Sustainability Factors in Industrialised Building System

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Summary

In Malaysia, Industrialised Building Systems (IBS) are being promoted as a potential to enhance sustainability by the building industry and government. Known elsewhere as prefabricated construction, IBS employs a combination of ready-made components in the construction of buildings that promote quality of production, enhance simplification of construction processes and minimise on-site work. The components are manufactured in a factory either on or off site. They are then positioned and assembled into building structures. The unique characteristic of IBS has the potential to respond well to the sustainability challenge facing the construction industry. Despite the promises however, IBS has yet to be effectively implemented in Malaysia. There are often misconceptions among key stakeholders about IBS applications and some of the rating schemes fail to assess IBS towards sustainability deliverables.

A holistic approach to improving IBS implementation is necessary to consider sustainability perceptions on IBS among key stakeholders. As IBS design is one of the most important development phases to incorporate sustainability requirements and expectations, a framework of embedding sustainability factors into IBS design is being developed through research. This paper presents an improved IBS design process focused on sustainability, showing where and how sustainability should be assessed to improve IBS construction. The framework being developed can provide guidance and decision making assistance to not only design consultants but all relevant stakeholders by integrating sustainability concepts into IBS applications. Outcome of the research will also provide a benchmark for developing countries in adopting prefabricated construction systems.

Keywords: Sustainability, Design, Industrial Building System, Stakeholder

1. Introduction

The construction industry plays an important role to the developing countries. In Malaysia, the industry contributes up to 5 per cent of Gross Domestic Product per annum and employs about 8% of the workforce [1]. On top of that, this industry acts as a domestic demand multiplier effect by working together with other industries, such as materials manufacturing and property services [2]. Despite the rapid advancement in the construction industry, most of the construction work in Malaysia is still applying conventional methods which are often not sustainable.
Sustainable construction has become a growing concern throughout the world over the past year. Kibert [3] highlighted that sustainable construction will result in the creation and responsible maintenance of a healthy built environment and promote efficient use of resources. The construction industry players need to have a broader perception in achieving their objectives. They should not only focusing on economics, but also the benefits to the societies and the construction workers [2]. To achieve this, entire activities in the construction value chain should be analysed to determine their effects and contribution to sustainable development.

IBS is a construction system with a combination of components that promotes simplification and minimise on-site work. The production in a controlled environment reduces the numbers of workers involved, reduces construction time, increases quality of buildings, reduces cost and enhances occupational health and safety [4-6]. More importantly, it reduces construction waste [7-8]. These advantages provide opportunities for IBS to better contribute towards the agenda of sustainable building projects.

However, according to previous reports, the usage level of IBS in the Malaysia construction industry stands at 15 % in 2003 and only 10 % in 2006 [9]. Possible reasons include limited understanding among stakeholders on the potential of IBS and its relevance to sustainability. Most of the stakeholders have negative perceptions in IBS and are unable to foresee the benefits of this innovative method. Therefore, feasibility for change is difficult due to insufficient information regarding IBS [9]. Moreover, decision making in the selection of IBS methods is not made consistently due to the lack of decision tools that embrace the concept of sustainability.

In this context, there is a need for better understanding of the potential of IBS in enhancing sustainability before its wider adoption. Specifically, an integrated assessment process and an effective collaboration between key stakeholders on the key attributes and evaluation of sustainability factors can work towards sustainable IBS delivery. Key stakeholders involvement is imperative to ensure the success of the construction project by providing consensus input for the decision making.

The purpose of this paper is twofold. First, to review and assess the conceptual framework that can be adapted for sustainable deliverables in IBS. Second, it will discuss factors that have a potential to facilitate sustainability integration in IBS application. This whole process is encapsulated in a general sustainable framework for decision making of IBS implementation.

2. Sustainability and IBS

The Natural Step provides an intensive framework to visualise the importance of sustainability consideration in a construction project [10]. A funnel is used as a metaphor to show an increasing demand in contrast to declining available resources and ecosystem services (Figure 1). The space available at the top of the funnel envisages option and constraint that are available in making a decision for any solution. A proper path is required in order to shift toward sustainability and begin to open up the walls of the funnel.

On the other hand, the injection of sustainability principles in the IBS can restore and maintain the harmony between the environment and construction, improve human self-respect and encourage economic development. The implementation of sustainable IBS can also ensure institutional sustainability. This dimension of sustainability plays an important role in catalysing development holistically especially for developing countries. With cooperation and understanding among stakeholders, sustainability principles will integrate these efforts in each stage of IBS implementation.
Based on similar application by previous research studies, sustainable IBS construction can be described as the projects which are economically, environmentally, socially and institutionally sustainable [11-16]. Therefore, an integrated conceptual framework is proposed for this research to improve sustainable deliveries for IBS construction. With reference to 'The Funnel' by Roberts [10], the proposed framework is illustrated in Figure 2. There are four main elements involved in this framework for ensuring sustainable deliverables in IBS: 1) Enablers, 2) Integrated decision making guidelines, 3) Sustainable IBS design and 4) Sustainable deliverables in IBS.

For the first element, enablers are the factors that can influence the motivation for sustainable deliverables for IBS construction. Seidel et al. [17] stated that enablers can be categorised into four groups, namely: 1) strategy definition, 2) organisational support, 3) motivation, and 4) traceability. The nature of the construction industry requires a high commitment from the project team in ensuring the successful delivery of the projects. Each project participant should understand the strategy and available support to achieve the project’s goals. Organisation should provide clear instructions to their team members in incorporating sustainable principles in the IBS projects. Self awareness and motivation among the personnel involved will encourage the sustainable implementation in IBS. In addition, traceability in the sense of transparency and measurement are also very important to manage the adoption of sustainable deliverables [17].
Secondly, integrated decision-making guidelines are required to assist decision-makers in selecting appropriate construction methods in order to improve sustainable deliverables. Next few sections will discuss the sustainability factors that can be integrated into IBS construction.

Thirdly, these proposed sustainable IBS design guidelines will be used to ensure sustainability in construction projects. Even though the designer is the one who makes the ultimate decisions, considerations of key stakeholders must be taken into account. These design guidelines can be developed on the basis of consensus between key stakeholders, including manufacturers, regulatory authorities and also contractors.

Finally, sustainable deliverables in IBS need to be linked to the ‘enablers’ to stimulate motivation and inspiration so that better outcomes can be achieved. It needs to be monitored in order to prevent failure due to the existing constraints. The outcome of sustainable deliverables in IBS balances supply and demand without destroying our natural resources for the future generation.

3. Integrated sustainable IBS approach

Most of the IBS projects in Malaysia are still adopting the traditional approach that involve separated design and construction stages (Figure 3) [18]. There are four main processes relating to the design stage which is usually initiated with a client briefing. Here, an appointed designer will be briefed by the client about the concept and requirement of the project. The architectural design can then be developed and handed to engineer to develop the structural design. Finally, the quantity surveyor will estimate the cost involved and get an approval from the client. The construction stage involved two main processes, which are 1) production and 2) construction and installation.

![Figure 3: Traditional IBS Approach](image)

This traditional approach restricted contractors and manufacturers to be involved in the design stage. As a result, cooperation among key stakeholders is lacking. The lack of integration will result in need for plan redesign and consequently, will increase the project cost [9]. Moreover, most of the research studies agreed that sustainable deliverable initiatives require earlier cooperation among the stakeholders [18-23]. This is important in allowing each player to define issues and set sustainability goals prior to schematic design and continuing through construction, operation and demolition of the building.

The improvement of sustainable design practice must be driven from two directions, firstly the integration of stakeholders and secondly sustainability factors in IBS. The improved relationship is illustrated in Figure 4 where more emphases are placed on the earlier stages to ensure a clear project strategy in achieving sustainable objectives. This approach offers opportunities to learn from each other based on previous experiences and incorporating improvements such as not repeating mistakes, wasteful processes and fire-fighting management practices [24]. In addition, segregation and isolation are removed from the different organisation, which provide them a space to work together in an integrated approach. On-going research in Queensland University of
Technology (QUT) has identified six major factors to improve sustainable deliverables in IBS: 1) Ecological performance, 2) Economic value, 3) Technical quality, 4) Sustainable awareness, 5) Socio equity and culture and 6) Implementation and enforcement.

Figure 4: Integrated Sustainable IBS Design Consideration among Key Stakeholders

4. Review of related decision making tools

To develop a strategic framework linking different stakeholders' decision, it is essential to identify the potential factors that can enhance sustainable deliverables in IBS construction. Many research projects have identified factors, indicators and attributes to improve sustainability in building construction. These include PPMOF (Prefabrication, Preassembly, Modularization and Offsite Fabrication), IMMPREST (Interactive Method for Measuring PRE-assembly and Standardisation), PSSM (Prefabrication Strategy Selection Method), Structural Frame Selection (SFC) and CMCM (Construction Method Selection Model).

PPMOF was developed to help stakeholders overcome project challenges and improve project performance by using available opportunities in prefabrication [25]. However, this tool focuses solely on the strategic level analysis and failed to weigh each factor objectively which will consequently produced a biased decision [26]. The IMMPREST brings “softer issues” such as health and safety, sustainability, and effects on management and process into the decision-making. However, the limitation of this tool include inadequate information available at the early stage of a project and many of the factors and consideration failed to represent the actual context of sustainability [26].

Luo et al. [5] stated that selection of the best alternatives is important to enhance the sustainability outcome for the construction project. By choosing the most efficient component in every stage, effective prefabrication decision would be obtained after comparing different options available. PSSM was developed to focus on curtain wall systems, mechanical systems, and wall frame systems. For structural frame selection, Soetanto et al. [27] developed SFC, a simple framework in evaluating performance of various options such as traditional structural technique, steel frame and hybrid concrete, based on seven main criteria: 1) Physical form and space, 2) Construction...

The latest tool, CMCM was divided into two sequential levels: strategic and tactical level [26]. The strategic level is initially used to evaluate the potential of prefabrication method to be employ for the construction project such as project characteristics, site conditions, market attributes and local regulations. This is followed by evaluation at the tactical level, to examine the potential of prefabrication in terms of economic, social and environmental. This tool enables the evaluation of the construction method more objectively, and it is apparent in a sense that it considers project’s characteristics and decision makers’ risk attitudes [26].

While these existing tools provide a benchmark in assessing the selection of IBS, they are limited and inconsistent in evaluating this construction method, especially in embracing the concept of sustainability. Existing tools and methodologies tend to omit institutional, socio-equity and culture issues such as legislation, local economy and community disturbance. As such, most the tools failed to understand the full benefits of IBS. Thus, these limitations reflect the significance and necessity to incorporate sustainability principles into IBS so that it will restore and maintain the harmonization between the environment and construction, especially for a developing country.

5. Potential sustainability factors

The authors have developed potential sustainability factors from an extensive review of past research reported as shown in Figure 5. These factors contribute to economic, social, environmental and institutional objectives [5, 21, 25, 28-32].

![Figure 5: Factors Enhancing Sustainable Deliverables in IBS](image)

Each factor contains attributes that can be designed and weighted differently depending on the building profile over the entire lifecycle. Notwithstanding this progress, six major factors were identified as having the potential to enhance sustainable deliverables in IBS. The factors are:
• **Ecological performance** - defined as any attributes that will increase the possibility in IBS construction to preserve natural resources and reduce negative impact to environment. Jaillon and Poon [21] stated that IBS has major benefits in environmental, namely material conservation and reduction in waste, air pollution and water consumption. For example, factory productions have the potential to incorporate solar energy and reduce dependency on fossil fuel. Improvements in IBS components quality are ensuring consistent standards of insulation and service installation which reduced an operational energy [33].

• **Economic value** - attributes that reduce not only tangible cost but also intangible cost for the whole IBS building lifecycle. The economic consideration needs to be expanded including in terms of flexibility, adaptability and local or domestic economic situation. Traditional management parameters (time, cost and quality), is aiming for economic objectives but it requires a further evaluation for economic value such as speed of return investment, IBS components production and design stage adoption [25, 29-30, 34].

• **Technical quality** - the factor that provides physically measurable attributes of procedures in IBS construction to meet professional standards. It is mandatory in any engineering works. Controlled production environment reduces defects and damages for IBS components as well as improving durability of the buildings [29, 33-34]. Generally known, the construction industry is unique and subject to constant change. However, adaptability and flexibility features in IBS allow the system to fit in different building functions and accommodate the future technical condition [11, 25, 34].

• **Sustainable awareness** - the positive consciousness to provide a better future for next generation. Valuable experiences, knowledge and skills by designers, construction professionals and building owners can significantly improve the sense of responsibility to consider sustainability features [11]. Public participation and awareness are vital to improve willingness of stakeholders to invest for not only financial profit but also intangible benefits.

• **Sosio equity and culture** - the factor that offers long-term opportunities for workers and enhances the quality of life in the local community. It is vital in sustaining the well-being of the people and communities in which the IBS construction is to be operated. The appreciation of the significance of non-technical issues gives a recognition to this factor equally important to economic sustainability [35]. Communal impacts such as local disturbances, labour availabilities and economic developments have a direct impact to those who resides in the surrounding area. The workforce for the IBS comes from the surrounding locality, and their standard of living would be directly improved because of these factories.

• **Implementation and enforcement** – the factor that ensures any planning will be carried out accordingly. Any good planning will be meaningless without proper implementation and enforcement. Construction Industry Master Plan 2006-2015 illustrated the full commitment of the Malaysian Government to implement IBS in minimising construction time and reducing the number of foreign workers in the industry. The Government has put forward regulatory requirements and incentives in order to promote IBS [1]. Standardisation and regulation provide modular and standardised components to enhance buildability and reduce waste generation [32].

The attributes from these six major factors are listed and put in a questionnaire to aid the industry in identifying the crucial sustainability factors in IBS. Then, these factors will help the authors to develop decision making guidelines for IBS implementation. The guidelines will be used in the design stage to integrate sustainable concepts into IBS applications. This will result to sustainability in construction.

6. **Conclusion**

Industrialised Building Systems have the potential of enhancing sustainability in construction. To fully capitalise on the potential of IBS to enhance sustainability, common understanding on key IBS
capabilities and collaboration among key stakeholders are necessary. Major development processes, such as design, can benefit from an effective design making guidelines that involved key stakeholders. This is to ensure that they have a unified views and follow commonly agreed approaches to IBS implementation. In fact, this paradigm may be achieved by integrating key stakeholders in the early stages. Owners, occupants, designers, manufacturers and builders need to collaborate in the design process to minimise change orders, increase constructability, and explore various dimensions and alternatives to enhance sustainability in the proposed project.

Based on “The Funnel” theory, this paper has developed a conceptual framework for sustainable IBS delivery consisting of four major elements: 1) Enablers; 2) Integrated decision making guidelines; 3) Sustainable IBS Design; and 4) Sustainable deliverables in IBS. Critical factors will be incorporated into the framework during the next phase of research, eventually forming part of the IBS decision making guidelines. It is expected that this framework can serve as a guide to develop appropriate guidelines that will aid the designers making front end decisions during an IBS project in favour of sustainability deliverables.

References


