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RESEARCH ARTICLE

# Integrated design approach for improving architectural forms in industrialized building systems

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**Abstract**
An architectural design process is investigated to achieve form flexibility in industrialized building systems (IBS), as IBS constructions do not have sufficient flexibility to develop varied architectural forms. The ethnography method has been used to examine the issues related to "form" flexibility in the design life cycle of IBS constructions by observing the constructions of live experimental models. The major tasks and respective design aspects that facilitate form flexibilities in architectural design have been identified. Furthermore, an integrated life cycle model has been developed to effectively address the interfaces between the design tasks and eventually fulfill the needs of IBS in the design life cycle.


## 1. Introduction

For achieving sustainable development in Malaysia and transforming the construction industry to be one of the best in the world, the framework of the Malaysian Construction Industry Master Plan fosters the implementation of industrialized building systems (IBS) in building projects (CIDB, 2006). However, several construction and engineering aspects related to the IBS are yet to be fully realized in actual practice. One of these aspects is "design flexibility," which is one key aspect that governs the efficacy of IBS applications. However, this aspect has been largely neglected in both applications as well as literature. As stated by Hamid et al. (2008), a majority of the current IBS applications—both in design and prefabrication—mainly support conventional building forms (e.g., rectangular and square forms). Such monotonous approaches can hinder an architect's ability to

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develop flexible forms. In particular, prefabricated elements are considered to be inflexible to changes that would be normally required over their life spans (Warszawski, 1999; Sarja and Hannus, 1996). Simultaneously, architectural designs aimed toward IBS constructions should possess the attributes of manufacturing feasibility and onsite assembly. From the architectural perspective, flexibility can be defined as the ability of a unit to respond to the changes necessitated by the client, design, and manufacturing requirements (Sarja, 1998). While architectural design ultimately deals with the configurations, connections, shapes, and orientations of the physical forms, flexibility in architectural design is predominantly related to spatial design and building "forms" (Do and Gross, 2001). As such, architects are often inclined to develop varied and unusual architectural forms (Saleh et al., 2003). Therefore, further investigation is required to improve the form flexibility in both architectural design practice and construction.

To overcome this barrier, this article presents the results obtained from a research sponsored by the Universiti Putra Malaysia. The issue of achieving form flexibility in IBS constructions during the design stage was investigated based on the premise that "it is extremely important to incorporate system thinking in the architectural design process to foresee and resolve complex issues during the implementation of IBS." As opposed to concrete and steel constructions, timber construction was investigated in this study since timber is easy to handle and timber elements (used in the experiment) could be easily fabricated. Further, timber comes from a sustainable source; therefore, timber has been fostered by the Construction Industry Development Board (CIDB), Malaysia, as an alternate material for IBS constructions (CIDB, 2003). A series of ethnography methods of investigations have been proposed with regard to the construction of live timber houses. Consequently, the most appropriate approach for achieving an integrated system design has been developed. This article describes an integrated system design model that can be used for improving the form flexibility in IBS designs. The proposed model will help architects in understanding the relationship between building systems and their designs, and therefore, incorporate creativity and flexibility in IBS constructions.

### 1.1. Problems in IBS attributable to design flexibility

In Malaysia, IBS was initially implemented to promote systematic construction processes and minimize the number of foreign workers. However, impediments to achieving this goal have been widely reported in literature. For instance, Hamid et al. (2008) stated that the supply and demand, economic volume, general readiness, and social acceptability were major hurdles. Badir et al. (2002) stated that professionals were not aware of the basics of IBS such as modular coordination as well as volumetric and nonvolumetric construction methods. This argument was supported by many scholars (Gibb, 1999; Davidson, 1990; Benros and Duarte, 2009). Mawdesley and Long (2002) and Jaillon and Poon (2009) argued that future modifications to manufactured building components were not possible as they resulted in less flexibility during the construction phase. Hassim et al. (2009) and Lessing et al. (2005) added that the IBS approach impeded the creation of a customer-oriented design. 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 (Gibb, 2001). The transportation of building components depends largely on the local conditions. For example, to be transportable, the component sizes should be designed in accordance with the carriageway. 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 (Thanoon et al., 2003). Tam et al. (2007) suggested a lean construction approach to deliver better standardized products. However, the consequent construction defects were difficult to conceal, possibly leading to structural failures and water leakages. All these impediments adversely impact the design creativity in IBS, resulting in monotonous and aesthetics-deprived buildings.

In the past, conventional building construction has been adopted in the Malaysian housing sector (IEM, 2003). Consequently, the CIDB, Malaysia, has promoted IBS technologies so that prefabricated building components are utilized to the maximum possible extent in the construction industry. As stated by Junid (1986); Padrid (1997); Trikha (1999); Lessing et al. (2005) and Tam et al. (2007), it is a known fact that IBS integrates the manufacturing and construction processes that involve mass production, where the building components are prefabricated to optimize the majority of onsite construction activities and workmanship, reduce material wastage, reduce the time required, and reduce the overall cost of the project. IBS can also create engineering benefits for the construction industry since it mainly encourages the production of standardized buildings rather than varied ones. Studies have not investigated the manner in which IBS can be incorporated in the development of architectural design to meet contemporary design changes such as "form flexibility" (Howes, 2002). On the other hand, architects are unaware of envisioning the incorporation of IBS building components in the architectural design process. The lack of an IBS data repository and inadequate knowledge of IBS among architects has resulted in redundant design flaws during detailed construction documentations, which has further delayed projects (Kamar et al., 2009). Moreover, the IBS approach has created a negative perception among the architects and customers because of the following factors: it hinders flexibility; it only allows internal flexibility in the layout; it creates jointing problems; it promotes monotonously manufactured building components; it creates repetition in standardized building components and it does not allow varied forms that can yield creative architectural designs. In spite of these defects, the existing IBS construction practices need to be revitalized in the minds of the designers such that they can efficiently incorporate "system thinking" in the architectural design process. A systematic approach often limits the freedom of designers, notably architects.

Besides the standardization of building components, IBS should be able to develop compatible systems that can integrate building components with the spatial design.