Selection criteria frameword for choosing industrialized building systems for housing projects

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SELECTION CRITERIA FRAMEWORK FOR CHOOSING INDUSTRIALIZED BUILDING SYSTEMS FOR HOUSING PROJECTS

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An Industrialized Building System (IBS) has been accepted as an innovation strategy to assist in overcoming key problems in the Malaysian housing sector. The manufacturers and producers of IBS have claimed that their systems have a multitude of advantages and benefits. The selection criteria used to choose the appropriate type of IBS for housing projects have been identified as one the critical issues in the decision-making process at the conceptual stage of using IBS. The criteria such as cost, time and quality play a major role in the selection tasks. Through a literature review, this paper highlights the criteria that have been considered in the adoption of IBS in the UK and in the Malaysian construction industry. It also reviews existing decision-making support and tools associated with choosing types of IBS. It is concluded that a wide perspective and an extensive variety of factors may contribute to the impact of the effectiveness of the decision-making process associated with the selection of type of IBS. These include the structure and materials' design, site orientation, safety, client perspectives, environmental issues and sustainability, organizational issues and risk. This paper recommends that a structured and holistically approach in decision-making for selecting the type of IBS is important and needed in housing projects and in the Malaysian construction industry.

Keywords: capacity building, culture, industrialized building system, strategy.

INTRODUCTION

Over the last four decades Malaysia is being successfully transforming from a nation with a traditional industrial economy to a developing nation with a modern economy. The evolution of the economy from a labour-driven economy to an investment, productivity and knowledge and technology-based economy sums up the paradigm shift in economic activities (Victor, 2000). The construction industry has been identified as one of the significant sectors that contribute to Malaysia's economic growth. The sector accounted for nearly 3.3% of GDP in the year 2005 and employed about 600,000 workers including 109,000 foreign workers (MALBEX, 2005).

In 2003 and 2004 CIDB and the Department of Immigration in Malaysia recorded the number of foreign workers involved in the Malaysian construction industry as 2.1 million. It is estimated that hundreds and thousands of workers are illegal workers. The Malaysian economy has attracted and employed a huge number of foreign workers. According to a report from the Malaysian Department of Immigration, foreign workers represent forty four percent [44%] of the total workforce in the construction industry. In order to change the current state of the construction industry

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from being labour intensive to producing knowledgeable workers, the implementation of an innovative method of construction should be actively geared up in order to decrease the labour force.

Kadir *et al.* (2005) highlighted the five major factors that cause project delay. These included materials' shortage at the project site; non-payment [financial problems] to suppliers causing the stoppage of materials' delivery to site; late issuance of progress payments by the client to the main contractor; lack of foreign and local workers in the market and incapability of site management to organize site activities. With the identified challenges and difficulties faced by the construction industry, it would seem that a decision-making process for selecting the best option of an Industrialized Building System (IBS) as a new construction method and philosophy could become significant.

The adoption of new methods or technologies in construction is influenced by a few drivers. Pan (2005) believed that the most significant drivers for using new methods of construction and offsite technologies are skill shortages, achieving agreed costs and time, achieving high quality and minimizing on-site duration.

THE HOUSING SECTOR IN MALAYSIA

Kadir *et al.* (2005) stated that the provision of suitable housing is still one of the biggest problems faced by the world because of increasing population, immigration and natural disasters; all these being the main reasons for a large housing demand. The industrial revolution caused an increase in building demand, hence new developments in building construction systems emerged at that time.

It is reported that 680,000 units of houses were targeted to be constructed in the Seventh Malaysia Plan [1996-2000] with a majority of them being low and medium low cost houses but the achievements were disappointing as it has been reported that only 20% of them were completed. This slow and unsatisfactory result was due to both the global and Malaysian economic crisis at that time [1998-1999]. Shortages of skilled labour and materials were also identified as major reasons. The growth of IBS in Malaysia has been attributed to the huge demand by the housing industry during the Eighth Malaysian Plan [2001-2005] whereby 600,000 to 800,000 houses were expected to be built. It was believed that the conventional building systems would not have coped with the demand (Kadir *et al.*, 2005).

A solution was put forward that IBS would help to assist housing programmes under the Eighth Malaysian Plan to overcome the shortage demand. The above demand has been achieved and 844,043 units were built [some 137.2%] (Ministry of Housing and Local Government, 2006). To break it down further the actual amount that the private sector contributed to the housing construction was 216.3% compared to public sector which contributed 60.5% only. The issue of differences in the effective approaches to the construction system between the public and private sectors is one that cannot be ignored.

AN INDUSTRIALIZED BUILDING SYSTEM [IBS]

An Industrialized Building System [IBS], as defined by the majority of authors, often represents the technical methods of, the processes of, or the philosophic approach to, the building industry (Elliot, 2003). It has been argued that a total adoption of an IBS will bring out some relevant issues. This particular concept has been questioned by various stakeholders in the construction industry. The issues of perception, work culture, awareness and knowledge have been under discussion as potential major barriers to IBS adoption. It is quite likely that the decision-making process could be based on knowledge and strategic information. Hence, it is necessary to provide guidelines or criteria for the selection of an appropriate category of IBS.

Definition of an Industrialized Building System (IBS)

Hamid (2008) highlighted that definition of an IBS was not commonly accepted and agreed by the industry at large. However, a few common definitions have been established by authors in this area of study and were found in the literature. These definitions emphasized prefabrication, off-site production and mass production of building components (Rahman 2006; Warszawski,1999; Lessing, 2005; Trikha, 1999; Esa, 1998). An IBS is often referred to by the literature as off-site construction (Pan, 2008) off-site production (Blismas, 2006), industrialized and automated construction (Warszawski, 1999), off-site manufacturing, prefabricated building, pre-assembled building (Gibb, 2003), pre-cast building, pre-cast construction, non-traditional building and a Modern Method of Construction [MMC]. According to Warszawski, (1999), an IBS can be defined as a set of interrelated elements that act together to enable the designated performance of the building. Gibb (1999) defined an IBS as pre-assembly for a given piece of work; the organization and completion of a substantial proportion of its final assembly work before installation in its final position including forming any temporary work or pre-assembly and it can also be carried out on or off-site which would involve the standard coordination.

Parid (1997) described an IBS as a system which uses industrial production techniques either in the production of components or in the assembly of the building or both. Trikha (1999) discussed an IBS as a system of construction that has been made to be mainly industrialized in its manner and process, such as the manufacturing of automotive components and furniture. Additionally, Trikha (1999) defined an IBS as a system in which concrete components are prefabricated at site or in a factory and are assembled to form the structure with minimum on-site construction. Chung (2007) outlined an IBS as mass production of building components either in a factory or at site according to specifications with standard shapes and dimensions and which are then transported to the construction site to be re-arranged with certain standards to form a building. The Construction Industry Development Board in Malaysia's Roadmap of IBS (CIDB, 2003) defined an IBS as 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 works.

DECISION-MAKING AND SELECTION CRITERIA

A criterion for decision-making was defined by Hayword and Sparkes (1990) as a discipline, rule, principle or standard which can be evaluated and judged. Lim and Zain Mohamed (1999) discussed criteria as a significant character such as first or possessed an autocratic power.

According to Astrand (2002), the existing process of selecting innovative building systems or IBS can be divided into two main stages, identified as pre-occupancy and occupancy. In this study, the pre-occupancy stage will be investigated in-depth. The decisions to be made by stakeholders can be considered as collective and consensus decision-making because the design teams and clients will discuss the best option or alternative for the building system to be implemented. The best decision-making process should be supported with sufficient information and knowledge. Knowledge-based decision-making can reduce uncertainty for better risk management. The right tools and techniques for decision-making support will be used by the project decision-maker. According to Rogers (2000), the selection criteria may include total labour outlay on the preparation of prefabricated elements and total labour outlay on equipment; material demands which comprises cement, aggregate and steel consumption and energy demands i.e. energy consumed by the built-in materials and energy consumed by the equipment.

*Table 1: Selection Criteria from Previous Studies**

CRITERIA	1	2	3	4	5
Building Regulations/Planning Systems/Legal Issues			X		
Client Satisfaction with Product	X			X	X
Client Satisfaction with Service	X				X
Company Strategy/Profile CV				X	
Cost: Capital and Construction, Facility Management	X	X		X	X
Defects	X				
Disposal Costs for Demolition					X
Flexibility and Tolerance of Materials and Components					X
Form is Well Conceived					X
Health and Safety	X	X	X		X
Integration of Layout, Structure and Eng. System					X
Meeting the Perception Needs					X
Predictability Cost/Cost Certainty	X		X		
Predictability Time/Time Certainty	X		X		X
Previous Experience/Performance					
Process Constraints/Process Flow		X	X		X
Procurement Constraints		X	X		
Productivity	X				
Profitability	X				
Quality and Standardization		X	X	X	
Reduce Environmental Impact					X
Risk Averse Culture					X
Site Constraints		X			X
Structure and Durability					X
Sufficient Floor and Ceiling Clearance Height					X
Sustainability		X	X		
Time: Minimizing Onsite, JIT	X	X			X
Well Design Connection and Simple Build Ability					X

** Housing KPIs [Constructing Excellence, 2004], CIRIA Offsite Project Toolkit [Gibb and Pendlebury, 2006], Wei Pan Value Tree DSS [2006], Astrand [2002], R. Soetanto, A.R.J.Dainty, J.Glass, A.D.F Price [2006].*

For this paper, the selection criteria are based on those looked at in previous research conducted by other authors, as discussed in the above paragraphs. It has been justified that to establish general and comprehensive criteria, a combination of all of the previous studies can be summarized in the following Table 1. From this Table showing information from previous studies by researchers between 2002 and 2006, it can be suggested that the criteria of selection for an appropriate type of IBS are based on several factors and variables. To simplify this research, the groups of factors or criteria are categorized and clustered into twelve elements. Hence, the client, cost, design, environment, knowledge, law, materials, organizational factors' process, quality, risk and time shall be the domains of criteria to be considered when designing further survey for this research in future.

DECISION-MAKING SUPPORT AND TOOLS AS DISCUSSED IN PREVIOUS STUDIES

Pan (2006) outlined and grouped the criteria for Build System Selection (BSS) into eight domains known as value for decision. Cost, time, quality, health and safety, sustainability, process, procurement and regulatory and statutory acceptance were identified as the selection criteria. Soetanto (2004) highlighted that the criteria should include both "hard" and "soft" aspects and metrics for the better capture of the potential "value" of structural frames. Sexton (2005) reused the criteria selection for structural performance as quoted by Soetanto in the development of HyCon tools and divided the thirty-one variables into seven categories of groups: physical form and space, construction process, long-term sustainability, establishing confidence, building impact, physical appearance and client satisfaction.

The structural frame is an essential element of any large building. The appropriate selection of materials for, the configuration and capacity of, such a frame is vital to the short- and long-term performance of the building. Structural performance is defined as the capability of a building to meet its specified requirements throughout its design-life (Soetanto *et al.*, 2004). It is generally agreed that to identify the best choice of structural frame, the design process needs to be more innovative in exploring, selecting and using or combining materials to obtain an optimum solution for a particular situation (Soetanto *et al.*, 2004). Soetanto (2004) also advocated previous research (Ballal, 2003) that traditionally the structural frame has been selected based on heuristic decision-making processes predominated by subjectivity and qualitative reasoning.

WIDER PERSPECTIVES ON SELECTION CRITERIA

Structure and Materials' Design

Labour, material and infrastructure costs account for more than 60% of the cost of a house. Any upward movement of these costs will have an impact on house pricing. Keeping these costs low is a big challenge to the industry. As it is, the Malaysian housing industry in general adopts the conventional method of construction and for this purpose relies heavily on foreign workers. Contrary to the popular belief that developers use foreign workers because of lower wages, these workers, particularly skilled and semi-skilled labourers, are by no means cheap (Chen, 2003) and likely to continue to be expensive in the future. IBS has a significant role to play in meeting housing demand.

Site Orientation

Trikha and Ali (2004) highlighted that IBS components should be kept minimal by simplifying details of connections which embed inserts and bond plates for bolting or welding or in situ concreting. Pan *et al.* (2007) suggested that the Modern Method of Construction (MMC) can provide the drivers for maximizing the environmental performance during the lifecycle and restricted site specifics. Blismas *et al.* (2006) described that clients' perceptions of the benefits of Offsite Production (OSP), as discovered by Gibb and Isack (2003), are: less snagging, less site disruption, reduce to use wet trades. OSP enhances the control over environmental issues that are normally faced by the conventional construction system.

Health and Safety

Safety and health on site is one of the major factors that determine the success of project implementation. In IBS the transportation and delivery of components issues are associated with safety issues, i.e. route planning, traffic regulations, and logistics. Site orientation, as discussed above will contribute to the level of safety during the handling of IBS components. As IBS reduces the number of workers on site, this may reduce the potential risk of incidents occurring. Most architects who acted as project superintending officers felt that IBS promoted cleaner and neater construction sites (CIDB, 2007).

Client Perspectives

Soetanto *et al.* (2006) highlighted the agreement with the evidence shown by the Housing KPI on putting emphasis on the role of client perspectives such as client satisfaction with product, process and service. Pan *et al.* (2007) determined that other factors associated with client satisfaction were: manufacturer/supplier capacity and competency; building images of occupiers that the building enhances the team/clients' confidence, the clients' need for industrial capacity; that the building's colour and texture (physical appearance) enhances enjoyment; confident as built theory equation and self finished.

Environmental Issues and Sustainability

Malaysian weather and climate create a significant impact due to extreme temperatures and heavy rain over the years. The amount of time lost by the Malaysian construction industry due to bad weather can only be speculated upon. It seems that IBS usage will rise due to it being the best option to increase the existing productivity of construction output. The issues of the 3Ds, i.e., "dirty, dangerous and difficult" have been perceived as negative issues due to the performance of conventional building systems (Shaari, 2003). IBS can be viewed as one of the solutions to overcoming this negative perception. IBS construction sites have been proven to look tidier and more organized as compared to the wet and dirty conventional construction method sites. Also wastage of temporary works such as timber formworks and props, which are normal in conventional construction, is not there or is reduced if an IBS construction method is used instead (Aziz, 2002).

Organizational Issues

Investments in equipment, organization, human resources and facilities associated with industrialization can only be justified economically when large production volumes are observed. Such volume provides a distribution of the fixed investment over a large number of product units without unduly inflating their ultimate cost (Aziz, 2007). Therefore, the implementation of IBS is hindered by organizational issues such as a lack of scientific information (Kadir *et al.*, 2005) and designed organization of IBS (Warszawski, 1999). Marsono *et al.* (2006) viewed that the precast concrete industry for IBS is very challenging for the people concerned as the manufacturers compete amongst themselves for business opportunities, technology and quality in production and market reputation. Governmental organizations and departments such as the Public Works Department and local authorities are responsible for introducing modular coordination and IBS through the building regulations and specifications. The execution of modular coordination through legislation is very important to gain success in industrialized building programmes. The implementation of modular coordination into Uniform Building by Law, planning standards and building specifications needs to be executed.

CONCLUSION

A balanced and holistic approach in adopting IBS strategic issues is significant in the Malaysian construction industry. This approach should reflect the maturity of the organizations. Many factors affect the selection of IBS in the housing construction in Malaysia. These include economic, social, political and environmental factors. The Malaysian government, through regulations and improved planning standards and building specifications, can help improve the adoption of IBS. There is scope for research to better understand how IBS adoption and implementation can add real value to the construction process for the benefit of clients and also to increase social benefits.

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