THE APPLICATION OF ANALYTICAL HIERARCHY PROCESS (AHP) AS A DECISION TOOL IN CHOOSING THE TYPE OF INDUSTRIALISED BUILDING SYSTEM (IBS) FOR HOUSING PROJECTS

Mohd Rofdzi Abdullah[1] and Charles Egbu

School of the Built Environment, University of Salford, Greater Manchester, M5 4WT, UK.

An Industrialized Building System [IBS] generally has been accepted as an innovative approach to overcoming critical issues in the Malaysian construction sector. IBS contractors are faced with challenges in choosing an appropriate type of IBS for a housing project. A decision maker would have to prioritize multi criteria to achieve project goals. The criteria such as cost, time and quality play a major role in the selection of appropriate type of IBS. Through a literature review, this paper highlights the criteria that need to be considered in selecting an appropriate type of IBS for choosing projects in Malaysian construction sectors. It also reviews related tools and decision support systems with regards to the selection of type of IBS. Analytical Hierarchy Process [AHP] has been determined as a simple, logical and quantitative approach to reach "the best decision". The pair wise comparison matrices facilitate the decision makers to prioritize the level of importance for each criteria and type of IBS. The recommendation from AHP will provide the basis for a manager to consider the implementation of IBS during design and construction stage of a project. A spreadsheet software application has been utilized to produce the protocols of AHP. Recommendations are also offered for the benefit of decision makers in the selection of types of IBS.

Keywords: analytical hierarchy process, decision-making, industrialized building system, selection criteria.

INTRODUCTION

It is generally known that Industrialised Building System (IBS) is not a new concept of construction method, but the innovations and evolution of newest materials, machineries and techniques for construction have become more modernized and industrialized. Therefore, IBS is seen not only as a technique or method but a philosophy. IBS has been identified as one of the solutions for the innovative approach to solving some of the existing Malaysian's construction issues and dilemmas, especially the issue of a high number of foreign workers, many of whom are illegal immigrants who are not skilled or competent. Record and statistics show that this group has created more negative impact in terms of social, economic and political stability. In addition this group is partly instrumental in creating a low image which the construction industry is held. Hence the idea to introduce IBS is vital as a solution to reducing the heavy reliance of migrant workers in the country, many of whom are illegal, and with little or no skills. In Malaysia, increased market forces and

[1] M.R.Abdullah@edu.salford.ac.uk

Abdullah, M R and Egbu, C(2011) The application of Analytical Hierarchy Process (AHP) as a decision tool in choosing the type of Industrialised Building System (IBS) for housing projects *In:* Egbu, C. and Lou, E.C.W. (Eds.) *Procs 27th Annual ARCOM Conference,* 5-7 September 2011, Bristol, UK, Association of Researchers in Construction Management, 555-562.

regulation are fuelling the increased demand for appropriate of IBS. This has also heightened the need for effective decision making in the selection of IBS by providers of IBS and construction players, especially project developers and contractors. It is well known that suppliers or manufacturers of IBS all claim that their systems offer the best value for money to contractors and developers in terms of time saving, cost reduction and higher quality standard. Therefore, the selection of appropriate types of IBS and the decision making in the selection process need to be carried out before possession of a site takes place and/ or during the design stage of the project. Nevertheless, the procurement routes and other factors play vital roles in justifying and prioritising the criteria for selecting types of IBS.

The use of decision making support system or tools is often argued as the best approach to rationalize the best solution. However, due to the current industry scenario, experience of the individual decision maker and heuristics seem to be the dominant approach in decision making. This paper, inter alia, discusses the idea of using the decision making tools to help managers underpin their decision and judgments. The Analysis Hierarchy Process [AHP] is, arguably, a simple and easy concept to support decision makers.

INDUSTRIALISED BUILDING SYSTEM IN MALAYSIA

Abdullah and Egbu (2009) highlighted some of the limitations in the definition of IBS. IBS is often seen as representing the technical methods of, the processes of, or the philosophic approach to, the building industry. Earlier definitions take a more technical perspective - considering technical construction and materials used in construction (Hamid et al. 2008). However, Warszawski (1999) sees IBS as a set of interrelated elements that act together to enable the designated performance of a building. Construction Industry Development Board, CIDB (2003) considers IBS as construction techniques where components are manufactured in a controlled environment [on or offsite], transported, positioned and assembled into a structure with minimal additional site works.

In this research, IBS is defined as a process of building construction using the method of the production system to prepare the building elements either on a site or off site within controlled working environments. IBS in the Malaysian construction industry has its origin in 1963. Since the successfully completed pilot projects in Kuala Lumpur and Penang in Malaysia, the development of IBS became more popular. During the late 1980s housing projects benefited from IBS. Growth in IBM use also increased between the Seventh and Tenth Malaysian Plan, when the demand for housing increased due to growth in population. Swee (1998) reported to the United Nations on the status of IBS in Malaysia that 140 IBS systems were registered with the Malaysian government at that time, and classified under six categories (Sarja 1998). The categories are: Large Panel Systems. Metal formwork system, Framing System, Partially precast system, Modular systems and Hollow core slab reinforced concrete frame system.

Trikha (1999) recorded that in an IBS Seminar held in 1996, thirteen (13) manufacturers claimed to produce different types of IBS. However, only four main categories of IBS were established from the 13 manufacturers. These categories are: Panel Systems, Formworks Systems, Building Blocks Systems and Steel Frame System. Ali and Samad (1999) also categorized 19 building system from various manufacturers into four categories, which are: Precast Concrete Frame, Panel and Box

System; Formworks System, Blockwork System and Steel Frame System (Ali and Samad 1999).

The Construction Industry Development Board (CIDB) of Malaysia categorizes IBS into six main types. These are: precast panel, frames and box systems in one category, while the others are Timber Framing, Steel Framing, Blockwork, Formworks System and Hybrid or Combination of the System. In a recent statistics reported by CIDB (2010), there are 118 manufacturers of which 36 manufactured precast concrete framing, panel and box systems; 16 Steel formwork systems; 29 Steel framing systems; 16 Prefabricated Timber Framing Systems; 10 Block Works Systems, and 11 other IBS types, such as on site manufacturing. However, Kamar (2011) revised the number of IBS manufacturers registered with CIDB as it was reported that 104 manufactured Precast concrete framing, panel and box system; 79 Steel Formworks system, 32 Steel Framing system; 25 Prefabricated Timber framing system; 14 Blockwork system; 35 On site manufacturing system and 16 manufactured other innovative solution system.

It was also reported by CIDB that 894 contractors are registered as IBS Contractors (CIDB 2009). Kamar (2011) also highlighted that only 334 contractors considered are large scale contractors who were also registered under the category of Grade G7 contractors (Hamid et al. 2008). Hence, effective decision making by contractors in choosing appropriate types of IBS is vital given the huge range of alternatives or choices of IBS for selection.

DECISION TO SELECT THE TYPE OF IBS

Aziz (2007) recommended that an understanding of factors, such as communication and knowledge, which impact the decision making on the adoption of IBS in Malaysia is crucial. The decision to use IBS in construction projects is, inter alia, dependent on consideration of strategic issues relating to technological, economic, sociological and psychological factors (Zakaria *et al.*, 2010). This viewpoint also seems to be consistent with those of Abdullah and Egbu (2010). The latter authors, in their review of literature, noted that other issues such as structure and materials' design, site orientation, health and safety, client perspectives, environmental issues and sustainability and organisation issues also need to be taken account when the decision to adopt an IBS is considered. Abdullah and Egbu (2010) also concluded that a holistic approach is needed in the decision making process in adopting IBS, which should consider strategic issues, including the level of maturity of organisations and decision makers. It is generally accepted that the pre-tender stage is the best stage to introduce an IBS. During the design phase, the maximum project benefit could be gained by the adoption of IBS (Gibb, 1999), hence, it makes sense for decision to be made during that stage. The selection process should identify the IBS contractor to whom the client can confidently entrust the responsibility to execute project satisfactorily.

ANALYTICAL HIERARCHY PROCESS (AHP) AS DECISION TOOLS

Analytical Hierarchy Process (AHP) is a well-known multi-criterion decision making technique. It is a useful, simple and systematic approach (Felix *et al.,* 2008). It was introduced by Thomas L. Saaty in 1980 as a theory of measurement concerned with deriving dominant priorities from paired comparisons of homogeneous elements with respect to a common criterion or attribute (Saaty 1990). Fong and Choi (2000) infer that a study about AHP by Nydick and Hill (1992) established a methodology to rank alternative courses of action based on the decision maker's judgments concerning the importance of the criteria and the extent to which they are met by each alternative. In a study carried out by Pan (2006), it is claimed that AHP has been widely used and is applicable as a mathematical tool in multi criteria decision analysis. In the context of AHP structure, the overall objectives of a decision lie at the top of the hierarchy, the criteria [elements affecting the decisions], sub criteria and decision alternatives on each descending level of the hierarchy as shown in Figure 1 (Fong and Choi, 2000).

Figure 1 : Hierarchy Model used in AHP [Adapted from Saaty, 1990)]

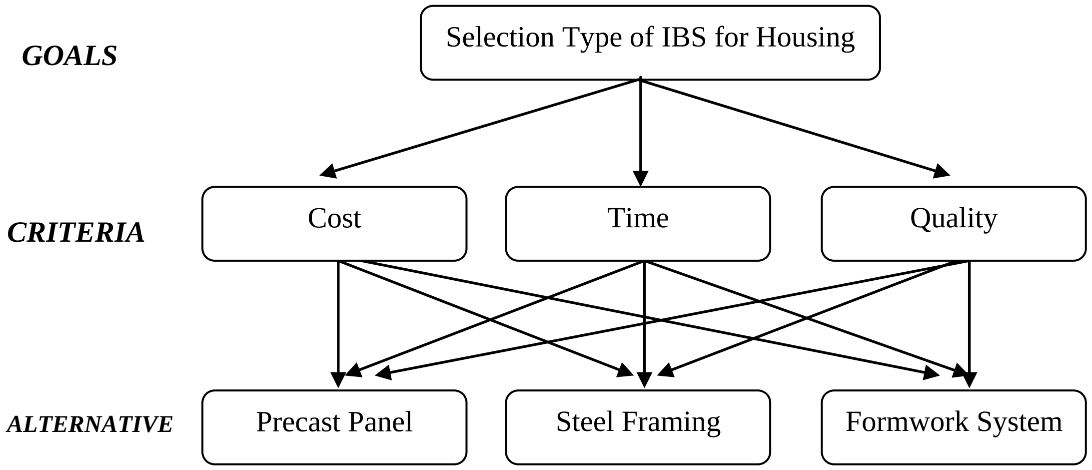


Table 1 : Value point of comparative scale Source: Saaty, 1990)

Numerical Values	Definition
1	Equally important or preferred
3	Slightly more important or preferred
5	Strongly more important or preferred
7	Very strongly more important or preferred
9	Extremely more important or preferred
2,4,6 and 8	Intermediate values to reflect compromise

Table 2 : Matrix Table of Criteria Pair-wise Comparison [Source: Saaty, 1990)]

Criteria	Cost	Time	Quality	Safety	Relative Priority
Cost	1	1/3	5	2	0.233
Time	3	1	8	5	0.579
Quality	1/5	1/8	1	1/4	0.050
Safety	1/2	1/5	4	1	0.139
					CR = 0.035

AHP offers the scale of rating sets of point comparative from 1 to 9 as table 1 shows. The assessment steps of AHP starts by pair judgments in each hierarchy structure of criteria and alternatives in the form of a matrix table. For example, the degree of importance between Time criteria and Cost criteria is slightly more important or preferred [value of 3], so the revert value of Cost criteria towards Time is 1 over 3 [1 /3] as per table 2. The number comparison depends on the amount of n. Given n criteria or alternatives, the judgment's need is a simple equation of n {n-1} / 2. The acceptance value of Consistency Ratio [CR] should be smaller or equal to 10% of Consistency Index [C.I]. If the CR is greater than 10%, the judgment of criteria or alternatives compared shall be reviewed (Saaty 1990). The chosen factors can be considered by calculate the multiplication of priority weights of decision alternatives with the priority weight of criteria or sub criteria if any.

SPREADSHEET APPLICATION AS MODEL OF DECISION SUPPORT TOOLS

The conceptual model of this decision tool has been developed based on the Thomas Saaty calculation theory. Microsoft Excel 2007 in Windows 7 has been utilized to prepare the frameworks of decision tools based on AHP. Figure 2 shows the interface of the model. The decision makers or users will be guided, steps by step, in handling the information and data entry in that model.

The process of identifying and selecting the criteria has been included in the model. The most important part is to judge the weight-age of importance as indicated in Table 1. This exercise is laid in a book-sheet as shown in Figure 3. From the information of criteria performance measurement that has been entered, the recommendation of alternatives system or type of IBS is recommended as per figure 4.

The use of MS Excel spreadsheet application to build the AHP model has been identified to be an advantage due to several reasons. The simplest, easiest and user friendliness of the application or software are some of the criteria. The potential that MS Excel possesses, such as basic formulation properties, varieties of control box links of a calculation results, compatibility with MS Visual Basic to create and develop more formulas and logical output is worthy of note. In terms of cost and financial criteria for the use of MS Excel is almost e free of charge, as compared to working in the other's tools such as Expert Choice software and other private Expert System [ES] developer. Therefore, the development of MS Excel‘s AHP model is, arguably, an important economical framework decision tools to be developed.

Figure 2: Interface of the Selection of Alternatives

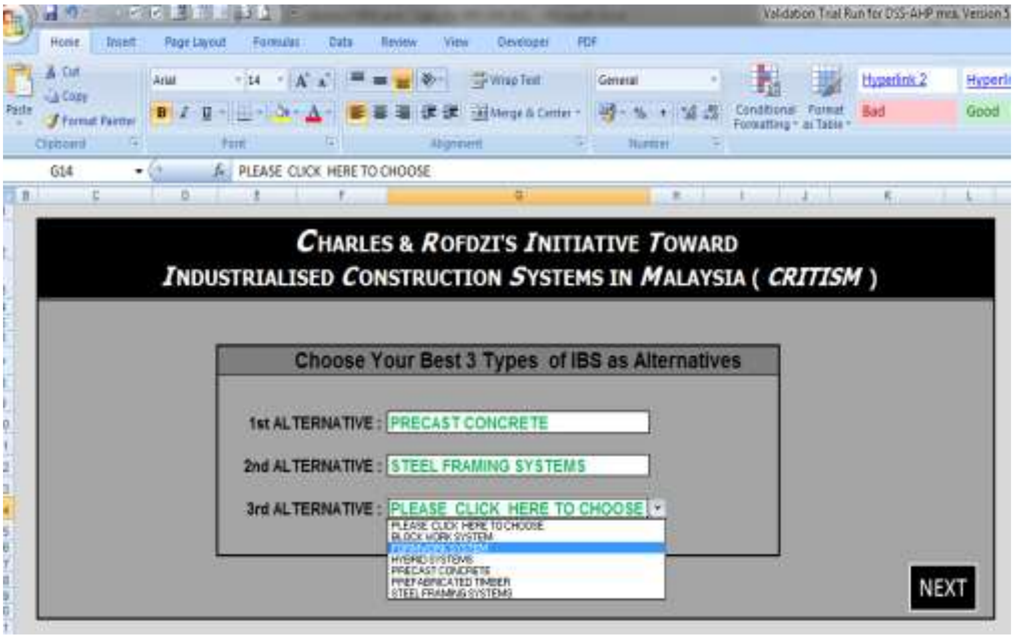


Figure 3: Interface of Criteria Table Matrix

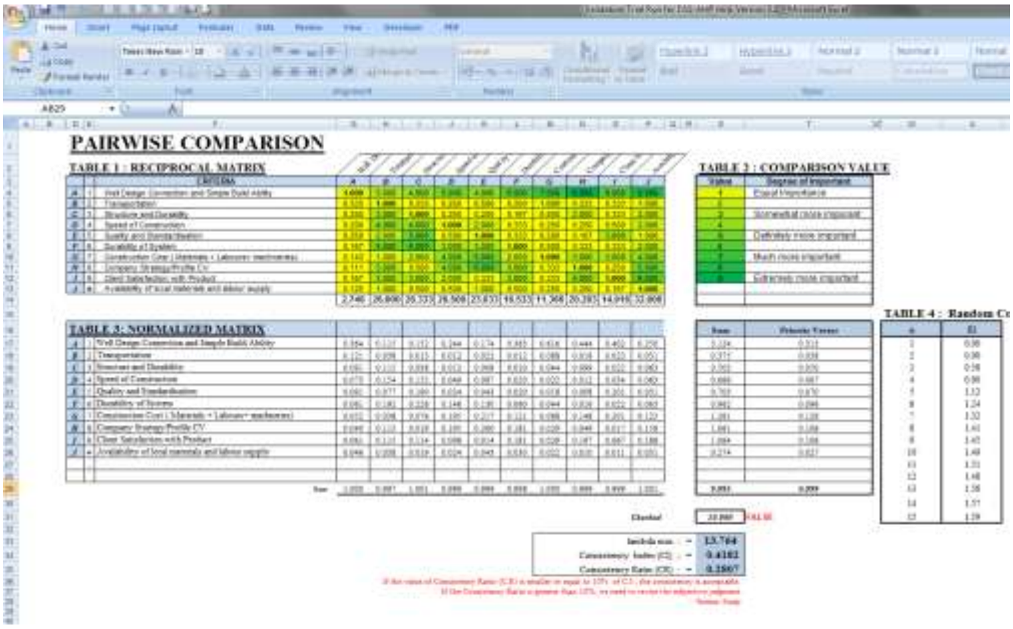
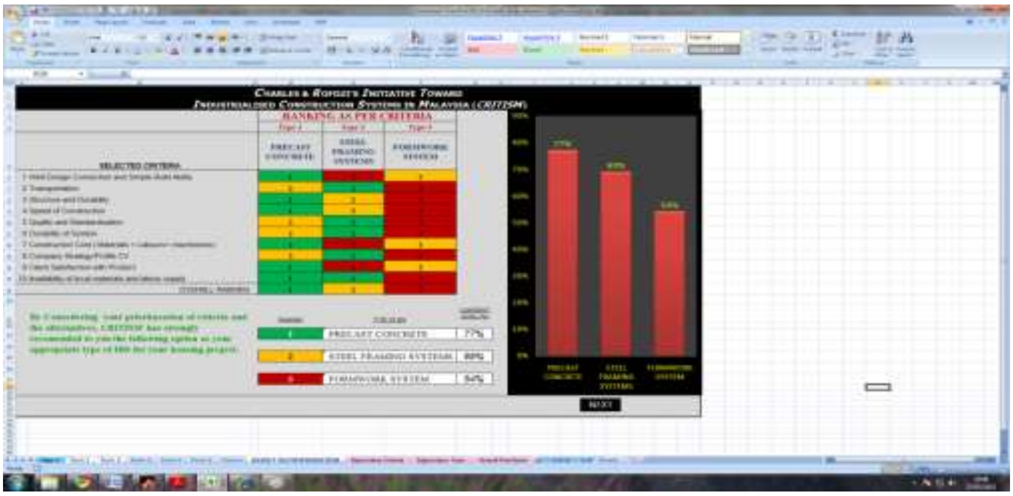


Figure 4: Interface of final recommendation of selection type of IBS



CONCLUSIONS

The construction industry is considered as one of the most complex industries. It deals with a host of factors from different and complex perspectives. Therefore, decision making in the construction industry at whatever stage of the project life cycle should be taken very seriously. Managers and decision makers involved in the decision to select an IBS face many issues and challenges, especially in the absence of sufficient information.

A host of factors needs to be considered in arriving at the decision to use a particular IBS/ These include structure and materials' design, site orientation, health and safety, client perspectives, environmental and sustainability issues, and organisational issues. A holistic approach is also needed in the decision making process in adopting IBS, which should consider the level of maturity of organisation and decision makers. The use of decision support system or tools, such as AHP, may help managers or decision makers. An Analytical Hierarchy Process [AHP] is a simple, logical and quantitative approach to support decision makers in arriving at an “optimum best decision”.

REFERENCES

Abdullah, M. R. and Egbu, C. O. (2009), “A Consideration of Key Issues in The Implementation of IBS in Malaysia”, *4th Scottish Conference for Postgraduate Researchers of the Built and Natural Environment - PROBE 09*, Glasgow Caledonian University, Glasgow, Scotland, UK., 19th – 20th November 2009.

Abdullah, M. R. and Egbu, C. O. (2010), *A Selection Criteria Framework (SCF) for Choosing Industrialised Building Systems (IBS) in Housing Projects*, Leeds University, UK.

Ali, A. A. A. and Samad, A. A. A. (1999), “Industrialisation in the Building Industry”, *Seminar Teknologi dan Pengurusan PKNS*, Menara PKNS, Petaling Jaya, Selangor, Malaysia.

Aziz, A. A. (2007), *Adoption of Industrialised Building System in Malaysian Housing Industry*, unpublished MSc Thesis University of Technology MARA (UiTM), Selangor, Malaysia.

CIDB (2003), *Industrialised Building System (IBS) Roadmap 2003 -2010*, CIDB, Kuala Lumpur, Malaysia.

CIDB (2009), *National IBS Implementation Strategy*, CIDB, Kuala Lumpur, Malaysia.

CIDB (2010), *Status Semasa Perlaksanaan Program IBS*, CIDB, Kuala Lumpur, Malaysia.

Felix, T. S., Chan, T. S., Kumar, N., Tiwari, M. K., Lau, H. C. W. and Choy, K. L. (2008) , “Global Supplier Selection : A Fuzzy AHP Approach”, *International Journal of Production Research*, **46**(14), 3825-3857.

Fong, P. S. W. and Choi, D. K. Y. (2000), “Final contractor selection using the analytical hierarchy process”, *Construction Management and Economic*, **18**, 547-557.

Gibb, A. G. F. (1999), *Off-site fabrication*, Caithness, Whittles Publishing, Scotland, UK.

Hamid, Z. A., Kamar, K. A. M., Zain, M. Z. M., Ghani, M. K. and Rahim, A. H. A. (2008), “Industrialised Building System (IBS) in Malaysia : The current State and RandD initiatives”, *Malaysian Construction Research Journal*, **2**(1), 1-13.

Kamar, K. A. M. (2011), *An Investigation into the Critical Success Factors of Industrialised Building System (IBS) Contractors: The Malaysian Case*, unpublished thesis (PhD), University of Salford, UK.

Nydick, R. L. and Hill, R. P. (1992), “Using the analytic hierarchy process to structure the supplier selection procedure”, *International Journal of Purchasing and Materials Management*, Spring, 31-36.

Pan, W. (2006), *A Decision Support Tool for Optimising the Use of Offsite Technologies in House building*, Unpublished PhD Thesis, University of Loughborough, UK.

Saaty, T. L. (1990), “How to make a decision: The analytic hierarchy process”, *European Journal of Operational Research*, **48**(1), 9-26.

Sarja, A. (1998), *Open and Industrialised Building*, Taylor and Francis e-Library.

Trikha, D. N. (1999), “Industrialised Building Components and Systems - Prospects in Malaysia”, translated by Trikha, D., Samad, A. A. A., Jaafar, M. S., Thanoon, W. A. and Nesan, L. J. (Eds), *Perpustakaan Negara Malaysia*, Subang Jaya, Selangor, Malaysia.

Warszawski, A. (1999), *Industrialised and Automated Building System : A Managerial Approach*, E&FN SPON, UK.

Zakaria, S. A. S., Brewer, G. and Gajendran, T. (2010), "Conceptual Framework of Psychology Decision Making on Industrialized Building System (IBS) Technology", *2010 International Conference on Engineering, Project, and Production Management, Pingtung, Taiwan*, 14 - 15th October 2010.