method not only ensure comfort and safety, but also minimise the risk of noise, pollution and occupational accidents at the construction site. This is especially important when applied in industrial parks with high labour density and increasingly high living standards [20]. The MC method minimises the environmental impact thanks to the use of recycled materials and reduces the amount of waste generated during construction. This is in line with the trend of sustainable development in the construction industry and contributes to reducing the carbon footprint of industrial parks [15].

Despite the many benefits, the implementation of MC in industrial parks still faces challenges such as high initial investment costs, limited stakeholder awareness, and a shortage of skilled manpower [21, 22]. To overcome this, it is necessary to have financial support strategies, provide intensive training for workers in the construction industry, and implement model projects to increase trust and encourage the adoption of this technology [21, 22]. In the context that Vietnam is promoting industrialisation and urbanisation, MC technology has great potential to solve the problem of social housing for workers in industrial parks. The application of this technology not only improves the quality of life of employees but also contributes to creating a safer, more efficient, and sustainable working environment. Supportive government policies and collaboration among stakeholders will be important drivers to promote the widespread adoption of this technology.

While many international studies have highlighted the advantages and challenges of MC, there remains a lack of empirical research that systematically investigates the barriers and drivers of MC adoption in the context of Vietnam—particularly from the perspective of multiple stakeholders involved in social housing projects. Existing studies tend to focus on technical or economic aspects in isolation, without considering the interlinked institutional and cognitive barriers that may inhibit adoption. Two key research gaps are identified here: first, a practical gap concerning the limited evidence on MC within the Vietnamese context; and second, a theoretical gap involving the lack of comparative analysis of perceptions across key stakeholder groups. This study seeks to address both by exploring stakeholder perceptions across five key groups—clients, contractors, consultants, academics, and policymakers—thus providing a context-specific understanding of sustainable social housing development that can inform policy and practice in Vietnam.

2.2. Potential barriers and drivers of modular construction for social housing development

a. Barriers to applying modular technology

The implementation of MC in Vietnam and other developing countries remains limited due to a wide range of barriers [22]. These challenges can be categorised into four primary groups: cognitive, knowledge-based, technological, and financial. Understanding these barriers is essential for stakeholders to develop targeted policies and implementation strategies.

Cognitive barriers refer to public perceptions, behavioural resistance, and market acceptance. Rahman [23] identified scepticism and resistance among clients as a major obstacle to the adoption of new construction technologies. Despite the potential benefits of MC—such as cost reduction and faster project delivery—customers often remain unconvinced of its reliability and quality. Steinhardt and Manley [24] further emphasised the influence of cultural and social norms, especially in developed contexts, where prefabricated housing is often associated with poor quality. Gan et al. [25] also found that clients in China perceive MC as expensive and lacking long-term value, resulting in continued preference for traditional methods. This lack of trust and understanding continues to hinder broader acceptance of modular practices.

Knowledge-related barriers involve the technical and human resource constraints of the construction ecosystem. Wuni and Shen [21], Cheng et al. [26], and Zhang et al. [27] pointed out that many stakeholders—suppliers, manufacturers, and designers—lack experience with modular systems. The limited number of suppliers capable of producing standardised components, combined with a shortage of skilled labour trained in modular techniques, restricts scalability. Furthermore, inadequate educational and training programmes contribute to a limited understanding of modular principles and hinder knowledge transfer across the sector.

Technological barriers encompass limitations in modular design, production, and logistics. Luo et al. [28] and Shahtaheri et al. [20] noted that MC often lacks the flexibility to modify designs during the construction phase, which poses risks for projects with dynamic requirements. Challenges also include transportation constraints, limited R&D infrastructure, and insufficient testing facilities, which collectively undermine the quality and adaptability of modular solutions. Wu et al. [29] and Zhang et al. [30] highlighted additional barriers, such as the lack of clean manufacturing technologies and logistical difficulties related to transporting large modules through congested urban areas.

Financial barriers are widely recognised as some of the most significant challenges to MC implementation. Studies by Luo et al. [28], Nadim and Gouldin [31], Hwang et al. [32], and Lee and Kim [33] found that the high initial capital investment, long payback periods, and substantial fixed costs deter many developers. The cost of building modular production facilities, combined with expensive logistics and the need for highly skilled (and well-paid) labour, makes the approach less attractive. Moreover, difficulties in securing financing and the perceived risk among investors exacerbate the problem. Wuni and Shen [34] stressed the need for sound financial strategies to mitigate these risks and promote industry confidence.

A total of 22 barriers synthesised from the literature are presented in Table 1, serving as a comprehensive reference for identifying critical constraints to MC adoption.

Table 1. Barriers to the implementation of modular construction

Group	Code	Barriers	References
Cognitive barriers	BA1	Customers are sceptical and unwilling to accept innovation and change.	[23–25]
	BA2	Customers are not satisfied with current market products.	[23]
	BA3	Belief that modular construction is costly.	[25]
	BA4	Belief that modular housing has low market value.	[25]
Knowledge barrier	BA5	Lack of experience from suppliers, manufacturers, and designers.	[21, 26, 27]
	BA6	The lack of suppliers and manufacturers providing suitable modular products.	[26, 27]
	BA7	Shortage of skilled and trained human resources.	[21, 27]
	BA8	Lack of experience in design and installation of modules.	[21, 26]
	BA9	Limited understanding of the role of stakeholders in modular projects.	[26]
	BA10	Lack of educational program on modular structure and architecture.	[29]
Technological barriers	BA11	Limited flexibility to change design during construction.	[20, 29]
	BA12	Design constrained by transportation limitations.	[20, 30]
	BA13	Inadequate production and supply capacity for modular components.	[30]
	BA14	There is a lack of research and development (R&D) centers for modular construction.	[28, 29]
Financial barriers	BA15	Difficulty in achieving a high return on initial investment.	[28, 32]
	BA16	Difficulty in raising the necessary financial resources.	[34]
	BA17	Large fixed costs and significant investment capital are required to build production plants.	[28, 31]
	BA18	Higher capital costs compared to traditional construction.	[28, 33]
	BA19	Long payback periods for modular construction projects.	[28]
	BA20	High costs associated with repairs and rework.	[20]
	BA21	Expensive shipping and logistics.	[20, 30, 31]
	BA22	Highly skilled workers are needed, demanding higher wages.	[28, 33]

b. Drivers in the adoption of modular construction technology

The effective implementation of MC within emerging economies necessitates not only the mitigation of well-documented barriers but also the strategic activation of key drivers that facilitate its broader acceptance and integration. These drivers operate across multiple dimensions, including cognitive, knowledge-based, technological, and financial, and are critical for fostering a supportive environment for modularisation in the construction sector.

In terms of cognitive factors, stakeholder perceptions and attitudes significantly influence the willingness to adopt modular methods. Trigunarsyah et al. [35], through the application of explanatory structural modelling in the Saudi Arabian construction context, identified attitudinal resistance as a prominent barrier to off-site construction. The study underscores the importance of raising awareness through targeted interventions such as marketing campaigns, industry exhibitions, and educational workshops. These efforts are essential in reshaping stakeholder perceptions and promoting acceptance of modular technologies. In parallel, O'Connor et al. [36] emphasise the need to communicate the often-underappreciated advantages of early project completion associated with MC, such as accelerated revenue generation, reduced site supervision requirements, and mitigated safety and productivity risks. Failure to adequately convey these benefits may contribute to continued reluctance among potential adopters.

Addressing knowledge-related constraints is equally imperative. Trigunarsyah et al. [35] highlight the lack of technical expertise among construction professionals as a significant limitation. To overcome this, the authors advocate for structured capacity-building initiatives, including intensive technical training and skill development programmes aimed at engineers and construction workers. Complementarily, O'Connor et al. [36] propose conducting early-stage supplier assessments to ensure the availability of manufacturing capabilities aligned with project specifications, thus reducing downstream operational risks. The recruitment of experienced foreign specialists is also recommended as a means of facilitating knowledge transfer and enhancing project execution. Furthermore, Wuni and Shen [37] argue for the integration of circular economy principles into MC practices, stressing the need for continuous professional development to enable engineers and contractors to implement sustainable and resource-efficient solutions effectively.

Technological drivers also play a vital role in ensuring the feasibility and robustness of MC. Trigunarsyah et al. [35] advocate for early design finalisation and the freezing of critical specifications to prevent delays and minimise dimensional mismatches during production. The deployment of comprehensive pilot projects is identified as a valuable approach for testing equipment, evaluating design feasibility, and accumulating experiential knowledge. O'Connor et al. [36] concur, noting that such demonstrator projects assist stakeholders in appreciating the long-term value and operational reliability of modular systems. This view is further supported by Wuni and Shen [37], who recommend strategic investment in pilot studies to optimise MC processes and support project-specific innovation.

From a financial perspective, cost-related challenges remain a central concern. O'Connor et al. [36] suggest leveraging empirical data from completed modular projects to establish reliable cost benchmarks and support investment decisions. In addition to direct labour cost reductions achieved through off-site manufacturing, further savings can be realised through decreased expenditures on scaffolding, material storage, and on-site safety measures. Collectively, these financial advantages contribute to making MC an economically viable and attractive alternative.

A total of twelve enabling drivers derived from the literature are summarised in Table 2 to provide a comprehensive framework for guiding MC implementation in developing contexts.

Table 2. Factors driving the implementation of modular construction

Group	Code	Drivers	References
Addressing Cognitive Barriers	DR1	Construction project stakeholders need to raise awareness of modular technology through promotional campaigns, workshops, and exhibitions.	[35]
	DR2	The State needs to carry out propaganda about the benefits of modular technology.	[36]
Addressing the Knowledge Barrier	DR3	Engineers and workers need to improve their skills and knowledge of module construction through training sessions and workshops.	[35, 37]
	DR4	Investors and contractors should carry out screening studies early to select suitable manufacturing plants to ensure that they meet project requirements.	[36]
	DR5	Hire foreign experts to leverage their knowledge and experience in the field of module construction.	[36]
Addressing technological barriers	DR6	Finalise the design from the early stages.	[35]
	DR7	Avoid situations where the dimensions of the module components are not suitable (e.g., improper aspect ratio), as this may limit transportability.	[35]
	DR8	Implement a sample pilot project that fully applies modular technology to draw early lessons on the selection of equipment, technology and scope of work.	[35, 36]
	DR9	Investors need to be willing to invest in early studies on opportunities to apply modular technology to maximise benefits.	[36, 37]
Addressing financial barriers	DR10	Contractors and developers should use data from past modular projects to build cost-effective standards.	[36]
	DR11	Reduce the cost of adopting modular technology by reducing the cost of labour and material supervision.	[36]
	DR12	Reduce the cost of applying modular technology through reducing the cost of scaffolding, formwork, material storage and safety management costs.	[36]

3. Research methodology

This study employed a quantitative research approach, employing a survey methodology to gather empirical data on factors related to barriers and drivers associated with the adoption of MC for sustainable social housing development in Vietnam. To formulate the questionnaire, a comprehensive literature review of existing literature was conducted, complemented by expert consultations with stakeholders across the Vietnamese construction industry. The key stakeholders involved in MC for Vietnam's social housing sector have been identified as clients, consultants, contractors, academics, and policymakers [38–40]. These consultations were instrumental in validating and contextualising the initially identified factors, which were subsequently integrated into a structured questionnaire. In particular, expert participants involved in the preliminary consultation phase expressed strong consensus regarding the consolidated list of 22 barriers and 12 drivers associated with MC adoption. Consequently, none of the identified factors were excluded, and all were retained for inclusion in the final survey instrument.

3.1. Questionnaire development

The questionnaire comprised two primary sections. The first section collected demographic information, including respondents' professional roles, years of experience in the construction sector, and previous involvement in MC projects. This information was vital for contextualising responses and verifying the relevance of participants' expertise. The second section contained items related to 22 identified barriers, and 12 drivers of MC implementation in the social housing sector. Participants were asked to indicate their level of agreement with each statement using a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree).

3.2. Data collection and analysis

Prior to full-scale distribution, a pilot test was conducted involving five purposively selected experts with extensive knowledge of MC and social housing. Selection criteria for these experts included: (i) a minimum of 10 years of professional experience in MC, (ii) current or prior involvement in social housing or public-sector housing programmes, and (iii) proven academic or practical contributions to construction innovation. Feedback from these experts was used to revise the wording of several items for clarity, merge overlapping factors, and improve the logical flow of the questionnaire. As a result of this iterative process, the final instrument reflected both conceptual rigour and practical relevance.

The data collection process was carried out online using a snowball sampling approach between November and December 2024. The survey link was initially disseminated via professional networks, construction associations, and academic forums, and participants were encouraged to forward the link to eligible colleagues. Only individuals with direct or indirect experience in modular or prefabricated construction projects—particularly within the context of housing or social infrastructure—were invited to participate. This ensured the relevance and reliability of the dataset. By the end of the collection period, 256 completed responses were received and deemed valid for analysis.

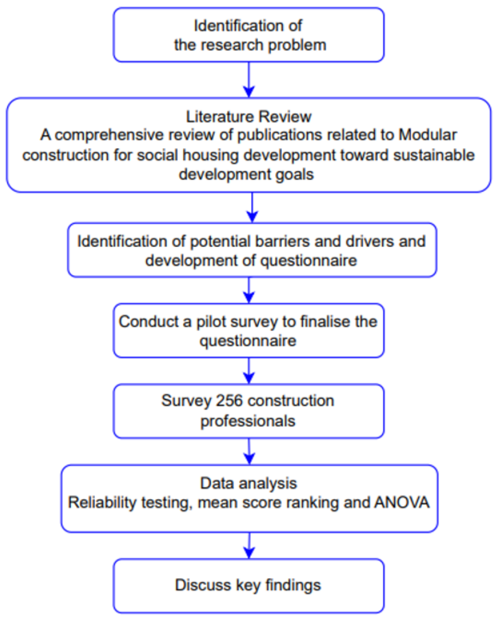


Figure 2. Research framework

The respondent sample represented a cross-section of key construction stakeholders: 62 participants (24%) were clients, 27 (11%) were consultants, 129 (50%) were construction contractors, 29 (11%) were policymakers, and 9 (4%) were academics or researchers. In terms of experience, 41 respondents (16%) had less than 3 years, 52 (20%) had 3–5 years, 70 (28%) had 5–10 years, and 93 (36%) had over 10 years of experience in construction-related roles.

Although there was a variance in sample sizes across stakeholder groups, this distribution is reflective of the actual composition of actors currently engaged in MC practices in Vietnam, with the sample considered robust enough for meaningful analysis and generalization of findings [11]. To address potential bias arising from unequal group sizes, one-way ANOVA was applied to detect statistically significant differences in stakeholder perceptions, ensuring that variations in ranking were analytically examined [11]. Additionally, the reliability and internal consistency of the questionnaire were confirmed using Cronbach's alpha [40]. Descriptive statistics, including mean scores and standard deviations, were calculated to rank key factors [41].

4. Results and discussion

4.1. Results

a. Cronbach's alpha test

Cronbach's Alpha test is implemented to examine whether the variables included in the quantitative study have affected the latent variable. The threshold for evaluating the level of relevance of the model, which is expressed by the failed safety of scale, is a value of more than 0.6 [40]. In this study, the result of Cronbach's alpha for "Drivers and Barriers" is 0.9; for "Drivers" is 0.696 and for "Barriers" is 0.876. All these values are greater than 0.6, thereby the reliability of these variables is acceptable.

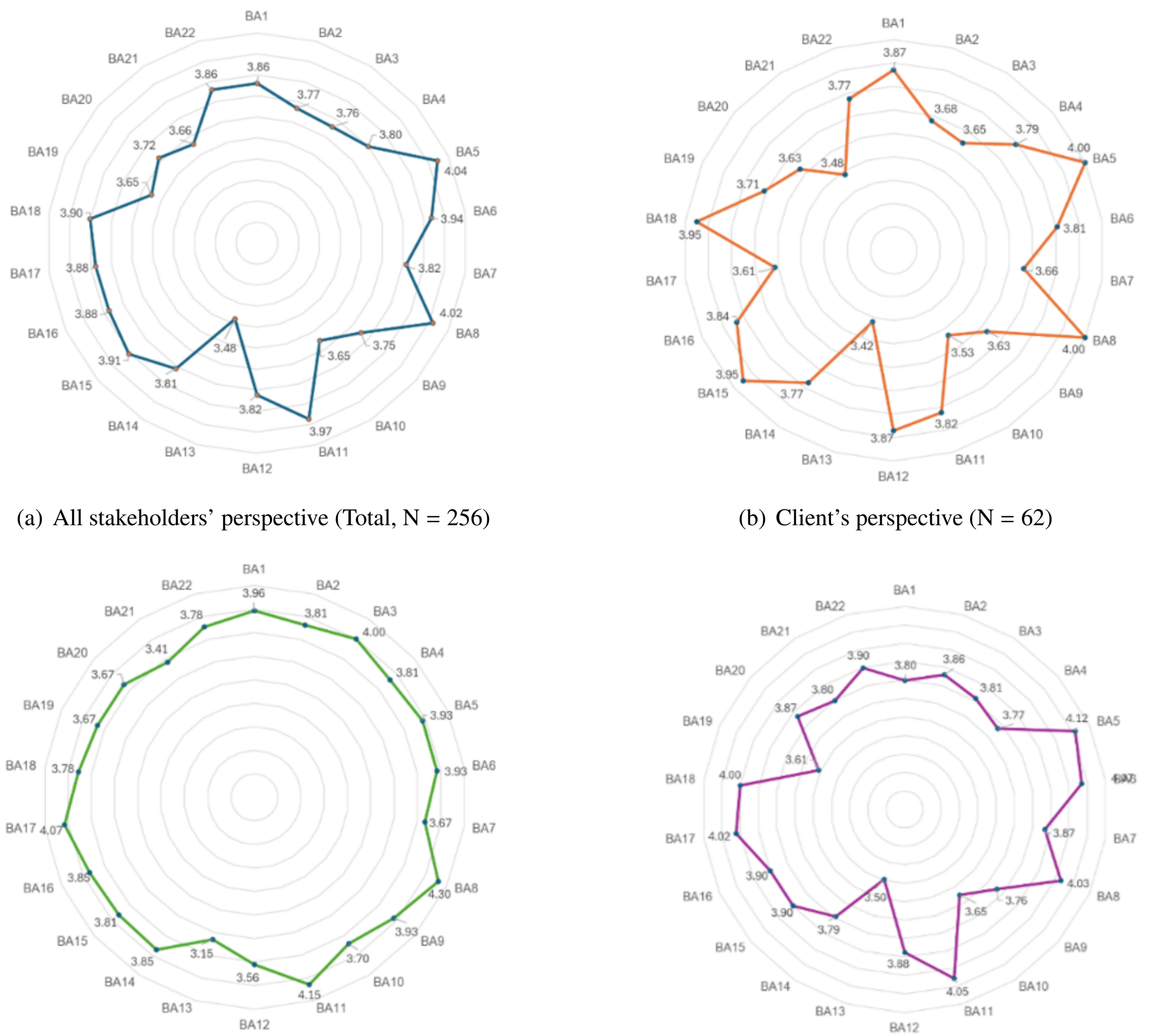
b. Ranking barriers and drivers of modular construction implementation among major construction project stakeholders

• Barriers of modular construction

The analysis presents an in-depth overview of the challenges perceived to hinder the adoption of MC in Vietnam, based on feedback from five key stakeholder groups: clients, construction contractors, consultants, academics, and policymakers. A total of 22 impediments were evaluated and ranked using mean score analysis, providing a detailed insight into group-specific concerns and priorities (Table 3 and Fig. 3). While Table 3 presents the rankings of all five stakeholder groups, Fig. 3 focuses on the three key stakeholder groups—clients, consultants, and construction contractors—who hold the greatest responsibility for project performance [41–43].

Table 3. Ranking of modular construction barriers by five major construction project stakeholder groups

Barriers	Total (N = 256)			Client (N = 62)			Consultants (N = 27)			Contractor (N = 129)			Academia (N = 9)			Policy maker (N = 29)			ANOVA
	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank	Sig.
BA1	3.86	1.190	10	3.87	1.221	6	3.96	1.224	5	3.80	1.208	16	4.11	1.054	7	3.93	1.100	3	0.903
BA2	3.77	1.133	15	3.68	1.277	14	3.81	1.075	11	3.86	1.081	13	3.89	0.782	18	3.48	1.184	19	0.521
BA3	3.76	1.167	16	3.65	1.229	16	4.00	1.144	4	3.81	1.095	14	4.00	1.118	13	3.45	1.352	21	0.348
BA4	3.80	1.075	14	3.79	1.088	10	3.81	1.210	12	3.77	1.057	18	4.00	1.414	14	3.90	0.939	5	0.955
BA5	4.04	0.995	1	4.00	1.071	1	3.93	1.107	7	4.12	0.907	1	4.00	1.000	15	3.93	1.132	4	0.816
BA6	3.94	1.079	4	3.81	1.157	9	3.93	1.035	6	4.07	1.032	2	4.11	0.928	8	3.59	1.150	15	0.187
BA7	3.82	1.121	12	3.66	1.173	15	3.67	1.330	17	3.87	1.063	11	4.11	1.054	9	3.97	1.085	2	0.547
BA8	4.02	1.072	2	4.00	1.131	2	4.30	1.031	1	4.03	1.060	4	4.44	0.726	1	3.62	1.049	12	0.122
BA9	3.75	1.197	17	3.63	1.204	17	3.93	1.385	8	3.76	1.144	19	3.67	1.414	21	3.86	1.217	7	0.826
BA10	3.65	1.198	21	3.53	1.264	20	3.70	1.235	16	3.65	1.210	20	4.44	0.726	2	3.62	1.049	14	0.329
BA11	3.97	1.104	3	3.82	1.181	8	4.15	1.199	2	4.05	0.979	3	4.33	1.323	3	3.66	1.261	11	0.207
BA12	3.82	1.108	11	3.87	1.180	5	3.56	1.340	20	3.88	1.046	10	4.22	0.833	6	3.62	1.049	13	0.392
BA13	3.48	1.304	22	3.42	1.313	22	3.15	1.199	22	3.50	1.341	22	4.00	1.414	16	3.66	1.173	10	0.429
BA14	3.81	1.046	13	3.77	1.137	11	3.85	0.989	9	3.79	1.021	17	4.11	0.928	10	3.86	1.093	8	0.915
BA15	3.91	1.091	5	3.95	1.093	3	3.81	1.039	13	3.90	1.081	7	4.00	1.581	17	3.90	1.081	6	0.985
BA16	3.88	1.025	7	3.84	1.089	7	3.85	1.064	10	3.90	0.991	8	4.00	1.118	12	3.83	1.037	9	0.986
BA17	3.88	1.055	8	3.61	1.014	19	4.07	1.072	3	4.02	1.027	5	4.33	0.707	4	3.45	1.152	20	0.007
BA18	3.90	1.067	6	3.95	1.015	4	3.78	1.219	15	4.00	0.976	6	3.89	1.054	19	3.48	1.353	18	0.195
BA19	3.65	1.168	20	3.71	1.077	13	3.67	1.240	18	3.61	1.155	21	4.11	1.167	11	3.55	1.378	17	0.756
BA20	3.72	1.109	18	3.63	1.191	18	3.67	1.209	19	3.87	0.987	12	4.33	1.000	5	3.10	1.175	22	0.005
BA21	3.66	1.150	19	3.48	1.004	21	3.41	1.448	21	3.80	1.128	15	3.89	1.364	20	3.59	1.150	16	0.278
BA22	3.86	1.090	9	3.77	1.093	12	3.78	1.219	14	3.90	1.067	9	3.67	1.225	22	4.00	1.069	1	0.835



(a) All stakeholders' perspective (Total, N = 256)

(b) Client's perspective (N = 62)

(c) Consultant's perspective (N = 27)

(d) Construction Contractor's perspective (N = 129)

Figure 3. Radar chart for ranking the barriers of modular construction

Among all stakeholders (N = 256), knowledge-related barriers emerged as the most prominent obstacles to MC implementation. The highest-rated barrier overall was BA5: "Lack of experience from suppliers, manufacturers, and designers," with a mean score of 4.04. This was followed closely by BA8: "Lack of experience in the design and installation of modules" (Mean = 4.02) and BA11: "Limited flexibility to change design during construction." (Mean = 3.97). These results are consistent with the findings of Wuni and Shen [21], Zhang et al. [27], and Luo et al. [28], who highlight that insufficient experience and technical inflexibility are significant constraints, particularly in developing economies where the MC ecosystem remains nascent.

BA6 (Mean = 3.94), relating to the lack of capable suppliers and manufacturers, and BA15 (Mean = 3.91), referring to difficulties in achieving a high return on initial investment, round out the top five barriers in the overall ranking. Financial challenges, such as BA16 (Difficulty in raising required financial resources, Mean = 3.88), BA17 (Large fixed costs and investment required for production facilities, Mean = 3.88), and BA18 (Higher capital costs compared to traditional construction, Mean

= 3.90), also featured prominently. These findings echo earlier studies (e.g., Nadim and Goulding [31]; Hwang et al. [32]) that point to financial uncertainty as a key deterrent to MC adoption.

A breakdown by stakeholder group reveals important variations in perceived barriers. For clients (N = 62), financial risks and supplier reliability are most critical. BA5 (Mean = 4.00) and BA15 (Mean = 3.95) topped the list, followed by BA16 (Mean = 3.84) and BA6 (Mean = 3.81). These results indicate that clients are particularly sensitive to the investment-related risks and the reliability of the modular supply chain.

Consultants (N = 27) placed the greatest emphasis on design-related inflexibility. BA11 (Mean = 4.15) was ranked highest, followed by BA18 (Mean = 4.07) and BA17 (Mean = 4.07). These stakeholders, who often serve as intermediaries in design coordination, are evidently concerned about the constraints of modularity in accommodating design changes during construction. The high scores given to BA5 and BA8 by this group also reflect the perceived shortage of technical know-how in the supply chain.

Construction contractors (N = 129) similarly highlighted the importance of technical and knowledge-based challenges. BA5 (Mean = 4.12), BA6 (Mean = 4.07), and BA11 (Mean = 4.05) were the top three barriers, suggesting a strong demand for more experienced suppliers and greater design flexibility. Contractors also identified BA18 (Mean = 3.91) and BA8 (Mean = 3.87) as significant issues, aligning with previous findings by Gan et al. [25] and Zhang et al. [27].

The academic group (N = 9) consistently rated the barriers more severely than other groups, perhaps reflecting their broader awareness of systemic issues. BA11, BA5, and BA8 all received perfect or near-perfect mean scores (4.33 and 4.00), while BA6 and BA14 (Lack of R&D centres) also featured highly. This focus on capacity building and institutional infrastructure aligns with Wu et al. [29], who advocate for stronger research and innovation support for MC in Asia.

Policymakers (N = 29) rated BA5 and BA15 as the most significant barriers (Mean = 3.93 and 3.90 respectively), followed by BA1 (Customer scepticism) and BA14 (Lack of R&D). Their concerns span supply-side deficiencies, financial feasibility, and public perception, suggesting a broader view of the systemic and regulatory conditions affecting MC adoption. These findings echo Steinhardt & Manley [24], who emphasise cultural acceptance and policy readiness as key determinants of MC success.

• Drivers of modular construction

In contrast, the evaluation of enabling factors for MC implementation offers insight into the strategies and mechanisms stakeholders consider pivotal for driving adoption. Responses from the same five stakeholder groups—clients, contractors, consultants, academics, and policymakers—were used to rank 12 potential drivers based on mean scores (Table 4 and Fig. 4). These drivers were grouped into four domains: technological enablers, financial mechanisms, awareness-building efforts, and knowledge development. Similar to the presentation of barrier-related findings, Table 4 offers a comprehensive comparison across all five stakeholder categories. In contrast, Fig. 4 concentrates on the three most influential groups—clients, consultants, and contractors—due to their pivotal roles in shaping project execution and overall performance [41–43], especially toward sustainable goals [44].

Technological refinement emerged as the foremost facilitator across the full sample (N = 256). DR7, "Avoiding situations where the dimensions of module components are not suitable," received the highest rating (Mean = 4.18), reflecting consensus on the need for improved precision in component design and transport planning. DR6, "Finalising the design at early stages," followed closely (Mean = 4.06), reinforcing the importance of upfront coordination and reduced mid-project disruptions—key principles also underscored by Trigunarsyah et al. [35] and O'Connor et al. [36].

Table 4. Ranking of modular construction drivers by five major construction project stakeholder groups

Drivers	Total (N = 256)			Client (N = 62)			Consultants (N = 27)			Contractor (N = 129)			Academia (N = 9)			Policy maker (N = 29)			ANOVA
	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank	Mean	SD	Rank	Sig.
DR1	3.96	1.071	5	4.02	0.949	4	3.89	1.155	7	3.97	1.096	5	3.78	0.972	10	3.90	1.205	6	0.957
DR2	3.94	1.083	7	3.79	1.058	11	3.67	1.209	9	4.03	1.068	3	4.33	0.707	1	3.97	1.149	3	0.286
DR3	3.82	1.088	11	3.85	0.973	10	4.15	1.134	2	3.78	1.104	12	4.11	0.928	5	3.52	1.214	11	0.235
DR4	3.76	1.176	12	3.73	1.148	12	3.59	1.279	11	3.83	1.193	11	4.11	0.928	6	3.59	1.150	10	0.650
DR5	3.99	0.994	3	4.00	0.849	7	4.04	1.018	5	3.93	1.077	8	4.33	0.707	2	4.10	0.976	1	0.742
DR6	4.06	1.014	2	4.02	0.967	5	4.07	1.141	4	4.12	1.013	2	4.22	0.667	4	3.83	1.104	7	0.689
DR7	4.18	0.906	1	4.26	0.904	1	4.11	1.050	3	4.19	0.858	1	4.33	0.866	3	3.93	0.998	4	0.546
DR8	3.86	1.165	9	3.89	1.057	9	3.44	1.340	12	3.90	1.217	9	3.89	1.054	9	4.03	0.981	2	0.373
DR9	3.86	1.073	10	4.03	0.905	2	3.89	1.251	6	3.86	1.109	10	3.67	1.118	11	3.48	1.022	12	0.241
DR10	3.99	1.004	4	3.98	0.967	8	4.22	1.155	1	3.96	0.995	6	4.00	0.866	8	3.90	1.047	5	0.774
DR11	3.89	1.068	8	4.02	0.914	6	3.70	1.137	8	3.96	1.114	7	3.44	1.236	12	3.62	1.015	9	0.226
DR12	3.94	1.127	6	4.03	0.940	3	3.63	1.275	10	3.99	1.156	4	4.11	0.928	7	3.76	1.272	8	0.451

Cross-border expertise was also seen as a strategic resource. DR5, advocating the recruitment of international experts to supplement domestic know-how, was jointly ranked third (Mean = 3.99), with consultant contractors showing especially strong support (Mean = 4.18). This reflects the prevalent perception that local capacity, while growing, remains insufficient for large-scale MC implementation —paralleling insights from Wuni and Shen [37].

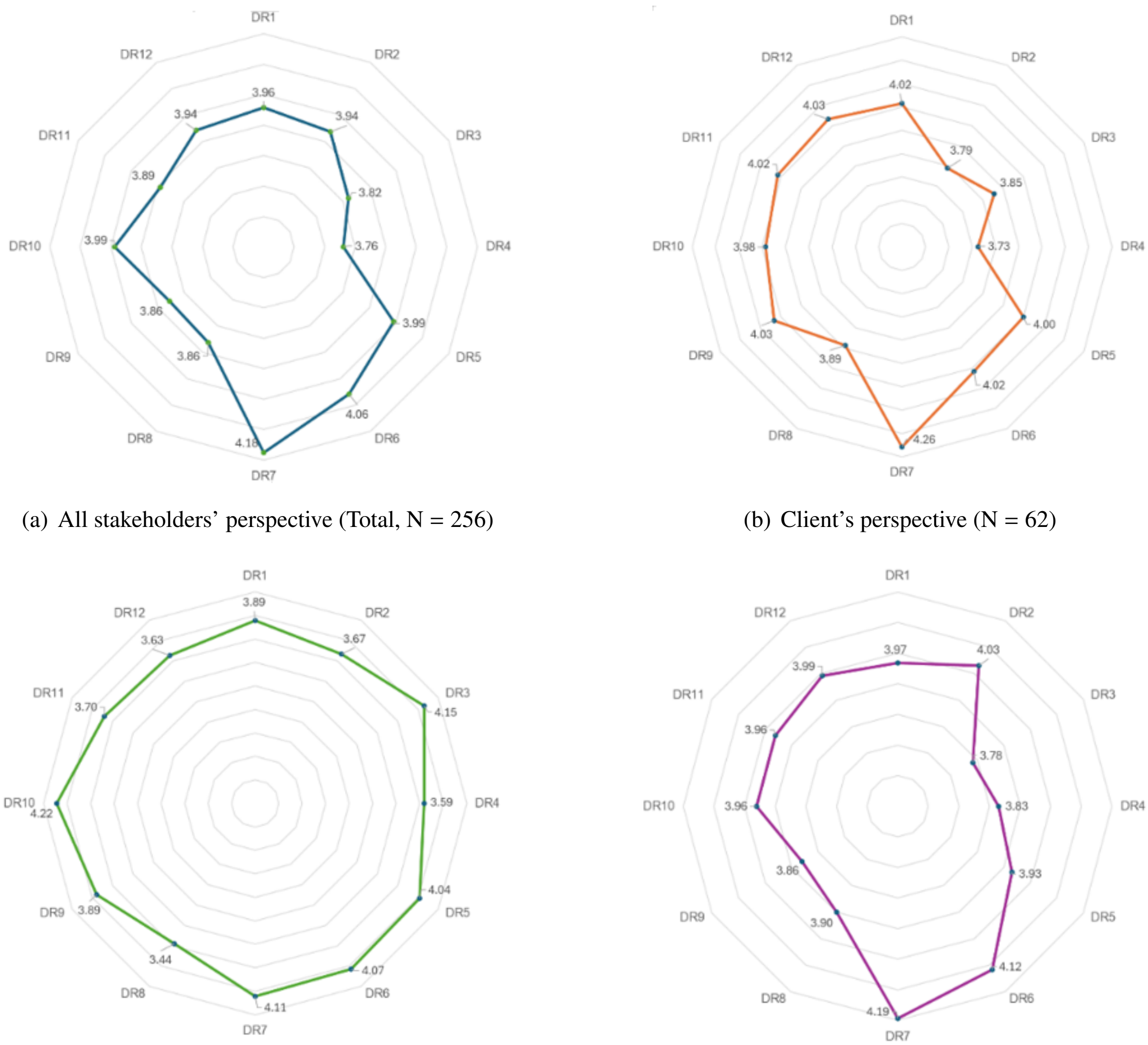
Cost-related incentives formed the next significant group of enablers. DR10, which encourages leveraging data from prior MC projects to create cost benchmarks, shared the third spot (Mean = 3.99), suggesting that institutional memory and benchmarking are seen as effective tools for mitigating financial risk. DR12 (Mean = 3.94) and DR11 (Mean = 3.89) were also well-regarded, indicating that logistical savings—such as reduced need for scaffolding or on-site supervision—can meaningfully lower operational costs and ease adoption barriers.

Awareness and communication also featured prominently, albeit slightly lower in the ranking. DR1, focused on raising stakeholder awareness through events and outreach, ranked fifth (Mean = 3.96). DR2, concerning state-driven advocacy and communication efforts, came seventh (Mean = 3.94). These results underscore the importance of education and perception management in cultivating public and professional support for modular solutions.

Finally, knowledge-based interventions, although rated more moderately, remain essential for long-term sectoral transformation. DR3 (Mean = 3.82) and DR8/DR9 (both at Mean = 3.86) pertain to workforce training, pilot initiatives, and early-stage research—strategies viewed as key to embedding modular principles into local practices over time.

Analysis by stakeholder group reveals some divergence in priorities. Clients favoured awareness-building (DR1) and design finalisation (DR6), indicating their concern for both communication and efficiency. Consultants prioritised DR5 and DR3, reflecting their emphasis on external knowledge and technical training. Contractors valued technical clarity above all, ranking DR7 and DR6 highest. Academics offered the most uniformly high assessments, notably for DR7 and DR6, which aligns with their broader institutional perspective. Policymakers highlighted DR1 and DR2, confirming their focus on systemic promotion and regulatory signalling.

In summary, the findings suggest that successful MC adoption in Vietnam will hinge on a combination of strategies that blend technical standardisation, financial rationalisation, knowledge transfer, and targeted awareness campaigns. Where barriers reflect capacity gaps and systemic rigidity, drivers offer a roadmap to bridge those divides—emphasising the transformative potential of strategic coordination across stakeholder groups.



(a) All stakeholders' perspective (Total, N = 256)

(b) Client's perspective (N = 62)

(c) Consultant's perspective (N = 27)

(d) Construction contractor's perspective (N = 129)

Figure 4. Radar chart for ranking the drivers of modular construction

4.2. Discussion

a. Summary of Cross-Stakeholder Insights

The comparative analysis of stakeholder perspectives reveals both convergence and differentiation in how key actors perceive the adoption of MC in Vietnam. While earlier sections detail the specific rankings of barriers and drivers, this synthesis distils broader relational patterns and strategic implications.

One prominent insight is the mutual emphasis across all groups on the importance of early-stage coordination, dimensional accuracy, and financial optimisation as prerequisites for successful MC deployment. This alignment reflects a consensus that overcoming implementation difficulties requires proactive investment in both design rigour and systemic efficiency. Such findings are in line with the literature emphasising the criticality of front-end planning and cost certainty in modular projects [36, 37, 45].

The results also underscore the perceived deficiencies in domestic institutional capacity and supply chain maturity, particularly in areas such as skilled labour, design flexibility, and research infrastructure. This is evident from both the widespread identification of knowledge-related constraints and the strong support for enabling measures such as foreign expert engagement, structured training programmes, and pilot demonstrations. Prior studies have similarly highlighted that capacity-building and knowledge transfer are central to facilitating MC adoption in emerging markets [37, 46].

Moreover, a role-specific lens reveals patterns of complementary concerns: clients and policymakers prioritise visibility, risk reduction, and public engagement; contractors and consultants concentrate on executional challenges; and academics adopt a more systemic viewpoint encompassing governance, infrastructure, and long-term innovation. Rather than being divergent, these orientations point to a division of labour in advancing MC—where each group brings specific expertise and influence to different parts of the implementation chain. This is consistent with findings by Steinhardt and Manley [47] and Bello et al. [48], who argue that successful MC deployment requires collaborative multi-stakeholder alignment.

Crucially, many of the highly rated barriers have corresponding drivers among the top enablers. For instance, concerns over lack of supplier expertise (BA5) and inflexible design procedures (BA11) are counterbalanced by the promotion of design finalisation (DR6), dimensional standardisation (DR7), and knowledge importation (DR5). Similarly, financial concerns (BA15–BA18) are addressed through learning from past projects (DR10) and operational cost reductions (DR11, DR12). This reciprocal pattern suggests that stakeholder perceptions are not only problem-oriented but also solution-aware—offering a practical roadmap for targeted policy responses.

In summary, the findings indicate that while technical, institutional, and financial barriers persist, stakeholder insights also point toward tangible, context-sensitive strategies for addressing them. A multi-pronged approach is essential—one that integrates regulatory clarity, ecosystem strengthening, workforce development, and public communication. In the context of Vietnam's social housing sector, where affordability, speed, and carbon reduction are pressing concerns, such coordinated action will be instrumental in mainstreaming MC as a viable and sustainable solution.

b. Policy implications and recommendations

Based on the study's findings, a set of targeted policy implications and recommendations can be formulated to support the effective adoption of MC in Vietnam's social housing sector. These recommendations are structured according to the key stakeholder groups involved, including policymakers, contractors and consultants, clients and developers, as well as educational and research institutions.

For policymakers, the integration of Building Information Modeling (BIM) across all phases of MC projects is strongly recommended. BIM facilitates early-stage design finalisation, dimensional standardisation, and improved coordination across supply chains [7, 39, 49]. Its adoption in public-funded MC projects could be mandated to institutionalise cost savings and design efficiency, as suggested by several studies [49]. Furthermore, policymakers should introduce financial mechanisms such as tax incentives, low-interest loans, and credit guarantees to alleviate investment-related barriers (BA15–BA18), which are often exacerbated by cognitive resistance (BA1), consistent with findings from [41, 49, 50]. Public campaigns, seminars, and targeted communication strategies should also be employed to shift traditional mindsets and promote the socio-cultural acceptance of MC [40, 49, 50]. Additionally, efforts to establish R&D centres focused on modular innovation are essential to address systemic institutional gaps (BA14) [40, 41].

For contractors and consultants, the adoption of BIM should extend beyond design to include logistics planning, clash detection, and installation sequencing [49]. Participation in pilot projects

(DR8) can further build technical confidence and serve as training platforms [40]. Clients and developers, who often face uncertainty and perceived risks, would benefit from access to benchmarking databases (DR10) that document cost, time, and quality performance of past MC initiatives [51], as well as opportunities for international knowledge exchange (DR5) [40]. The challenges faced by clients and developers include a negative image of prefabricated buildings, risk of uncertain market demand [39], the need for early design finalisation which can conflict with individual designs [39], and a lingering stigma associated with modular homes [52]. Economic deterrents such as high initial investment costs and financing challenges also exist [53], along with cognitive resistance from customer skepticism [39].

Meanwhile, educational and research institutions must address the prevailing human capital deficits, including a shortage of skilled workers and insufficient training [49]. This can be achieved by developing comprehensive training programs in partnership with industry stakeholders [40, 41, 49]. These programs should encompass the full MC lifecycle, from planning and design to demolition and reuse [38], and be integrated into formal curricula and continuing education [39]. Moreover, research institutions should collaborate internationally and establish modular-focused innovation labs to produce context-specific solutions tailored to Vietnam's social housing needs [49]. Collectively, these stakeholder-aligned recommendations offer a coherent roadmap for mainstreaming MC in support of sustainable housing development [40, 51–54].

5. Conclusions

This study presents a comprehensive assessment of the benefits, barriers, and drivers associated with the adoption of modular construction (MC) for social housing development in Vietnam's industrial parks. By conducting a structured analysis of 22 barriers and 12 drivers—evaluated across five stakeholder groups (clients, contractors, consultants, academics, and policymakers)—the study offers insights into the multidimensional factors influencing MC uptake.

MC holds considerable potential, particularly its ability to significantly reduce construction time, which is especially pertinent given the urgency of Vietnam's affordable housing demand. Nevertheless, the implementation of MC faces several notable challenges, including knowledge-related and financial barriers. These are most evident in the shortage of local expertise, inflexible design processes, and substantial initial capital requirements, reflecting systemic limitations in human capital, supply chain maturity, and institutional preparedness—issues similarly recognised in prior studies [21, 27, 31].

Crucially, the study identifies several drivers with the potential to mitigate these barriers. These include technical enablers such as early design finalisation and dimensional control, international knowledge exchange, and data reuse for cost optimisation. Complementary social and cognitive drivers—such as stakeholder awareness and pilot demonstration projects—are also essential for fostering long-term acceptance and diffusion.

While modest in scope, this study contributes to the evolving discourse on MC by contextualising it within Vietnam's social housing agenda—an area still relatively underexplored in Southeast Asia. Through triangulated stakeholder insights, the research proposes an empirically informed framework that may support future policy formulation and industry engagement. That said, several limitations must be acknowledged. The study is based on perceptual data, which may be influenced by individual biases and the localised nature of stakeholder experiences. Future research could adopt more quantitative methods—such as cost–benefit modelling or life-cycle assessments—to assess the economic and environmental impacts of MC more objectively. Longitudinal studies tracking the performance of completed modular housing projects would also be valuable in informing long-term strategies and evaluating policy efficacy.

In conclusion, unlocking the full potential of MC in Vietnam will require an integrated approach that simultaneously addresses technical, cognitive, financial, and institutional challenges. With targeted policies, strengthened capacity-building initiatives, and practical demonstration efforts, MC can become a transformative pathway toward achieving scalable, sustainable housing solutions for the nation's rapidly urbanising population.

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