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AN INTEGRATED APPROACH FOR SUSTAINABILITY IN THE APPLICATION OF INDUSTRIALISED BUILDING SYSTEM (IBS)

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ABSTRACT: Malaysia is committed to improve deliverables of construction industry especially in meeting the sustainable objectives. Lack of systematic tools and poor collaboration between key stakeholders have been identified as the main barriers to meet the objectives. The purpose of this paper is to present an integrated approach that can be able to assist designers, who are at the forefront in decision making, to select the best strategies that have been shown to be effective in promoting sustainability for IBS application. Questionnaire survey and interviews of the local practitioners were conducted to identify critical factors and provide recommendations on how to enhance sustainability by holistically addressing the identified issues during IBS design. SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis framework was used to help decision-makers maximise the opportunities by using available strengths, avoid weaknesses, and diagnose possible threats in the examined issues. From the statistical analysis, eighteen critical factors relevant to IBS sustainability have been ranked. The guidelines were formulated based on the results from interviews to local practitioners and may be used as part of the project briefing documents for IBS designers. Holistic design strategies expand “Triple Bottom Lines” considerations in achieving sustainability. This study fills a current gap by responding to IBS project scenarios in developing countries. It also provides a balanced view for designers to better understand sustainability potential and prioritize attentions to manage sustainability issues in IBS applications.

Keywords: Sustainability, Prefabrication, Guidelines, SWOT Analysis, Designers

1. INTRODUCTION

Construction projects are become larger and more complex. With systematic and innovative solutions, the industry players will be able to meet new and emerging challenges such as improving construction efficiencies, integrating stakeholders’ management and reducing environmental impacts. Industrialised Building System (IBS) or prefabrication is recognised as alternative methods to replace conventional construction to enhance sustainable deliverables. Building production in a controlled environment offers many advantages such as reducing construction waste, minimising resources consumption, increasing the quality of buildings and improving the occupational safety and health [1-2]. In contrast, conventional on-site methods have long been criticised for being labour intensive, poor workmanship quality, overwhelming management control and excessive construction waste generation [3].

Understanding IBS benefits and its potentials, the Malaysian Government steering the local construction industry to shift from traditional practices to IBS based production. The Construction Industry Transformation Programme (CITP) 2016-2020 is specifically highlight government strategies in ensuring faster and higher adoption of IBS application in the local industry. Despite acknowledging its benefits and the top-level advocacy, the local construction industry is still not rapidly embracing IBS [2-4]. Arditi, Ergin and Gunhan [5] highlighted that most of stakeholders do not realize of the significant cost savings in the IBS application through speedy erection and long term investment. In addition, most of the developing countries are depending on technology from industrialised countries [6]. It was highlighted that the effective communication and higher financial capital are required to accelerate technology transfer.

Currently, the implementation of IBS was lack of communication and cooperation among the key stakeholders [4-8]. Manufacturers and contractors can only become involved after the design stage. The separate functional discipline in the implementation process is akin to the ‘over the wall’ syndrome [9].

This study aims to formulate sustainable guidelines from the perspective of the designer by critically examining the relationship between sustainability and IBS. Though other researchers have developed decision tools in IBS application, no previous studies in this field have considered the potential threats and weaknesses of pursuing sustainability. This study explored perceptions among the key stakeholders regarding both contexts and provides easy-to-understand guidelines for practitioners in developing countries such as Malaysia. This study also presents unified views from key stakeholders instead of single professions, the consideration of negatives instead of all "positives", and the justification to enforce a sustainability focus in developing economies still grappling with finding suitable solutions in local contexts.

2. LITERATURE REVIEW

There are many factors that are internal and external to building projects that enhance the sustainable deliverables. Some commonly identified factors include: energy use, transport, water efficiency, ecology, land use, materials and resources, indoor environmental quality, heatlh and well-being, sustainable site and management, and innovation [10-11]. A study of sustainable constructions aspects of using IBS in Hong Kong added to this body of literature by identifying factors that improve sustainable deliverables. Jailoon and Poon [12] found that IBS will be able to improved quality control, improved environmental performance (reduction of waste, dust and noise), improved site safety, the reduction of labour demand and construction time. In their case studies, on average, a reduction of 65% of construction waste, 16% of labour requirement on-site, 15% of construction time and 63% lower than the industry figure for the accident rate. In a similar study, Lam, Chan, Poon, Chau and Chun [13] identify principal factors leading to the success of preparing green specifications in construction projects and identified the following as the four major influencing factors: (1) green technology and techniques, (2) reliability and quality of specification, (3) leadership and responsibility, (4) stakeholder involvement, and (5) guide and benchmarking systems.

Pitt, Tucker, Riley and Longden [14] divided three key areas towards sustainable construction: (1) environmental responsibility, (2) social awareness, and (3) economic profitability. They research highlighted that financial incentives and building regulations were the two most important drivers that will be able to drive demand for sustainability buildings. An effective working environment will be able to reduce absenteeism and supports staff retention and recruitment. IBS promotes stable working conditions and organised working procedures. The local labourers have the opportunity to develop their skills and knowledge and reduce the possibility of being transferred to another region or location. Currently, IBS is seen as more expensive, especially as it involves high initial capital outlay, and higher design, cranage and transport costs compared to conventional construction [15]. Although the critical investment in the initial process is very high, once the break-even point is reached, the benefits from IBS will increase with the number of units produced [3-16]. By implementing IBS, Malaysia is on the right track for moving forward to develop the country.

Chan, Qian and Lam [17] found that the economic force and government interventions are the strong forces to arouse interests in pursuing sustainability. Their study highlighted that ‘‘rising energy costs’’ will present such an economic reality that people will have to take part in sustainable development for their own interest. The other economic attraction for all stakeholders in construction industry to be involved in achieving sustainability is "lower life-cycle". Any impact of the decisions for the long term, specifically for the demolition and deconstruction should need taken into account in making effective decision. They also stated that, it is important for a government to create mandatory regulation or building code to ensure stakeholders are taking part in sustainable efforts.

There have been several studies that integrate factors that influence the sustainability for IBS projects. Researchers have developed assessment tools to help stakeholders overcome project challenges and use opportunities available in IBS implementation [18-21]. The researchers argued that the measurement should also consider indirect attributes, such as reducing the environmental impact. While the proposed tools provide some assistance in the selection of IBS, few are capable of providing action plans on how to embed sustainability deliverables in the selected options. Most of the tools are focused solely on strategic level analysis and fails to consider sustainable factors objectively with specifics project requirement.

Current literature provides an understanding of potentials of IBS in improving sustainability. Despite this awareness, academic research has not established holistic criteria in IBS selection. It is vital to consider sustainability characteristics in improving IBS implementation, specifically to developing countries, such as Malaysia. The numbers of integral approach that takes into account all of the environmental, economic and social aspects is very small compare to approach that focus on individual aspects [22-23]. Most of the stakeholders, such as contractors and manufacturers are struggling to integrate sustainability in IBS implementation. This is due to unclear decision guidelines and the shortage of tools regarding sustainability criteria selection. All stakeholders should provide inputs on how sustainable deliverables can be achieved in the IBS implementation in the early stage. This study proposed the integration should be done in the design stage as shown in Figure 1.

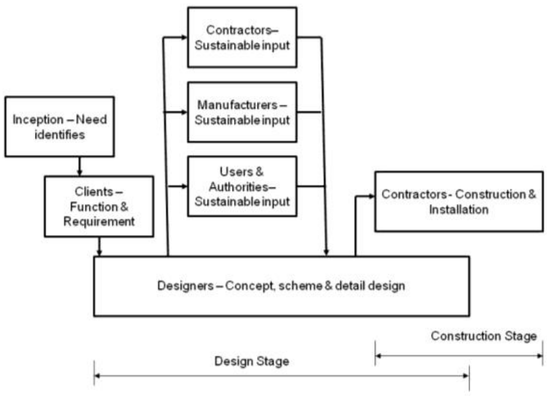

Fig. 1 Sustainable inputs by stakeholders in the design stage

Local and regional characteristics and physical environment plays a major role in measuring the level of sustainability [24]. With the flexibility for adaption, issues studied in developed countries are unlikely to be applicable or even relevant to developing countries [25]. Ofori and Kien [26] suggested that the stakeholders in the construction industry should initiate a strategy selecting the best solutions in their design and building construction. The importance of specifics actions assigned to particular stakeholders in evaluate their decisions, including the selection of raw materials to be used, energy consumed and the pollution and waste produced throughout the building life cycle was highlighted. Therefore, the study presented in this paper focuses on the holistic approach in integrating potential factors to improve sustainability at the early stage of construction.

3. RESEARCH METHODS

The quantitative data were collected and analysed to identify the level of significance of each potential factor in improving sustainability for IBS application. The critical factors were identified by using statistical test. Then, the qualitative interviews were conducted to further explain the details of each critical factor and to formulate the action plans. Accordingly, the guidelines were developed based on in-depth investigation on each issue using semi-structure interviews. In responding to the negative and positive contexts, the strategies on improving sustainability were properly investigated. Figure 2 shows the research design that adopted in this study.

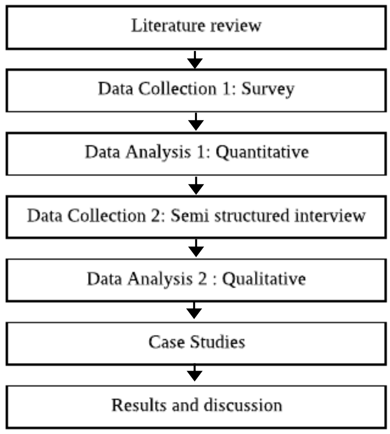

Fig. 2 Research design

The questionnaire survey involved seven sample groups categorised by their organisation type, namely 1) designer/consultant companies, 2) manufacturer companies, 3) user or facility management companies, 4) developers, 5) research/academic institutions, and 7) authority/government agencies. The respondents were selected from professional databases of the Construction and Industry Development Board, Industrialised Building System Centre, and Green Building Index Malaysia. The questionnaires were distributed by post, online survey and face-to-face consultation. From 300 copies of questionnaire, 115 questionnaires were returned and can be used in the analysis. Therefore, the response rate is 38 per cent.

Consequently, the factors were explored through semi-structured interviews to extract best practices of how these factors can be dealt with. A semi-structured interview form was used because it was flexible and it gave additional scope for the interviewees to provide detailed information based on their experience and capability. It also allowed the researchers to maintain focus on the research objectives. Twenty respondents participated in the interviews. They all have different backgrounds and vast experience in construction industry. This helps researchers identify the perception of each type of organisation in pursuing sustainability. As a result, the interviewees were able to provide more in-depth and detailed answers and suggestions in their responses to the questions. SWOT (strengths, weaknesses, opportunities, and threats) analysis was used to formulate a decision-making guideline.

With both quantitative and qualitative methods, the results covering perceptions of key stakeholders in a sustainable IBS shall underpin the basis for establishing the decision making process models for enhancing the feature of this innovative system. Ultimately, as the final outcome of the study, the guidelines will help promote more integrated approaches to decision making about the implementation of sustainability strategies in the designing stage.

4. QUANTITATIVE ANALYSIS

The ranking of the sustainability factors was carried out based on their mean values. In selecting the critical factors, the cut-off mean value is 4.00 which represents "significant". Out of the 62 factors identified in the literature review, only 37 factors were rated by the respondents as "significant" and "very significant" (mean ≥ 4.00). The standard deviations in this analysis show uniformity with most below 1, thus representing good data accuracy in this study. Accordingly, a t-test was used to identify the most significant factors among the 37 factors. This method was previously proven by several researchers such as Ekanayake and Ofori [27] and Wong and Li [28] in related studies. In this study, the null hypothesis (factors were neutral, insignificant, and very insignificant) is accepted if the t-value is smaller than 1.6583 (the critical t-value). The significant factors are shown in Table 1.

Table 1 Sustainable Factors for IBS Implementation

No.	Sustainable factors	Mean	Std. Deviation	*t*-value
1	Construction time	4.64	.665	10.380*
2	Production	4.52	.742	7.545*
3	Waste generation	4.50	.792	6.652*
4	Constructability	4.45	.728	6.657*
5	Knowledge and skills	4.45	.797	6.081*
6	Defects and damages	4.41	.687	6.380*
7	Labour cost	4.39	.780	5.379*
8	Waste disposal	4.38	.838	4.828*
9	Procurement system	4.37	.722	5.472*
10	Durability	4.36	.797	4.798*
11	Working conditions	4.33	.734	4.827*
12	Standardisation	4.33	.769	4.607*
13	Usage efficiency	4.30	.728	4.486*
14	Labour availability	4.30	.900	3.626*
15	Material consumption	4.28	.785	3.837*
16	Legislation	4.19	.915	2.262*
17	Project control guidelines	4.14	.895	1.682*
18	Maintenance and operation costs	4.13	.755	1.852*

The Kruskal-Wallis one-way ANOVA test revealed that there was no significant difference between various stakeholder organisations for 13 sustainable factors. They have a consensus regarding the perceptions and expectations in achieving sustainability. On the other hand, five factors have slight differences across the key stakeholders. They are: (1) constructability, (2) defects and damages, (3) labour cost, (4) material consumption, and (5) legislation. It is interesting to note that although "constructability" is among the top five critical factors, the seven groups ranked it at different significance levels.

Among these five factors, manufacturers and users have a different agreement to other groups in determining the significance level of "defects and damages", "labour cost", and "material consumption". A possible reason may be that manufacturers and users are only involved with the end product, which is contrary to other groups which play their roles in the briefing, design, and construction stages. Most of the decision-makers consider available options or potential factors based on their familiarity and personal preferences [30].

The Mann-Whitney test explores the differences between two independent groups on a continuous measure. The score on the continuous variable for the two comparable groups is converted to ranks in order to evaluate whether the ranks differ significantly. It is notable that the designer/consultant group has a different focus in improving IBS sustainability in regard to four factors, namely: 1) "constructability", 2) "defects and damages", 3) "labour cost" and 4) "material consumption". The designer/consultant group was found to have a different perception on the significance level of "defects and damages" and "labour cost" compared to the contractor, manufacturer and user groups. For "legislation", differences were identified between the contractor group and three other organisation groups (manufacturer, user and client). It is believed that from the institutional perspective, these organisations are more focused on the details in the legal documentation and regulations. On the contrary, the contractor group normally has a low level of concern about these issues because they are more focused on the physical activities.

The results showed that all the 18 factors can be statistically considered as the most significant and relevant in improving IBS sustainability. The respondents and their organisations represent different backgrounds and experiences which can either affect or be affected in IBS projects. As key stakeholders, their opinions and views are very important to stimulate sustainability deliverables in

IBS construction. Therefore, the factors selected and ranked as critical will provide a sound basis upon which decision-making guidelines for IBS implementation can be based.

5. QUALITATIVE ANALYSIS

Knowing the critical factors is important. But knowing how to deal with them requires appropriate and effective strategies. Based on the results from quantitative analysis, the logic and structure for processing critical factors was establish. The critical factors were grouped into 5 categories: ecological performance; economic value; social equity and culture; technical quality; and implementation and enforcement.

The semi-structured interviews elicited insights and points of view from the respondents that are useful for the formulation of efficient decision-making guidelines. The remarks provided from the respondents for each critical sustainability factors were produced from the reduction and transformation process. This is important to ensure the information is readily accessible, understandable, and to draw out various themes and patterns [30]. Their remarks were analysed and grouped to form the action plans in improving sustainability. The SWOT analysis was adopted to evaluate simultaneously the internal and external factors by collecting all the possibilities and opportunities. It is important to note that the designers require lots of information to guide them in making appropriate decisions, especially when integrating sustainability efforts [31-32]. Previous research has proven that SWOT analysis can be used to evaluate risks, to gain insight into the internationalisation of construction companies in the global market and to measure the performance of construction firms in developing countries [33-35]. SWOT analysis is ideal for analysing the situation each investigated factor presents. The template used for SWOT analysis is providing in Figure 3.

The interrelated criteria also help to develop potential strategies. Through such analysis, decision-makers can exploit new opportunities by utilising available strengths, avoiding weaknesses and diagnosing any possible threats in the examined issues. In addition, comments from respondents help the researcher to suggest recommendation actions that can be considered by decision makers in improving sustainability.

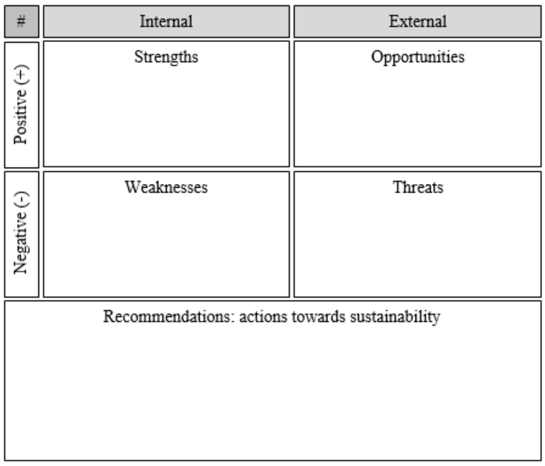

Fig. 3 Template for SWOT Analysis

Accordingly, the final guidelines were approved by the respondents. It is agreed that the guidelines will be able to provide a systematic decision support tool for the stakeholders in encapsulating sustainability. The importance of the stakeholders' participation and their full understanding of this approach were highlighted. These will increase the key stakeholders' interest in using the SWOT analysis which provided in the guidelines.

6. DISCUSSION

The promotion of IBS usage in Malaysian construction industry is constantly faced with a number of challenges to improve, meet market demand, and overcome skills shortages. Literature studies suggest the general lack of research efforts to assess the full sustainability potential in IBS applications. The few relevant research projects attempted to deal with one aspect in Triple Bottom Line (TBL) alone - such as economic or social dimensions. A holistic approach that encompasses all important issues of the TBL and beyond is not yet available. In Malaysia to date, IBS applications tend to be linked with government projects primarily. As such political scenarios and government support are very important aspect. The quantitative methodology adopted in this study has identified the 18 critical factors and interrelationships between these factors. This study probes into the environmental, economical and social aspects the IBS potential and extends them to include 'technical quality' and 'implementation and enforcement' aspects of the sustainability assessment. Implementation and enforcement are the factors that ensure that any planning will be carried out accordingly. An effort from the authorities was identified as a starting-point to integrate sustainability for IBS applications in Malaysia [36]. The technical issues provide physically measurable attributes of IBS construction and an opportunity to maximize the IBS benefits in improving sustainability. These considerations present a new level of thinking and knowledge paradigm in dealing with the IBS method.

Research findings noted that the adoption of SWOT analysis will be able to provide the necessary framework to understand the internal and external conditions of each critical factor.

7. CONCLUSION

Considerations of both the positive and negative aspects of pursuing sustainability can help "complete the scenarios" when making the best selection. Such a decision-making framework also includes action plans to present information on what and how to improve the sustainability of each critical factor. Ideally, this would form part of the project briefing documents against which sustainability solutions can be considered and implemented by the designers. Moreover, the clear responsibility of IBS participants in regard to the sustainability deliverables can be documented and potentially embedded in contracts. Developers and designers alike will have a tool to assess the potential of IBS and to enhance sustainability.

While research findings are considered to be "representative", as respondents covered a wide range of the construction industry stakeholders such as contractors, consultants and manufacturers, the delivered decision support guides are intended for the designers. These tools will be used in the design stage and early construction stage. Further research can extend the findings to include appropriate decision mechanism and preferences for other stakeholders.

8. ACKNOWLEDGEMENTS

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