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Industrialized Building System (IBS): Revisiting Issues of Definition and Classification

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Abstract. Industrialized Building System (IBS) is the term to represent the prefabrication and construction industrialization concept in Malaysia. The term was coined to shift from the typical paradigm of prefabricated systems. IBS has been introduced as a method with better productivity, quality and safety. In a nutshell, however, the terms used in construction industrialization are ill defined, often interchangeably with other term and their precise definitions depend heavily on user's experience and understanding, which vary from country to country. The lack of uniform definition and uncertainty in context and boundary contributed to the prejudices and misunderstanding. Many industrialized construction technologies co-exist with onsite work in hybrid construction, making it difficult to differentiate what constitute offsite practice. The definition and classification need to be evolved and incorporated with global views and understanding. This paper revisits the issue on definition and classification with respect to IBS. A conceptual definition has been proposed in this paper based on literature reviews. The classification of IBS should be expanded to cater for the scope of volumetric (modular) and hybrid construction. It is hoped that the concept highlighted in this paper will encourage positive debate on IBS and gain some attention from the practitioners and researchers at large.

Keywords: Industrialized Building System, definition, classification.

1 INTRODUCTION

One major hurdle for research in the area of construction industrialization is to define the boundaries and establish clear basis of measurement. The terms used in construction industrialization are ill defined, often interchangeably with other terms and their precise definitions depend heavily on user's experience and understanding, which vary from country to country. The lack of uniform definition and uncertainty in context and boundary contributed to the prejudices and misunderstanding. Many industrialized construction technologies co-exist with on-site work in hybrid

construction and thus, making it difficult to differentiate what constitutes off-site practice. As such, the workable definition needs to be developed for the research fraternity and practitioners.

Though many of the prefabrication and industrialization terminologies are still in use, Industrialized Building System (IBS) is become a term to represent those terminologies in the Malaysian construction industry. The term IBS is widely used by the practitioners, researchers and the government in this country to represent industrialization in construction. The term is however, cover a very wide scope which includes the application of onsite systems and one cannot distinguish it properly with conventional practice. While other terms used to represent construction industrialization often relates to innovative solution. Current definition by CIDB includes low-tech solutions and other practices which have already become common and not substituting conventional practices. The terms and classifications provided by the CIDB were also misinterpreted as a system limited only for construction of buildings, while IBS can be interpreted as an approach or process used in making construction less labor-oriented and faster as well as fulfilling quality concern [2].

The broader view of IBS is about the changing of conventional mindset, re-engineering of human capital development, developing better cooperation and trust, promoting transparency and integrity [2]. There is a consensus however that the move towards industrialization of construction industry is a global initiative and not a local or isolated initiative. The definition and classification need to be evolved and incorporate with global views and understanding. The definition and classification of offsite, prefabrication, offsite construction, modern method of construction, offsite production, offsite manufacturing and pre-assembly, therefore need to be examined. It gives a different perspective and enriches one understanding on IBS concept as whole.

This paper is about revisiting the fundamental issue on IBS which are its definition and classification. First, the paper will revisit current definition and classification on IBS. Secondly, it will review other terms used to describe IBS in the literatures. Finally, a uniform definition and classification will be developed. With the issues of global competitiveness, productivity and quality, global industry players are utilizing IBS as a tool to achieve better performance. Therefore, IBS should provide a clear understanding on its etymology and classification for practitioners and policy makers.

2 DEFINITION OF INDUSTRIALIZATION, INDUSTRIALIZED CONSTRUCTION AND BUILDING SYSTEM

Currently, there is a wide definition on Industrialization. It is therefore necessary to clarify exactly what is meant by industrialization. Dictionaries give a variety of descriptions but little consensus is found. The International Council for Research and Innovation in Building and Construction (CIB) in its latest report on industrialized construction linked industrialization with the use of mechanical power and tools, the use of computerized steering system and tools, production in

continues process, continues improvement of efficiency, standardization of products, prefabrication, rationalization, modularization and mass production [3]. However, industrialization means industrial method employed with reference to mechanization, standardization and prefabrication. In the perspective of construction, industrialization is a part of a wider modernization process through the development of modern methods of production and technology system, production operations are mechanized and are focused on mass production and mainly factory production where work is centrally organized [4]. Warszawski [5] highlighted that an industrialization process is an investment in equipments, facilities and the technology with the objective of maximizing production output, improving quality and minimizing labor resources. In the perspective of construction, CIB defined industrialized construction as a generic process of standardization and rationalization of the work processes in the industry to reach cost efficiency, higher productivity and quality [3]. More elaborate definition for industrialized construction is a change of thinking and practices to improve the production of construction to produce a high quality, customized built environment, through an integrated process, optimizing standardization, organization, cost, value, mechanization and automation [3]. One of the efforts towards construction industrialization in construction is through the introduction of Industrialized Building System (IBS). With this regard, the term building system is defined by Warszawski [5] as a set of inter connected elements that joint together to enable the designated performance of building. It is also characterized as a set of interrelated elements that act together to enable designated performance of building. In wider sense, it may include several procedures (managerial and technological) for the production and installation of these elements for this purpose [6].

2.1 Existing Definition on IBS

To date, there has been no one commonly agreed definition of IBS. However, there are a few definitions by researchers who studied in this field previously were found through literature. The paper revisits the definition of IBS from 20 literatures of local and international researchers from 1971 – 2009. The term IBS is ill defined, often interchangeably with other terms like offsite and prefabrication and their precise definitions depend heavily on user's experience and understanding, which vary from country to country.

Nonetheless, the lack of a uniform definition and uncertainty in context and boundary of IBS were contributing to the prejudices and misunderstanding. Many industrialized construction technologies coexist with onsite work in hybrid construction and so demarcating what constitute offsite practice is problematic. As such, the workable definition needs to be developed. Though many of the prefabrication and industrialization terminologies are still in use, Industrialized Building System (IBS) has become a term to represent those terminologies base on research in the context Malaysian construction industry. The term IBS is widely used by the government, practitioners and researchers in this country to represent

industrialization in construction. The term IBS is defined as an innovative process of building construction using the concept of mass-production of industrialized systems, produced at the factory or onsite within controlled environments, it includes the logistic and installation aspect of it, done in proper coordination with systematic planning and integration [7].

IBS was defined by Abdullah and Egbu [8] as a method of construction developed due to human investment in innovation and on rethinking the best ways of construction work deliveries based on the level of industrialization. The level of industrialization in IBS can be classified as pre-building system, modern construction, advance automation and volumetric construction [8]. In his work on IBS risks, Hassim [9] defined IBS as an organizational process-continuity of production implying a steady flow of demand, standardization, integration of the whole production process, a high degree of organization of work, mechanization to replace human labor. Chung [10] defined IBS as a mass production of building components either in a factory or at site with dimensions, standard shape and transport to the construction site to be re-arranged with certain standard to form a building but Hamid [11], Hong [12] and CIDB [13] neglect the mass production concept. MIGHT [14] also disagree with the definition of Chung [10] regarding the on-site fabrication. While Hong [12] and CIDB [13] have the similarity in definition but the CIDB [13] doubt the concept of structured planning and standardization.

Scrutinizing IBS challenges in Malaysia, Rahman and Omar [15] defined IBS as a construction system using pre-fabricated components. The manufacturing of the components is systematically organize using machine, formworks and other forms of mechanical equipment. The components are manufactured in the factory and once completed will be delivered to construction sites for assembly and erection. Lessing [4] defined IBS as an integrated manufacturing and construction process with well planned organization structure for efficient management, preparation and control over resources used, activities and results supported by the used of highly developed components. The term is also defined as a new construction method that can improve the quality and productivity of work through the use of better construction machineries, equipments, materials, and extensive project planning [16, 17].

In the Malaysian context, Construction Industry Development Board (CIDB) has defined IBS as a construction technique in which components are manufactured in a controlled environment (on or off site), transported, positioned and installed into a structure with minimal additional site works [1]. Further, in Badir [18] IBS is defined as a concept of mass production of quality building by using new building systems and factory produced building components. Earlier researchers like Parid [19] in his research defined IBS as a system which use industrialized production method either in the production of component or assembly of the building or both. Trikha [20] defined IBS as a system in which concrete components are manufactured at site or in factory are assembly to form the structure with minimum in situ construction. Esa and Nurudin [21] in the first IBS colloquium in Malaysia, defined IBS as continuum beginning from utilizing craftsmen for every aspect of construction to a system that make use of manufacturing production in order to minimize resource wastage and enhance value end users.

The earliest definition on IBS found in literature is a definition by Dietz [22]. Dietz [22] back in 1971, defined IBS as a total integration of all subsystem and components into overall process fully utilizing industrialized production, transportation and assembly methods. But the definition was improved by Junid [23] by adding the structured planning and standardization. The system includes balance combination between software and hardware component. The software element include system design, which is complex process of studying the requirement of the end user, the development of standardize component and market analysis [23]. All the above definitions emphasized on prefabrication, off-site production and mass production of building components as the main characteristic of IBS. The definition s are listed on the Table 1.

2.2 The Characteristic of IBS

In general there are several categories of IBS definitions. Fifteen authors have defined IBS as a method, approach and process. On the other hand, only five (5) authors defined IBS as a product, system and technology and these include the definitions from notable international researchers Warszawski [5] and Sarja [6]. From IBS definitions compiled above, one can observe that the definitions consist of six different characteristics of IBS; which are industrialized in transportation, production and assembly technique, mass-production, onsite fabrication, standardization and structured planning and process integration. While almost all literatures mentioned an offsite technology or factory production as an important attributes to IBS and also highlighted the use onsite technologies in IBS [1, 2, 10]. It includes innovative solutions such as onsite casting and mould systems. From the analysis, all definitions cover at least two or three characteristics of IBS as mentioned above. Definition by Chung [10] covered five out of six characteristics. The definition by CIDB Malaysia [1] which has been widely used in Malaysia had not covered the aspects of mass-production, structured planning and standardization and integration in its definition. Those characteristics, however, are essential as highlighted by other scholars and should be included in development of workable definition on IBS. Regardless of the terms, the idea of IBS is the same which is to move some effort away from the construction site to a controlled environment of the manufacturing floor. The paper, therefore suggested that the new definition on IBS should consist of the process and system point of view, as well as all six (6) characteristics highlighted on the Table 1.

Table 1. List of definition of IBS

Authors	Method Approach & Process	Product, System & Technology	Industrialized Production	Transportation & Assembly Technique	On-site Fabrication	Mass-Production	Structured Planning & Standardization	Integration
Dietz [22]	*		*	*				*
Junid [17]	*		*	*			*	*
Parid [19]		*	*	*				
Esa & Nurudin [21]	*		*					*
Sarja [6]		*					*	
Trikha [20]	*		*			*	*	
Warszawski [5]		*						*
Badir et al. [18]	*		*				*	
Shaari & Ismail [2]		*	*		*			
CIDB [1]								
Hamid et al. [11]	*		*	*	*			
Kamar et al. [7]								
MIGHT [14]	*		*	*		*	*	
Lessing [4]	*		*				*	*
Haron et al. [16]	*		*				*	
Marsono et al. [23]	*		*				*	
Rahman & Omar [15]		*	*	*			*	
Chung [10]	*		*	*	*	*	*	
Hong [12]	*		*	*			*	
CIDB [13]	*		*	*				
Hassim et al. [9]	*		*				*	*
Abdullah & Egbu [8]	*		*					

2.3 Other Term Used to Describe IBS

Many different terms are used to describe industrialized construction and prefabrication. Pre-assembly, prefabrication, Modern Method of Construction (MMC), , Offsite Manufacturing (OSM), Offsite Production (OSP) and Offsite Construction (OSC) are terms in common use at various times in the literatures. The IBS term is used interchangeable with other terms like offsite construction, prefabrication, offsite manufacturing, Modern Method of Construction (MMC) industrialized building and industrialized construction. Those concepts are often use interchangeably when describing the characteristics of industrialized construction. They are however, distinct. The terminologies provide a rich historical account of the development of the concept. Nonetheless, regardless of the terms, the idea is the same which refers to manufacture of structure components for the construction of buildings in a control environment rather than doing on site. Modern Method of Construction (MMC) is a term adopted in the United Kingdom as a collective

description for both offsite based construction technologies and innovative onsite technologies. The former represents prefabrication and manufacturing technology and the latter includes techniques such as thin-joint block work and tunnel-form construction [24]. In definition, MMC includes both industrialized and non-industrialized innovation. Non - industrialized innovation is the use of innovation method that has been seen in other industries including carpet reinforcement, metal shutters, core jump systems, double jumping cores, edge protection systems and service walls [25]. The other terms used to describe industrialized construction are prefabrication and offsite construction. Prefabrication is a manufacturing process generally taking place at a specialized facility, in which various material are joined to form a component part of final assembly [26]. Some prefabrication can be done onsite (onsite fabrication). CIB [3] defined prefabrication as building at factory, sub-assemblies or full modules which are quite similar to what is produced on traditional construction site, often using same processes and same materials. Offsite construction however, is a description of the spectrum or part there of which are manufactured or assembled remote from building site prior to installation in their find position [24]. In offsite family, Offsite Construction (OSC), Offsite Production (OSP) and Offsite Manufacturing (OSM) are loosely interchangeable terms which refer to the construction process which is carried out away from the building site, such as in a factory or sometimes in specially created temporary production facilities close to the construction site (or field factories) [24]. While, the components maybe assembled onsite and offsite, preassembly literally means to "assemble before" and covers the manufacture and assembly (usually off-site) of buildings or parts of buildings earlier than they would traditionally be constructed on-site [27]. Those terminologies reveal a wide range of contextual issue which associated with the definitions. Nonetheless, no previous research has explored the relationship between these terminologies. Table 2 highlighted by Pan [28] provides an approach to distinguish the many terminologies. This generates four categories of terms: OS, PRE, MM and Building. This categorization reflects the historical evolution of the concepts.

Table 2. Categorization of terminologies.

Terminology	Category Term
OS	Offsite Production (OSP)
	Offsite manufacturing (OSM)
	Offsite Fabrication (OSF)
	Offsite Construction
PRE	Pre-assembly
	Prefabrication
	Prefab
MM	Modern Methods of Construction (MMC)
	Modern Methods of House Construction
	Modern Methods of House Building
Building	System Building
	Non-traditional Building
	Industrialized Building

Source: Pan [28]

3 IBS CLASSIFICATION

Just as the definitions, IBS has a various different classification which is based on material, process and system. Table 3 shows the classification of IBS.

Table 3. Comparison of industrialized construction classification

Classification	Sub categories	Author
Mazjub's Building System Classification	• Panel system • Box system • Frame system	Majzub [32]
Industrialized System Classification (Razali-Badir's Classification)	• Conventional building system • Cast in situ formwork system • Table or tunnel formwork • Prefabricated system • Composition system	Badir et. al [13]
Warszawski's Building System Classification 1	• Timber • Steel • Cast in situ concrete • Precast concrete	Warszawski [5]
Warszawski's Building System Classification 2	• Linear • Skeleton • Planar • Planar systems • Three dimensional box systems	Warszawski [5]
Pre-assembly and Pre-fabrication Classification	• Component manufacture and sub-assembly • Non-volumetric sub-assembly • Volumetric pre-assembly • Modular system	Gibb & Issac [27]
IBS Classification (CIDB)	• Pre-cast concrete framing • Panel and box systems • Steel formwork systems • Steel framing systems • Prefabricated timber framing system • Block work system	Shaari & Ismail [2] CIDB [1] MIGHT [20] Chung [10] CIDB [23]
Modern Method of Construction (MMC) Classification	• Volumetric • Panellized • Hybrid • Subassemblies and components • Non-off-site-Modern Methods of Construction	Gibb & Pendiebury [33]
IBS Classification (UTM)	• Pre-cast concrete-framed building • Pre-cast concrete wall system • Reinforced concrete building with pre-cast concrete slab • Steel formwork system • Steel-framed building and roof trusses	Rahman & Omar [11]
Bruno-Richard's IBS Classification	• Site intense kit part • Factory made module • Hybrid	Richard [34]
Off-Site Manufacturing (OSM) Classification	• Volumetric system • Panellized system • Hybrid system • Sub-assemblies and component system • Modular system	Abosad et al. [35]

For further exploration of and discussion between researchers in this field, a generic classification for IBS can be derived as the followings:

1) Frame System (pre-cast or steel)
2) Panellised System
3) Onsite fabrication
4) Sub-assembly and components
5) Block work system
6) Hybrid System
7) Volumetric and Modular System

The classification is based on current CIDB's IBS classification which is well known in Malaysia, with an important addition of hybrid and volumetric (modular) system. The paper suggests the inclusion of hybrid and modular system into IBS classification. Both are essential systems in MMC's classification. Onsite fabrication term is used to replace steel formwork system. This is to move away from the prefabrication image of formwork system at site. The precast concrete framing, prefabricated timber framing system and steel framing system is combined under the term 'frame system' for simplicity reason. This term is also used in MMC's classification. Roof truss, balconies, staircases, toilets, lift chambers are classified under sub-assembly and components. This is a move to promote 'in-fill' and 'skeleton' concept which is an interesting concept in open system. The standardization of the IBS classification will be useful to the IBS players as there were speak in the same wave length and they will be using similar technical term.

3.1 IBS: A Product, Process or System?

The researcher observed that IBS could be either the product or process. The definition captured and discussed in this paper revealed that IBS is not necessarily restricting its scope to the final product which is a system but mainly involves the processes which lead to the production of the system and its construction application. Thus, the answer either IBS is a product, process or system is heavily dependent on its context and unit analysis of the observer. In general, a review on IBS definitions classified IBS into two categories; IBS as a method, approach and process and IBS as a product, system and technology.

Based on the literature search, the majority of scholars defined IBS as a method, approach and process. However, there are also authors who defined IBS as a product, system and technology particularly from an earlier scholar in this field including the definitions provided from notable researchers in Warszawski [5] and Sarja [6]. Thus, the importance for both definitions is not discounted. Therefore, IBS can be a product, process and system based on the research context and observer's perspective.

3.2 IBS as Innovation in Construction

The construction industry is commonly characterized as one of that is labor intensive with low level of innovation. Innovation in this sense is not only the invention as per say, but also the diffusion (acceptation and adoption) [3]. One could argue that IBS and innovation are two similar concepts as mentioned in Pan [28]. In the other case of Pan [28] the term used to describe industrialization in construction is offsite. Pan argued that one can adopt industrialized construction as similar as one should treat an innovation. It is based on the understanding of the concept of innovation itself. It has been widely accepted that 'newness' is one of the basic elements of innovation [29]. Rogers [30] defined innovation as an idea, practice, or object that is perceived as new by an individual or other unit of adoption. He later added that another element of innovation is successful exploitation of new ideas. Egbu and Young [31] defined innovation as the successful introduction, application and exploitation, within a role, group or organization, of ideas. Pan [28] argued in his thesis that IBS and innovation is a two concept, both can be interpret as products and processes, new to the unit of adoption and involve risks in its process of adoption. Similarly, both have no absolute guarantee to be successful or desirable [28]. He argued later that not all IBS are innovative and vice versa, but both are in the same context when “newness” is introduced. As such, the adoption of IBS as mentioned in CIB [3] should relate to the accumulation of knowledge and technologies in construction process from various areas in the course of time and can be related to the concept of innovation. To sum up, the understanding on innovation characteristics is important in order to introduce new technologies and processes of IBS.

3.3 IBS: A Working Definition

Drawing on the existing body of knowledge analysis on definitions from previous scholars and consideration from above discussion, a working definition for IBS has been developed. IBS is defined as, “An innovative process of building construction using concept of mass-production of industrialized systems, produced at the factory or onsite within controlled environments, it includes the logistic and assembly aspect of it, done in proper coordination with thorough planning and integration”. It literally means that those parts of building that are repetitive but difficult, time consuming, labor intense to cost at site are design and detailed as standardized components at factory. The definition also emphasized on coordination between design, manufacturing and construction. It is important to note that in this research, IBS involves onsite casting using innovative and clean mould technologies (steel, aluminium and plastic).

4 CONCLUSION

Industrialized Building System (IBS) represent the prefabrication and industrialised construction concept in Malaysia. The term is proposed to move away from the typical paradigm of prefabricated systems towards application of modernise construction concept using manufacturing principal. This paper proposed the definition, discussion on IBS classification and its degree of industrialization. The paper has made the following conclusion:

IBS should be seen as innovation in construction. The innovation agenda has been promoted worldwide as in industrialized construction. It is imperative that IBS is seen as an evolution of construction using new and innovative techniques rather than a revolution.

The classification of IBS should be expanded to cater the scope of volumetric (modular) and hybrid construction. IBS is not to be seen as a threat to traditional methods. Both methods should be able to work in tandem and improve their processes collectively. The usage of both method construction is important to ensure that the construction industry will obtain the best benefits from both system.

IBS should move up the degree of industrialization from prefabrication to reproduction through innovation. The mass-customisation concept which is vital to open building system agenda can only be achieved through the adoption of automation in the level of industrialization

The more advanced IBS is in the level of industrialization, IBS need to play more roles and has to be involved in project life cycle. The reproduction level of industrialization will involve the whole project life cycle from planning to maintenance. IBS can be seen as a solution to the whole project life cycle if only, it can achieve reproduction level of industrialization

It is hoped that the generic definition and classification that had been proposed in this paper will initiate positive debate into it and obtain constructive reaction from practitioners and researchers hoped, and thus will enhance our understanding of IBS.

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