Lecture Notes in Civil Engineering

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Advances in Civil Engineering Materials

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About this book

This book presents selected articles from the 4th International Conference on Architecture and Civil Engineering 2021, held in Malaysia. Written by leading researchers and industry professionals, the papers highlight recent advances and addresses current issues in the fields of civil engineering and architecture.

Keywords

- **Smart building materials**
- **Urban planning**
- **Structural engineering**
- **Concrete structures**
- **Structural analysis and design**
- **Seismic engineering**
- **Building technology**
- **Green buildings**
- **Structure durability**
- **Efficient transportation**
- **Traffic management**
- **Building maintenance**

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The Unresolved Design Issues in Malaysian Prefabricated Housing and Their Corrective Steps

Ahmad Bin Abdul Jalil, Fadhilah Binti Md Fazil, Dayang Afiqah binti Abang Mohamad Shibli, and Joy Natalie Cotter

Abstract Globally, prefabricated housing has been successful but in Malaysia, tremendous challenges still happening. We still face design issues which hinders industry to maximize the benefits of prefabricated concept. Research proves that we still practice improper way of design, where the drawings preparation is similar to conventional method, only convert into prefabricated design at mid-level. As a result, prefabricated housing cannot achieve its full advantages, thus many regard it as just to meet the government agenda. Many studies reported that the current design in prefabricated housing has no much different to conventional, thus lead to payment dispute, delay, contractual arguments, design clashes, rivalry relationship, and loopholes in warranty and insurance. Many also presume that prefabricated housing brings heavier risk than conventional housing. In this research, questionnaire surveys were distributed to address this issue, and the result was then verified through in-depth interviews with experts. Respondents consist of developers, contractors, prefabricated manufacturers, installers, architects, quantity surveyors, and engineers. The finding reveals the root problems on how and why the current design cannot meet prefabricated optimization. The contribution of this study is it highlights the main causes of design problems and suggests solutions that ensure prefabricated housing to reap maximum benefits.

Keywords Prefabricated housing · Procurement · Architectural · Design · Modular construction · Malaysian housing projects

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1 Introduction

Many efforts have been taken by the Malaysian government to accelerate and uplift the standard of housing, and one approach is implementing prefabricated housing. This concept has been proven to be effective in housing projects worldwide, where the housing can be completed faster, cost-saving, and better quality. Housing is most suitable to use prefabricated because of its natures that use repetitive design, similar method to construct, build many units in one time, and can reduce on-site labors to install the components [1, 2]. As stated in the Construction Industry Transformation Program (CITP) 2016–2020, developers are offered free training, tax exemptions, levi reductions and lower duty on machinery and equipment if they uptake this prefabricated housing concept [3].

Although prefabricated housing had been started in Malaysian since 1960s, many developers seem less confident to adopt this concept [4]. Developers complaint that due to this concept use automated produced components and apply manufacturing style, while industry still treats prefabricated housing similar to conventional housing; these circumstances cause many unresolved problems such as contractual and procurement disputes, design clashes, miss match drawings, coordination barriers among project members, insurance coverage, and warranty issues. Some research reveals that these problems happen because of late involvement of prefabricated manufacturers into the project team, less contractual power given to the prefabricated designers and drawings that are not suit prefabricated concept since early stage [5].

Many researches had studied on prefabricated construction, and they had covered on payment, supply chain, automation, critical success factors and barriers of implementation but lack research that covers on design aspect [6]. Thus, this research will study in depth on design aspect, where the focus will explore the challenges on design and coordination in prefabricated housing and after that, steps that can overcome those design problems will be revealed.

2 Literature Review

In Malaysian prefabricated housing, the design originally made in conventional format before converted into prefabricated design format [7]. The prefabricated company will only participate into the project after design stage, and thus they cannot join the design team to prepare the drawings [8]. This should not happen because for prefabricated to be successful, the design should be made in prefabricated format since beginning. Besides, the appointment of prefabricated company must be made since early stage to allow their designers to join since design stage.

If current practice still continues, its hard to maximize prefabricated benefits because since beginning the drawings are not made to optimize the prefabricated concept [9]. Without early involvement of prefabricated designers, errors easily can

happen due to no participation of prefabricated experts who can consult on prefabricated adoption. Besides, changes of drawings likely to occur during mid project progress because the designers need to suit the original design with the prefabricated design that come late.

Furthermore, due to late participation of prefabricated companies, there always no enough time to do design checking between the original design and prefabricated design causing mismatch and design clashes [7]. To make matter worse if the projects use mix construction, where the civil and structural (C&S) consultant only cater for the C&S drawings while the prefabricated companies cater for prefabricated drawings. The C&S engineers claim they only responsible to structure that they design and will not responsible to the prefabricated part. The C&S justify that the prefabricated components are made under the purview of prefabricated companies, not under them thus the C&S not responsible to certify the strength or guarantee the quality and this brings warranty and insurance issue.

3 Methodology

For construction research that focuses on exploring on specific issues, scholar suggests to apply a mixed method combining quantity and quality data, to ensure the data are not only collected but deeply verified by the experts [10, 11]. Therefore, this research conduct questionnaire survey and interviews with experts from all stakeholders in the prefabricated areas. The questionnaire result was tabulated using SPSS 17.0 software, then in-depth interviews were conducted with the experts using a thematic analysis technique.

Before the questionnaire was finalized, a pilot study was conducted with eight experts to ensure the questions are relevant and portray real situations. The eight experts include academician, developer, prefabricated companies, main contractors, and consultants. All of them were chosen based on their wide experience and direct involvement. The questionnaires have two parts, which first finding the challenges where respondents need to rate the frequency of situations on a scale of 1–5, from "Never" to "Very often," while second part to find solutions and they need to rate on a scale of 1–5, from "Strongly disagree" to "Strongly agree." Once tabulated, the result of each question will be shown through mean values as this had been accepted in construction study [12].

260 questionnaires were distributed to respondents in prefabricated housing but only 118 feedback, making the response rate of 45%. The returned questionnaires were tabulated and respondents that involved consist of 30.5% main contractors, 27.1% prefabricated companies and installers, 23.7% consultants, and 18.7% housing developers. Table 1 presents the category of respondents involved.

After tabulating the questionnaires result, the data then verified and deep explored through several in-depth interviews with twelve experts who have more than fifteen years experienced. This is in line with scholars practice where to ensure fairness in

Table 1 Category of respondents

Respondent	Distributed	Returned	Percentage (%)	Response rate (%)
Housing developer	49	22	18.7	45
Main contractor (Category G7)	70	36	30.5	51
Prefabricated companies/installers	61	32	27.1	52
Consultant	80	28	23.7	35
Total	260	*118*	100	*45*
(+6 not used)				

research that has various groups, the data must be verified with interviews with the experts who represent each group [13].

4 Results and Discussion; Design Issues in Prefabricated Housing

Table 2 shows the result of the questionnaire on identifying the design issues. The questions are then grouped into three major issues which are insufficient of M&E requirements, miss match design, and errors during converting the original design into prefabricated design.

4.1 Insufficient of M&E Requirements

This issue got the highest mean value with two questions, the first question with mean value of 4.43 where respondents agree that most prefabricated companies don't have qualified M&E engineers to look on M&E requirements. Another question that got mean value of 3.53 is regarding whether the prefabricated designs provide enough space for M&E requirements. This finding shows that most prefabricated companies don't employ qualified M&E engineers, and as a result, the prefabricated drawings they prepared have insufficient space for M&E requirements, causing design changes unavoidable.

To verify this result, during interview one respondent from prefabrication installer team stressed, "…insufficient space for M&E always occur, causing the plumbing, ducting and cables cannot fit into their location. This frequently happens due to the prefabrication companies have no M&E engineers to help them during design."

One respondent from prefabricated company justify why they don't employ M&E engineers, "…the prefabricated companies usually appointed during the mid project progress, and we never have chance to join during design stage. Our scope is just

Table 2 Questionnaire result on identifying the design issues in prefabricated housing

Design issues		Scale/Frequency					Std. deviation	Mean
No	Question	1	2	3	4	5		
1	The structural designs involving prefabricated works were made by the prefabricated companies without participation from consultant C&S	0	8	46	41	23	0.8678	3.67
2	The project drawings are made originally in conventional format, and later will be converted into prefabricated format	4	5	33	46	30	0.9858	3.79
3	The prefabricated designs provide insufficient space for M&E requirements, leading to design changes	3	15	35	46	19	0.9930	3.53
4	In preparing the prefabricated designed, the prefabricated companies do not have qualified M&E engineers to look on M&E requirements	0	0	9	49	60	0.6335	4.43
5	During mid project, design errors likely to occur thus redesign needs to be done to solve the errors	2	5	35	53	23	0.8739	3.76
6	The prefabricated companies join the project after design stage completed, they work without close integration with other project members causing mismatched drawings to occur	1	5	34	46	32	0.8920	3.87

(continued)

Table 2 (continued)

Design issues		Scale/Frequency					Std. deviation	Mean
No	Question	1	2	3	4	5		
7	Time and cost had been wasted to fix clashes of drawings or design errors	0	1	15	50	52	0.7198	4.30

to provide prefabricated works and not include M&E. The M&E is already under consultant works, thus we cannot have our own M&E team, besides M&E scope is not ours and no payment for that."

As consequence of not providing enough space for M&E, labors onsite have to use special tools and learn the techniques to alter the prefabricated components as these components are factory-made with high-grade concrete. In addition, each hacking or altering work must be supervise by the M&E consultant to ensure the new space is just nice and not damaging the other structures.

4.2 Miss Match Design

Next issue that received the second highest mean value is on miss match design with three questions relevant to this issue. First with 3.87 mean value where respondents emphasized that due to prefabricated companies appointed late and have limited time, and thus they focus to their scope without close integration with others. The second question received 3.67 where respondents agree that due to time constraint, the prefabricated companies prepare their design without the participation from consultant C&S, causing C&S design and prefabricated design exposed to clashes and the third question with 4.30, due to the two situations above, it makes the project wasting time and cost to fix the clashes of drawings.

One respondent from prefabricated company justifies, "we have to focus work in isolation due to we don't know the C&S consultant except after being appointed." Another respondent from C&S consultant explained, "…the reason why prefabricated companies work separately is because time constraint. They can only match their drawings with C&S drawings and have no chance to change anything. Not all part can be converted into prefabrication, but because the C&S wants so they have to. When they are forced even though it is hard, then problem occurs." This also agreed by the main contractor who stressed, "the prefabrication companies work in isolation because once appointed, they already in mid of the project and need to arrange the design, manufacturing of components, materials for fabrications, transportation, design overlap, installation and quality control. Too many task for them with time constraint." Respondent from prefabrication installer team said, "if design clashes occur, of course the project needs more cost and delay because fixing the components require specialist team, special equipment and detail steps to avoid further damage."

4.3 Errors During Converting the Original Design into Prefabricated Design

This last issue has two questions where each got the fourth and fifth highest mean values. First question with mean value 3.79 where respondents agree that initially the drawings are made in conventional format but then converted into prefabricated format. The second question with mean value 3.76, respondents admitted due to the conversion that happen during mid project, errors occur thus re-design needs to be done. One respondent from main contractor explained, "…as contractor, we deal with all stakeholders and always happen where prefabricated company needs to redo the drawings several times to suit with the original design made by C&S. At same time, the C&S request us to stick with C&S design. So before we do work, we must double-check with both designers. It causes tiring job and also bureaucratic."

Commenting on this, respondent from consultant architect mentioned, "converting the design from original format into prefabricated format during the mid project progress, will cause huge loss of time, cost and waste labor output. The conversion causes the client to spend two fees, one fee to make original design and another for conversion." This is supported by the consultant engineer who said, "due to conversion process, the clients cannot get value for money. The unnecessary cost and time for the conversion can be avoided if we really practice the 'do the right thing since beginning concept."

5 Results and Discussion; Steps to Overcome the Design Issues in Prefabricated Housing

Table 3 shows the result of the questionnaire on steps to overcome the design issues. Overall the steps are grouped into three which are detail process on drawing checks, longer duration for design stage, and no re-design or conversion of design.

5.1 Detail Process on Drawing Checks

This step received the highest mean value with three questions under it. First recommendation has received the highest mean at 4.44 where respondents agree to the recommendation on to avoid miss match, the prefabricated companies must get endorsement from M&E and C&S consultants where both must confirm all designs are tallied when overlap. The second received 4.26 mean value where respondents agreed that before manufacture the prefabricated components, the designs must be detail check by M&E and C&S consultants, and third with 4.25 respondents admit that with participation of prefabricated companies since early, they can consult all due process are align with prefabrication concept.

Table 3 Questionnaire result on steps to overcome the design issues in prefabricated housing

Steps to overcome the design issues		Scale/Frequency					Std. deviation	Mean
No	Question	1	2	3	4	5		
1	Longer enough duration must be given for design stage, to allow for BIM process, early integration among parties and effective sharing information since beginning	1	0	11	54	52	0.7147	4.32
2	The prefabricated company must be included in the design team with all designers work under close integration	1	2	10	58	47	0.7532	4.25
3	With the involvement of prefabricated companies since early project, they can ensure all due process are align with prefabrication concept	1	0	16	53	48	0.7503	4.25
4	Before prefabricated components are manufactured, their designs must be detail check by M&E and C&S consultants	2	2	11	51	52	0.8313	4.26
5	To avoid miss match drawings, the prefabricated companies must get endorsement from M&E and C&S consultants, confirming all designs are tallied when overlap	1	1	5	49	62	0.6985	4.44

(continued)

Table 3 (continued)

Steps to overcome the design issues		Scale/Frequency					Std. deviation	Mean
No	Question	1	2	3	4	5		
6	After designs are checked, verify, overlap, and endorsed, there will be no more changes allowed. No re-design or conversion design work	0	9	30	30	49	0.9914	4.01

A QS consultant responded during interview, "…to achieve cost accuracy and value for money, the project must follow the right steps including inviting the prefabricating company to participate since design stage. The tender process can be adjusted to allow this concept and as QS, we can help. Early involvement can improve the prefabricated components to be nearly perfect from design, installation until commissioning, thus no wastage on cost and time to rectify the errors or hacks the components to allow enough space for M&E." This is supported by an interviewee from housing developer, "…checking on drawings are too tedious, but it can be well done if the procedures are clear, so that can avoid to re-do, double work, miss allocation, work in isolation, miss M&E requirements, etc."

Another interviewee from QS consultant stressed, "if prefabricated manufacturer joins since design stage, all designers can do the design at once, no more design conversion and double fee which fee for original design, then fee for converting into prefabricated design."

5.2 Longer Duration for Design Stage

This is the second step, and it receives the second highest mean value. It has two recommendations and first, with mean value is 4.32, respondents agree that longer duration must be allocated for design stage, and second with mean value of 4.25, they also agree that the prefabricated company must be included in the design team. With longer design duration couple with all designers work under close integration, this ensures the quality of design, quality control, BIM adoption, detail design check and overlap, proper planning, and risk mitigation. Early integration also encourages better communication, effective collaboration, sharing ideas, and developing good relationship.

A respondent from consultant architect commented, "most designers are not knowing each other until the end of design submission and work in isolation has become the culture. This happens because design stage is always too short." Another

respondent from main contractor suggested, "…the prefabricating company must also work closely with main contractor so that both parties can monitor each other. The prefabricated part usually comprises around 60% while ours around 40% and each prefabricated component has special size which only the prefabricated company know about it."

One suggestion from respondent representing developer, "more time for design stage can ensure all designers have chance to work 'under one roof' concept where every party can share their skills to help others to better understand the project. Here, the defects can early be traced, the design can be visualized into reality, choosing the best method or technique, anticipating the potential risks, projecting the challenges ahead before they occur and provide alternative ways if original plan is derailed."

5.3 No Re-design or Conversion of Design

This is the last step with the least mean value of 4.01, the respondents agree that after the designs have properly gone through the process of checking and verifying, no more changes will be entertained. This is to avoid re-design or conversion of design which from original design into prefabricated design.

One interviewee respondent from M&E consultant commented, "when all parties realize there are no more changes on design after finalized, thus they will work precisely since beginning. To meet this, all must enforce a teamwork culture, precision, check and balance on others work, zero defects practice, and cannot work in isolation."

The consultant C&S supported, "before implementing 'no design changes' policy, the project must first practice strict sequence on design checking and verifying. Each party will employ competent engineers or officials to meet this rule. With experts monitoring, risk for errors can be avoided."

6 Conclusion

This research reveals the real issue that causes design problems in prefabricated housing. The findings show that the most important issue start with prefabricated design doesn't provide sufficient M&E requirements, followed by issue on miss match design that bring many bad effects to other works and problems that occur due to converting the original design into prefabricated design. Respondents had categorized all the stated issues as "often," which shows that the list is truly happening and they also reveal the insight story where the above problems occur due to late participation of prefabrication companies, insufficient time to integrate and each party work in isolation. The research then recommends the steps to overcome the issues with highest step is project must provide detail process on drawing checks, followed by giving longer duration for design stage and no redesign or conversion

of design. Respondents also suggest other steps such as prefabricated company must work together with contractor because their part consists of 60% or more, thus their role is big and should be regarded as major party in the project. Besides, respondents also recommended teamwork must be enforced since early so that every defects can be traced, design can be visualized with enough M&E space, and project selects the best method or technique that suits prefabricated natures. The findings contribute to the body of knowledge by listing the real issues that had been verified by all stakeholders who involved in the prefabricated industry. It also provides the insight story of the root cause that brings design issues and recommends steps from the perspectives of the various experienced respondents.

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