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# TOWARDS DESIGNING MODULAR OF INDUSTRIALIZED BUILDING SYSTEMS

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## Abstract

Although applying industrialization methods on the construction industry is well-documented as one of the best solutions of high housing demands, implementation progress of industrialized building system (IBS) rather slow is picking up due to barriers associated with complexity of its design stage. The paper presents an extant literature survey focusing on application of modular design process on IBS projects to benefit from abstraction of design process of these projects in order to facilitate the industrialization process of the construction industry. Results indicate that designing based on modularization could assist design process of IBS projects so that it prevents emerging conflicts in IBS life span that is rooted in IBS design stage. The study is presently expecting to improve awareness in various phases of IBS projects regarding the significance contributions of Modular Design Method as a respond to the complexity of IBS design method.

*Keywords*: IBS, Modular Design Process, Standardization, Sustainable Design Informatics, Design Integration

## Abstrak

Walaupun aplikasi kaedah pengindustrian dalam industri pembinaan didokumentasi sebagai salah satu penyelesaian terbaik bagi memenuhi permintaan perumahan tinggi, progres implementasi sistem pembinaan berindustri agak perlahan diambil kira kerana kekangan berkaitan kompleksiti semasa peringkat reka bentuknya. Kertas ini membentangkan survei literatur memfokus kepada aplikasi proses mereka bentuk modular projek-projek IBS yang memanfaat dari pemahaman proses mereka bentuk projek-projek sebegini agar dapat mempermudahkan proses perindustrian industri pembinaan. Hasil dapatan menyaksikan bahawa mereka bentuk secara modular mampu membantu proses mereka bentuk projek-projek IBS di mana ianya dapat mencegah percanggahan di sepanjang hayat IBS yang bermula dari peringkat mereka bentuk IBS. Kajian ini dijangka akan menambahbaik kesedaran pelbagai fasa projek IBS dan sumbangan signifikan kaedah reka bentuk modular dalam menangani kompleksiti kaedah mereka bentuk IBS.

*Kata kunci*: IBS, proses reka bentuk modular, standardisasi, Informasi reka bentuk mampan, integrasi reka bentuk

# 1.0 INTRODUCTION

## 1.1 The Construction Industry

The history of man shows that the creation of a comfortable shelter has known as one of the basic requirement of people life. Since, buildings have being played a vital role in the advancement of human civilization so that is being listed as a factor of society's progress. Further, evidences prove that societies are struggling with vast majority of barriers to respond their housing sector's needs due to specific characteristics of the construction industry itself.

Indeed, the construction industry sector is yet being known as a traditional sector [1] that its traditional construction methods make unresolved problems during projects life-cycle. Such these issues in construction projects are delays on schedule, poor qualities and cost overruns [2], design conflicts, unproductivity, health and safety problems and various conflicts during implementation process.

However the important of the construction industry is not hidden to all, the provision of suitable housing is yet one of the biggest problems faced by the world in terms of high housing demands which is known as a result of numerous factors such increasing population, immigration and natural disasters and etc., [3].

## 1.2 High Housing Demands

As the societies are rapidly progressing in terms of population, changing of life style, desiring for goods and services, consequently demand of housing is also increasing. Particularly this phenomena is being aggregated in many developing countries where the construction industry is one of the second largest economic sectors [4] and can affect residential building, non-residential building and engineering construction. Besides, more than 50% of the world's population lives in developing countries at high population densities and increasing urbanization [5]. Therefore, demands of building have been ranked as a challenge for the construction industry sector.

For example, Malaysia is such a rapid developing country. The demand for residential buildings alone in this country between the years 1995 and 2020 has been projected to be around 8,850,554 units (including 4,964,560 units of new housing units) in the light of the increase in population [6]. As a result, the supply of houses is inadequate [4]. Therefore, stakeholders are finding out the industrialization in the construction industry as a respond to the high housing demands in particular and other construction sector barriers in general.

As a matter of fact, the growing demands for affordable housing, increasing construction costs, lower productivity rate, and heightened concern for energy-efficiency has prompted the Malaysia's construction players to realize the immense benefits of industrialization in buildings [7].

## 1.3 Industrialization

Conventional construction methods, because of their slow pace and higher cost, have not enabled to meet the high demand gaps [8]. Besides, recent improvements of other industries such manufacturing, the construction industry is yet considered as backward so that review of historical data showed that while productivity in all non-farming industries had more than doubled over a 40-year period, construction productivity had fallen by around 5% [9]. Therefore, industrialization has been sought the only way to bridge the gap between demand and supply of buildings [10].

In fact, industrialization in the construction industry comes out to tackle with the problems of the construction industry which can be listed such lagging behind other industries in taking advantage of, and benefiting from, new technologies and innovative practices [11]. Further, industrialization in construction claims to improve, meet market demands, and hence, shift the (heavy) dependence on labor towards a "knowledge-based" industry taking advantages of (new) technologies [12].

In order for eliminating the inherent issues of construction industry; therefore, stakeholders are embarking on series of initiatives to encourage new ways of working and thinking; therefore, the industrialization is used as a panacea for the construction industry. Moreover, it describes a number of innovations in house building in particular, and construction industry in general, most of which are offsite technologies, moving work from construction site to the factory [13]

However, industrialization is known as illness term than can be used interchangeably with other term and their precise definitions depend heavily on user's experience and understanding, which vary from country to country [14]. Eventually, in a very similar meaning, the term pre-fabrication has been set equal to the term industrialization in many technical texts [15]. Meanwhile, Industrialized Building System (IBS) has become a term to represent those terminologies base on research and the prefabrication and construction industrialization concept in the context Malaysian construction [14].

# 2.0 THE CURRENT STUDY

## 2.1 IBS Projects

The construction industry in Malaysia is experiencing a migration from conventional methods to a more systematic and mechanized method known as the Industrialized Building System (IBS). It defines as a means of a construction technique in which components are manufactured in a controlled environment either on or off-site [16]. These are transported, positioned and assembled into a structure with the least of additional site work. The

components of the IBS are materials like floors, slabs, walls, windows, facades and etc. that are produced in factories where quality of producing process are highly controlled.

With respect to the numerous contribution of industrialization to the construction industry, Blismas [17] has documented in his book that Off-site Construction -which IBS is known somehow an OSC- has been seen to reduce construction time; simplify construction processes; provide higher quality, better control, and more consistency; produce products that are factory tried and tested; reduce costs when resources are scarce or in remote areas; result in improved working conditions and reduced on-site risks; alleviate skills shortages in certain areas; revitalize traditional manufacturing regions; provide fewer trades and interfaces to manage and coordinate on site; facilitate the incorporation of sustainable solutions; and achieve better energy performance.

However, the usage rate of IBS implementation progress slow rather is picking up [18] in various countries [19] such offsite construction only contributes a very small proportion of construction activity in both developed and developing countries. For instance, it has not yet been established in Hong Kong's private sector projects; and in the UK, the market share is only around 6% mainly run by small companies, and approximately 7% in the USA, without any comprehensive framework for the evaluation of applicability of these systems to the applied buildings, yet this is around 20% in Japan.

Therefore, according to review of numerous research barriers have been found such the following which might affect the progressing. Hamid *et al*. [20] stated that the supply and demand, economic volume, general readiness, and social acceptability were major hurdles, while Badir *et al*. [8] stated that professionals were not aware of the basics of IBS such as modular coordination as well as volumetric and non-volumetric construction methods. The coordination between spatial design and dimensioning of elements was poor and was not appropriately incorporated into the designing of spatial and functional space relations [21]. In addition, incompatible interfaces between manufacturers, poor coordination between the manufacturers and architects during an early design phase, and limited applications of building materials (i.e., mainly using concrete for fabricating precast beams, columns, and panelized wall systems) are some of the pressing problems that mar IBS constructions [22].

Therefore, numerous research around the world like [23], [8], [24] and [19] have advocated that design phase of industrialization is the source of emerging problems. Moreover, shifting process of IBS projects from site based to a controlled environment is emphasized new method of project delivery. In addition, it can be interpreted that IBS is categorized under overarching umbrella of modern method of construction; therefore, there is a need to revolutionize the design method to hit the objectives of industrialization in the construction industry.

### 2.2 Specific Design Method

Although industrialization in the construction industry has improved high housing demands, productivity and efficiency of the construction industry, adoption of IBS because of its complexity and novelty implementation process introduced new construction problems in terms of design, transportation, supply chain, and installation processes [25]. Since, due to having significant role of design division on the IBS projects, there is a precise focusing wherein many of the most important decisions are made [26]. Besides, a special focus on the design process is required, because managing the design process is a core issue in the AEC sector so that around 78% of quality problems in AEC are attributable to design [27]. As a consequence, it is noticed that design part of IBS projects plays a major role in the cost effectiveness, timeliness and quality of the entire IBS projects [28]; therefore, specific design method is being sought in order to meet the objects of industrialization in the construction industry.

As the IBS projects constitute from various separated components, numerous designers and sub-designers are needed to complete the design process of these projects to work as various disciplines. On the other hand, IBS projects are gradually becoming complex and subsequently the numbers of participants in different stages of projects from pre-construction, construction and post-construction are being increased due to shifting from the conventional method of construction into industrialization [29] which can be called a group of designers who make a team in order to deliver design phase of the IBS projects. Therefore, moving toward specific method of designing is required common codes, communication mediums or standards to decrease the misunderstandings among all participants.

As a matter of fact, IBS is classified as an AEC large scale project in terms of design phase which involve collaboration amongst a huge number of team members from various design disciplines [30]. Therefore, it defines particularly a specific method of design for IBS because of the participating various disciplines members within design stage. Otherwise, each team or individual participating in the project has its own agenda, goals and aspirations with respect to their work regions, which may be congruent with the project goals [31]. However, the specific conditions design method of IBS projects mark out the boundary of various disciplines which must be very clear, simple and readable for the all participants in order to prevent emerging likely conflicts. Therefore, it is needed to move toward abstraction of design process to benefit as much as possible of IBS which is known as a panacea of the numerous hinders of the traditional method of the

construction industry. Therefore, one of the most common concept f abstraction of design process is Modular Method of Design (MD) which the concept is emerged from the manufacturing sector.

## 3.0 THE STUDY FINDINGS

### 3.1 Modular Design Process

Due to fragmentation nature of the construction industry and complexity, it was a need to change to the metric system since few decades ago. A coherent system of coordinating dimensions in the building process is crucially needed to facilitate the communication at all levels from the designers to the manufacturers in the building trade [32]. Therefore, stakeholders refer to the Modular Coordination (MC) design concept for IBS projects which is rooted from the manufacturing sector. In facts a module is used as a base dimension for the whole design process so that the process follows by arranging spaces and producing proper plan base on defined module grades. Other design aspects will shape accordingly such as; elevation, facades, paneling types, sections etc. [33]. According to the European Productivity Agency's definition in 1961, "modular coordination is a system devised to coordinate the sizes of factory-made building parts with the designs of buildings."[15]. Likewise, modular coordination is a form of dimensional coordination which is based on the use of fundamental unit, the basic module, for the dimensions of building components as well as for those of the buildings [34]. Therefore, as the philosophy of IBS is based on mass production with regard to the MC design system and quality of finished products resulting in the reduction in the cost of production [35] which is a proving for IBS to get benefits from the applying MD in design phase.

MD process is a coordinated unified system for dimensioning spaces, components, fitting, etc. so that all elements fit together without cutting or extending even when the components and fittings are manufactured by different suppliers [36]; therefore, the introduction of MD system in building will constitute a positive step to streamline the industry towards proper metrication in building planning, design, construction, assembly and manufacturing of building materials and components. In fact, MD defines a common standard for all designers and sub-designers to facilitate their duties through using abstraction of design process. Further, it is interpreted that MD is paving the way for the participants during design process of IBS in order to get profits.

According to the guidelines from the Malaysian Standard Department the highlighted achievements of MD drawn from numerous benefits that could be interpreted 1) facilitates cooperation between building designers, manufacturers, distributors, contractors and authorities 2) in the design work, enables buildings to be so dimensioned that they can be erected with standard components without undue restriction on freedom of design 3) permits a flexible type of standardization, which encourage the use of a limited number of standardized building components for the construction of different types of buildings [32] that are related to the design part of MD in the IBS.

Moreover, according to the concept of MD which the all component are designed based on the unit of size or basic module that is used as an increment or coefficient in dimensional coordination, the design are able to use from maximum flexibility and convenience in their designs concepts. This usage of MD is to get maximum benefits from the IBS projects in order to facilitate the design process, mass production of components, standardized the building components based on the preferred sizes, abstract the process of design toward ease of design, manufacturing and assembling of IBS components respectively. Therefore, sub-designers who are non-collocated faced to a standard method of design so that they do not need to redesign their specific part according to received details. In fact, the MD facilitate as much as possible the process of design in order to prevent likely conflicts, ease the design process and moving toward the concept of industrialization in the construction industry.

## 4.0 CONCLUSION

With respect to the rapid progressing of societies in terms of population, changing of people life style, desiring for new goods and services, consequently demand of housing is also increasing. On the other hand, conventional method of construction have not enabled to meet the high demand gaps because of their slow pace, lack of quality, unproductivity, their higher cost and time over runs. Besides, recent improvements of other industries such manufacturing, the construction industry is yet considered as backward and lagging behind other industries. Therefore, stakeholders are embarking industrialization in the construction industry to tackle with the mentioned barriers. With respect to the specific delivering method of IBS projects, MD process which has been inspiration from manufacturing concepts. MD can be interpreted as a panacea for design phase of IBS where collaboration of numerous designers and sub-designers are necessary. Further, MD through abstraction of design process of IBS make the design process much more easy and readable for all disciplines. Moreover, MD could decrease the stage of likely conflicts during design phase in order to prevent rescheduling, cost and time over runs in implementation stages of IBS such manufacturing and construction phase. Finally, it can be said that although the concept of MD goes back even to last

centuries, the necessary usage of that is highly appreciated in the industry and academic sector in order to meet the aims of industrialization in the construction industry and a solution for the complexity of design phase of IBS projects with respect to the participation of numerous designers and sub-designers who are non-collocated.

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