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Embracing Industrialized Building System Construction Approach to Promote Sustainable Development: A Review

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Abstract—*The sustainability awareness has risen globally and the construction industry is under increasing pressure to improve efficiency and project delivery. The implementation of the Industrialized Building System (IBS) for which utility components are built offsite, has the potential of promoting sustainability deliverables. i.e.; the choice of using the IBS in a sustainable commercial development is expected to enhance the quality of life and work for today and future generation. As a unique building technology, IBS has not been effectively implemented. Possible reasons may include limited understanding among stake holders on the IBS potential and its relevance to sustainability.*
The study is limited to the practices and techniques of the IBS construction approach that are environmental friendly, energy efficient and minimization of waste. This paper will commence by identifying the correlation between IBS and sustainability, and then continue to discuss several aspects of the IBS that have potential of contributing to sustainable development and construction, the challenges and issues in the implementation of IBS projects, and so on. A list of attributes based on the sustainable performance criteria such as economic, social, environmental, etc. will be presented. They will provide a better understanding on the potential performance of the IBS methods, as well as to facilitate the sustainable development and performance of the constructed surroundings.

Keywords*: Industrialized Building System, sustainability, attributes, sustainable and commercial development, management factors.*

1. INTRODUCTION

The sustainability issues are increasingly of central concern to business. Once regarded as radical thinking, it is now fast becoming main stream and is increasingly recognized as beneficial to humankind, business and the environment. The construction industry plays a significant role in a developing country as an economically strategic sector by working together with other industries, such as materials manufacturing and property services. But the conventional on-site construction methods have been stigmatized as labour intensive, time consuming, less productive, dangerous and polluting. Thus, in this era of intensive competition for scarce resources in an increasingly competitive market, the construction industry has to rely on the concept of sustainable construction.

According to the World Commission on the Environment and Development, “sustainability” means economic development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs: and sustainable construction is defined as the creation and responsible maintenance of a healthy built environment based on resource efficiency and ecological principles. These principles include reusing, reducing and recycling resources, protecting the environment, applying life cycle economies and creating quality built-environment. Elements necessary for sustainable construction are already embedded in construction management: the concerns on time, cost, quality, safety, security, environmental and health. Although they may appear to be strange bedfellows, maintaining a positive balance of interaction among all these elements is paramount.

Sustainability has significant implications for all business, including the construction business. It necessitates a decision making process that balances the impacts associated with environmental, social and economic issues. It must be viewed as an essential business value that requires full integration in the core business strategies, management systems and processes. This is where the modern construction industry players and stakeholders believed that the Industrialized Building System (IBS) could play its role in materializing these key factors and at the same time meeting the needs of clients or stakeholders alike. IBS can be a potential solution to achieve greatness in the area of green construction and sustainability.

The output quality is highly dependent on skilled and semiskilled workers. The industry also has the highest level of accident injuries and fatalities. Construction activities are also inherently harmful to the environment, creating environmental nuisances such as noise, dust, muddy run-offs, and significant amounts of waste. Specifically, the use of IBS-related systems may help to ease the pressures of labour requirements whilst boosting quality and productivity. The wider adoption of IBS is also encouraged as a means to overcome environmental issues associated with conventional methods.

2. INDUSTRIALIZED BUILDING SYSTEM AND SUSTAINABILITY

Industrialized building system (IBS) is the term coined by the industry and government in Malaysia, as early as in 1960's, to represent the adoption of construction industrialization and the use of prefabricated components in building construction. Construction Industry Development Board of Malaysia (CIDB) defined IBS as low tech solutions and other practices which have already become common and not substituting conventional practices. IBS is a construction technique in which components are manufactured in a controlled environment (on or off site), transported, positioned and assembled into a structure with minimal additional site work. IBS is divided into five groups: precast concrete framing, formwork systems, steel framing systems, prefabricated timber framing systems and block work systems. As stated by the Construction Industry Development Board the standard characteristics of IBS are prefabrication, mass production, standardized components and design using modular coordination. These characteristics have the potential to enhance sustainability performance for the building constructed by offering significant advantages such as shortened construction time, lower project cost, improved quality, enhanced occupational health and safety, less construction site waste, less environmental emissions, and reduction of energy and water consumption. As such, IBS can be interpreted as an approach or process used in making construction less labour-oriented and fastest as well as fulfilling quality concern.

3. SUSTAINABILITY ATTRIBUTES OF IBS

There are several aspects of the IBS that have the potential of contributing to different aspects of sustainable development and construction. The base of principles of sustainable development, are economic, environmental and social. Hence the effective compliance of sustainable development should include these attributes.

Sustainability from controlled production environment: Natural aspects of conventional on-site work is the intense activities, which cause constant nuisances to local communities such as disorganized environment, traffic chaos, noise and air pollution. One of the main environmental benefits of IBS is that construction processes can be transferred from the site to a much better controlled factory condition. With the availability of production tools as well as jigs and fixtures, it is much easier to control the workmanship performance and quality thus ensuring a tighter construction leading to reducing energy losses due to thermal leakages.

- **IBS and waste minimization**: Studies reveal that the average wastage reduction level through the implementation of IBS is about 52 %. This is a rather remarkable rate compared to constructions without IBS operation. On the whole, IBS is accountable for the significant reduction of wastages through controlled production and this can be the catalyst to the sustainability in construction as well as the way to reduce the natural resources consumption However, several aspects of planning both in terms of materials and production management have to be monitored accordingly in order to achieve the waste minimization benefits as promised by the IBS.

- **IBS and building materials:** Several prefabricated technologies such as Structural Insulated Panels (SIPS) offer great potential in terms of fabrication of more energy efficient buildings. However, if appropriate process control and planning are not implemented, these potential benefits could be lost due to expensive on-site assembly processes. Therefore, advent of new technologies should be accompanied by proper process design for on-site assembly.

- **IBS and logistics**: Some estimates recently have put the amount of environment impact from material transportation activities to be one-third of the total environment impact on the entire construction process. IBS offers another benefit, and that is the ability to order large quantities of material and components thus reducing the number of trips taken. For this potential benefits, it is necessary that a detailed material and component transportation and logistics plan need to be carried out accordingly.

- **IBS and economic sustainability:** The main objective of a construction project is to ensure financial affordability to the stakeholders and clients, employment opportunities, competitiveness and maintain the needs of future generations. This certainly can be achieved by incorporating IBS in the project. IBS does not only benefit the environment it also promises profitable returns to the stakeholders and clients. The main advantages of IBS in the economic or monetary perspectives are the quality, speed of construction and cost savings. The high quality characteristics in IBS have reduced maintenance and operation costs. By adopting IBS implementation, the cost for labour and materials can be reduced significantly. But many contractors are reluctant to participate in any IBS project because of the cost, specifically the material and labour cost are spike high despite the overall cost saving it offers.

- **IBS and society**: The IBS also contributes to the social aspect by improving the quality of human life, skills training and capacity enhancement of the disadvantaged. The IBS has the potential to support local communities by diversifying the economy and creating more local employment opportunities. This can happen through the production of the building materials and components in the factory. This process will without doubt, reduce the amount of time on-site and lead to fewer detrimental impacts and disruption on the locality.

Based on the sustainability attributes and IBS characteristics and with the help of enabler, which is a support that provides a catalyst to the implementation of the sustainable IBS, a preliminary sustainable IBS model was developed by Yunus et. al (2011) (see Fig. 1).

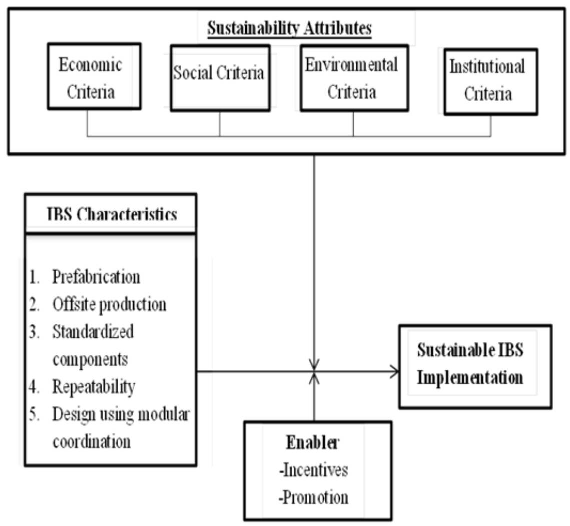

Fig. 1: Preliminary sustainable IBS model

4. BENEFITS OF ADOPTING IBS

Numerous benefits of adopting IBS had been reported by academicians around the world and becoming the driving forces to the construction industry players in deciding whether to use IBS or not. Some of the benefits are construction time reduction, increase in quality, onsite safety, and environment friendly. The benefits of IBS adoption are summarized in Table 1 as follows:

Table 1: Summary of IBS benefits

Benefits	Explanation
Cost and financial advantages	IBS offers cost saving through: a) Earlier completion time b) Repetitive use of system formwork made of steel, aluminium, etc. and scaffolding c) Less wastage and the usage of building material d) Reducing site infrastructure and overhead e) Increased certainty less risk
Construction speed	IBS construction process is governed by the speed of production and controlled environment of manufacturing facilities thus the need on fast delivery can easily be met by increasing the production capacity.
Reducing labour	The using of IBS component, which is manufactured in centralized factory, automatically will reduce labour requirements at construction site
Better quality	Better quality products can be produced with the adoption of IBS as it uses good quality components and involved numerous expertise throughout the process starting with manufacturing, installer, engineers, contractors and others
Health and safety measures	IBS application will improve site safety by providing cleaner and tidier site environment as the site activities become minimum and indirectly reduce construction hazards
Flexibility	IBS allows flexibility in architectural design, in order to minimize uniformity of repetitive facades. Simultaneously, the flexibility of different system used in IBS construction process produced own unique prefabrication method.
Waste minimization	All IBS components are manufactured from the factory, resulted in less wastage
Improving productivity	The application of IBS will overcome the problems of workers' insufficiency which affect contractor's productivity. At the same time it enhances productivity by removing difficult operation off-site and less site disruption

5. CHALLENGES IN PURSUING SUSTAINABLE DEVELOPMENT THROUGH IBS

In the context of the challenges, the implementation of IBS in Malaysia has found several factors. Some of the factors are discussed below.

5.1 Enormous Capital Cost

The most significant challenge to the adoption of IBS is higher capital cost. At the beginning, there is a requirement on large investment for setting up the plant, supplying machinery and mould, engineering consideration in dealing with the complexity of interfaces and expenditures of the transportation process. The adopters also require a large volume of work to break even on the investment which means IBS needs a large scale of production in order to achieve economic viability

5.2 Lack of Skilled and Knowledgeable Manpower

The IBS requires skilled and knowledgeable manpower. Since the current manpower lacks in training and education on this system, many contractors tend to shy away from adopting the system. The requirement of using skilled labor and machineries indirectly will incur the cost during the erection of IBS components.

5.3 Lack of Scientific Information

Lack of knowledge of IBS in the industry is one of the reasons on delay of IBS take-up. An IBS system can only be acceptable to practitioners if its major advantageous can supersede the conventional system. However, up to date, there is inadequate corroborative scientific research undertaken to substantiate the benefits if IBS system. It is therefore, arguable that the implementation of IBS is particularly hindered by lack of scientific information

5.4 Component Standardization

Standardization of building elements faces resistance from the construction industry due to aesthetic reservation and economic reason. One good example of this is when a 300mm thick modular standardized floor slab has to be used although a 260mm thick floor slab can achieve the similar structural performance. This results in the wastage of material. But the effect of low standardization will increase the initial cost due to the design cost and moulding which cannot be used for another project

5.5 Transportation

Among the challenges in managing IBS construction are transportation issue, which, revolve with the issues of size and weight limitations, route restrictions, permitting and the availability of lifting equipment. When the components reach the construction site, it requires additional lift planning. The complexity of lift normally increases with the increase in level of IBS usage. Transportation consideration will give impact on construction schedules, site design, crane cost and availability of designing the plan itself.

5.6 On-Site Construction Process

The components itself, for instance concrete panels, are heavy and difficult to align, which, may lead to the problem of improper assembly, leakage and crack in the future. Meanwhile, the connections also are not flexible enough to allow changes during mid-construction. Site specifics or constraints also cause problems in the IBS construction process since IBS components required additional space for storage, mobilization and circulation of machines and equipment.

5.7 Lack of Assessment Tools

Most of the available assessment guidelines and tools are only used after the design of the project is almost completed. There is a lack of cooperation among key stakeholders especially at the design stage. For example, IBS manufacturers are currently involved when the design has been completed. Hence, if they need to redesign the project, it will have to be done at an additional cost. Consequently, IBS is seen by the stakeholders as a burden instead of a helping hand.

Existing Tools Focus On 5.8 Economics

Most of the assessment tools for IBS only take material, labour and transportation cost into account when comparing various construction methods. They often disregard other costs related items and also some issues, which are perceived as insignificant such as, life cycle, health and safety and effects on energy consumption.

5.9 Different Issues and Attributes

Sustainable construction has different approaches as well as priorities in different countries. It is important that the local and regional characteristics in the physical environment are taken into account when measuring the level of sustainability. The issues studied in developed countries are unlikely to be applicable or even relevant to developing countries. But most of the existing ones are carried out based on the developed countries such as the United States of America, the United Kingdom and some other developed European countries.

6. COMPARISON BETWEEN IBS METHOD AND CONVENTIONAL METHOD

To compare IBS with conventional construction in terms of cost, time, quality and minimization and reduction of waste a case study based on the construction of 70 units of 2-storey houses in Malaysia was considered. Out of 70 units 34 units were constructed using IBS method while the remaining 36 units deployed the conventional method of construction. The Gross floor Area (GFA) for each unit was 348.39m2.

Table 2 shows the comparison of the construction costs for the IBS method and the conventional method. As shown in the table, the cost/m2 for IBS method is RM 1,180.24 while that of the conventional method is RM 1,314.97, where RM stands for Malaysian Ringgit. Evidently, the cost/m2 for IBS method is reasonably lower than that of the conventional method with a savings of 10%.

Table 2; Comparison Cost/m2GFA for IBS and the Conventional Method

Item Description	Conventional Method (Rm/M^2)	IBS Method (Rm/M^2)
Preliminaries	77.89	77.92
Piling	72.15	72.19
Building Works	821.86	761.36
External & Infra Works	15.32	159.39
Mechanical Works & Electrical Works	168.05	206.07
Provisional Sum	15.03	19.22
TOTAL	**1,314.97**	**1,180.24**

The construction period required to construct a 2-storey house using IBS was 9 months compared to 14 months using the conventional method. Thus, with the interlocking block system, the overall construction period can be potentially reduced by 35%. It was also shown that IBS has reduced construction durations, reduced overall cost, reduced labour requirements and so on. From site observations, waste reduction and improved quality control are among the important benefits of using IBS. These advantages are mainly due to the elimination of formwork, reinforcement bar or steel cage fabrication and installation, concrete placement, less utilization of labours, controlled production etc. Table 3 shows an overall comparison between the two methods of construction.

Table 3: Comparison of IBS and Conventional method

	IBS Method	Conventional Method
Construction Techniques	precast concrete panels	Onsite conventional masonry
Type of labour	Semi-skilled, crane operator, supervisor	Concreter, bricklayer, plasterer, carpenter, bar bender, general labour
Labour per day	2 or 3 teams in one day: a supervisor, a crane operator and two or three semi-skilled workers for erection.	3 skilled workers, 4 general workers for each work/ trade on site.
Type of plant & equipment	Crane	Concrete mixer, bar bending, bar cutting, vibrator set, crane.
Compressive strength	9 to 100N/mm^2	3- 50 N/mm^2
Waste Minimization	tidier and safer on-site working environment	waste-producing building work components such as formwork, finish work, masonry work, scaffolding, concreting, material handling and hoarding
Surface finishes	Smooth surface.	Plastering required
Painting	1-2mm thick skim coat	15-20mm thick plastering
Savings in Construction Materials	Absence of structural framing reduces the usage of cement, sand, steel and timber	Large usage of timber or temporary staging, bracing, forming,

Hence from the case study it is evident that the IBS approach has more to offer compared to the conventional method.

7. CONCLUSION

There has been an increased level of attention and importance attached to sustainable development within the construction industry. Sustainable development can be quite diverse and complex. It is about trying to get the proper balance between economics, social and ecological aims. A significant time saving is achievable by adopting IBS in a construction due to the standardization process in manufacturing hence it will shorten the lead time, improve quality control and reduce material. IBS will help to promote sustainability in construction, provided that each construction participants realize and has a better understanding on the potential of IBS in enhancing sustainability. With the encouragement and support from the government, a consensus among key stakeholders can be achieved and sustainable deliverables for IBS implementation can be enhanced. The support provides a catalyst to the implementation of the sustainable IBS and called as an 'enabler'. Yunus et. al (2011) have developed a preliminary model using these criteria, IBS characteristics and enabler, that improves sustainable deliverables for IBS construction (Fig. 1). Then, the significance attributes are identified from industry and use as a benchmark to develop guidelines for IBS designer.

Hence, on account of the above advantages it is possible to say that IBS is one of the main strategies to overcome most of the problems in development projects and it can also promote the sustainability in construction.

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