MULTI-PERSON DECISION FOR SUSTAINABLE DESIGN ON IBS FLOOR SYSTEM SELECTION

Christiono Utomo
Department of Civil Engineering, Institut Teknologi Sepuluh Nopember, Indonesia
Email: christiono@ce.its.ac.id

N.A. Rahman
Universiti Teknologi PETRONAS, Malaysia
Email: noorasi@petronas.com.my

A. Idrus
Universiti Teknologi PETRONAS, Malaysia
Email: arazi_idrus@petronas.com.my

ABSTRACT

Selecting a design solution (choice problem) is one of the natures of design decision. If the problem is more complex and involves multi participants, decision aid is necessary. This paper discusses the nature of group judgment and negotiation on multi-criteria decision-making methodologies. It presents a conceptual model of negotiation support in a multi-person decision on building floor system selection. Decision technique (AHP) was applied for decision process in a satisfying options and game theory for coalition formation. An n-person cooperative game is represented by a set of all players. The proposed coalition formation model enables each agent to select individually or coalition. It improves the value of building system decision. It further emphasizes the importance of performance evaluation in the design process and value-based decision. The support model can be extended to an automated negotiation and in different building system selection with proper modification.

Keywords: Multi-person, design decision, IBS, floor system selection.

1 INTRODUCTION

The construction and housing industry in Malaysia is often regarded as the least efficient and productive sector compared to the other sectors. Its image is one of labor-intensive, delays and an overhang in projects. Nevertheless, the construction sector remains a significant contributor to the sustainable growth of the national economy. The construction industry transcends all industries and serves to provide the vital infrastructure support for mining, manufacturing, agriculture, transport and support utilities, and services such as health, education and tourism.

Construction Industry Development Board (2003) notes that Industrialized Building System (IBS) is an alternative approach of construction. The use of IBS assures valuable advantages such as the reduction of unskilled workers, less wastage, less volume of building materials, increased environmental and construction site cleanliness and better quality control, among others. These advantages also promote a safer and more organized construction site, and reduce the completion time of construction (IBS Digest, 2007).

Industrialized Building System (IBS) may be defined as building systems in which structural components are manufactured in a factory, or on site, transported and assembled into a structure with minimal additional site works (Junid, 1986; Kamar and Hamid, 2011). The quality, speed of construction, and cost saving are the main emphases given in the building construction industry in Malaysia. The control in using materials, such as steel, sand, and timber, will result in substantial savings on the overall cost of the project.

Highly capital intensive is the main disadvantage of the IBS. The heavily mechanized approach has displeased a substantial number of the labor force from the building construction industry (IBS Digest, 2007). Aziz and Rauzan (2003) highlighted that the major reason for the acceptance of IBS is basically supply and cost of labor, speed of construction and wastage control.

Among the components of constructing a building, floor is the most tedious component to construct as well as time consuming and expensive if it is to be constructed in situ. If the floor construction can be made more efficient by IBS, the overall building time of construction and cost can be reduced. When the design decision for floor system selection is conducted by more than one person, decision must be made jointly in a group. Techniques, methods, and tools have been developed and studied for group decision making (Couger, 1995; Peniwati, 2007 and Vetschera, 2005). In this situation, negotiation plays an important role in many design decision, and is usually conducted informally.

2 CONCEPTUAL BACKGROUNDS

2.1 IBS Floor System

Waleed et al. (2003) highlighted that an IBS may be defined in which all building components such as wall, floor slab, beam, column and staircase are mass produced either in factory or at site under strict quality control and minimal on site activities. Generally, there are four types of building systems available in Malaysia, namely conventional, cast-in-situ, prefabricated and composite building system. As an addition, each building system is represented by its respective construction method which is further characterized by its construction technology, functional and geometrical configuration (Waleed et al., 2003). On the other hand, IBS can be divided into five major groups based on the structural aspects (CIDB, 2003) which are: (1) Precast Concrete Framing, Panel and Box Systems, (2) Steel Formwork Systems, (3) Steel Framing Systems, (4) Prefabricated Timber Framing Systems, (5) Block Work Systems.

Currently, IBS has been used in various applications of construction of residential buildings, quarters, condominiums, schools, office buildings, and hospitals. The principle advantages of precast floors are speed of construction, absence of scaffolding, large variety of types, large span capacity, & economy. Precast floors can also be classified according to their manufacture into totally & partially precast floors. There are 7 types of precast floor systems in Malaysia, which are: Hollow Core Slabs, Pre-stressed Solid Planks, M-Beams Floors, Double Tee Slabs, Half Slabs / Composite Planks, Bubble Floors / Bubble Decks, Beam and Block Floors

2.2 Design and Multi Person Decision

Design is a fundamental human activity. All designs involve creativity (the generation of alternative solutions) and decision (choice among those alternatives), both creativity and decision are ineffable and mysterious (Scott, 1999). Decision making in general, and engineering decision-making, in particular, often involves the balancing of multiple, potentially conflicting requirements (Sen and Yang, 1998). The performance attributes of the chosen solution meet some functional requirements in an engineering design. Some other complicating factors that appear in many decision-making problems in engineering design are those related to the complexity of the task, the need to take account of subjective as well as objective factors, and the inherent uncertainty in a given situation.

Rational decision-making involves choice within the context of multiple measures of performance or multiple criteria. Group decision-making (GDN) is defined as decision situation in which there are more than one individual involved. Those group members have their own attitudes and motivations; recognize the 'existence of a common problem, and attempt to reach a collective decision' (Lu et al., 2007). Moving from a single decision maker to a multiple decision maker setting introduces a great deal of complexity into the analysis. The group decision-making concept can be applied to Multi Attribute Decision Making (MADM) techniques (Rao, 2007). The advantages and disadvantages of group decision making have been summarized by Hunt (1992). Nevertheless, there are benefits and drawbacks of group decision-making, a manager should avoid judging the value of group decision making solely on the quality of decision reached (Barry, 2008). Baron and Kerr (2003:205-206) gave a comprehensive approach for group decision making.

There are many methods on group decision making. In summaries done by Couger (1995), Peniwati (2007) and Vetschera (2005), a model that consists of three groups of criteria was proposed for methods evaluation. First is structuring that includes analogy /association, boundary examination, brainstorming /brain-writing, morphological connection and why-what's stopping. Second is structural and measuring group that consists of methods that are Bayesian analysis, MAUT (multi attribute utility theory) and AHP. In this group of group decision making methods, Lin et al. (2008) proposed a modification and extension of TOPSIS (Triantaphyllou, 2000) to a group decision environments by adopting Minkowski distance function to solve the overweight problem in the original TOPSIS technique, the grey number operations to deal with the problem of uncertain information, and the aggregation approach to integrate experts evaluation.

Third is ordering and ranking group including some methods such as voting, nominal group techniques, Delphi, disjointed incremental, matrix evaluation, goal programming, conjoint analysis and outranking. Included in this group is data envelopment analysis (DEA) (Angiz et al., 2009) by mathematical model which is converted into a multi objective linear programming model from which the optimal solution is obtained.

There are two approaches in prior works of group decision making which are qualitative and quantitative. The qualitative approaches on the cooperative aspect of decision making that examines how members of a group jointly build reputations and influence others while attempting to make a decision. It addresses both the cooperative and non-cooperative aspects of group decision making. Quantitative approaches focus exclusive on non-cooperation (Contreras, 1997; McCain, 2004; Brandenburger, 2007). The work in quantitative approach generally follows the axiomatic approach. Collaboration in group decision making is a continuous process. Different phases in the evolution of a group decision making structure require an ongoing managerial task of balancing cooperation and non cooperation to develop the benefits of multiple competitive (Lawson, 2008).

2.3 Group Decision Support

DeSanctis and Gallupe (1987) defined Group Decision Support System (GDSS) as an interactive computer based system that combines communication, computing, and decision support technologies to facilitate formulation and solution of unstructured problems by a group of people. A major problem in supporting multi-criteria group decision is the aggregation of group preference. Davey and Olson (1998) proposed a multiple criteria group decision support systems by categorizing into two groups: value oriented, and goal oriented that consists of individual preferences, aggregation techniques, and conflict resolution.

There have been many research works in the area of application of decision support system in the construction industry. The application is divided into three types. The first type is knowledge based/expert system applied for construction planning, contractual dispute, site investigation, equipment selection, monitoring and risk management (Wanous, 2000; Thorpe, Tah and Mc Caffer, 1992). The second type of application is Artificial Neural Network and fuzzy system applied to planning, duration and cost forecasting, project selection and contractor pre-qualification (Provenzano, 2003; Tah and Car, 2000). And the last application is hybrid (integrated) systems and web-based systems for construction contracting by integrating operation research, artificial intelligence, and statistical and financial methods (Khosrowshahi and Howes, 2005). Most studies of negotiation support concentrate on the negotiation process modeling and data modeling rather than on strategies and efficiency for a multiple criteria decision making problem, in which many criteria are taken into account as attributes for decision making (Du and Chen, 2007).

3 MULTI PERSON DECISION TO SELECT BUILDING FLOOR SYSTEM

3.1 Decision Process

Figure 4 shows a model of decision hierarchy based on LCC and sustainable function for a public housing. Each of the objects in this model contains attribute representing their various properties and different preferences. The objective of the problem ("to select building floor system in sustainability function") is addressed by some alternatives (A = a1; a2; a3). The problem is split into sub problems (c1, c2, c3, c4, f1, f2, f3) which are the evaluation criteria. Three stakeholders were involved and each has his own preference. The result based on individual judgment is presented in Table 1. The alternatives of building floor systems are:

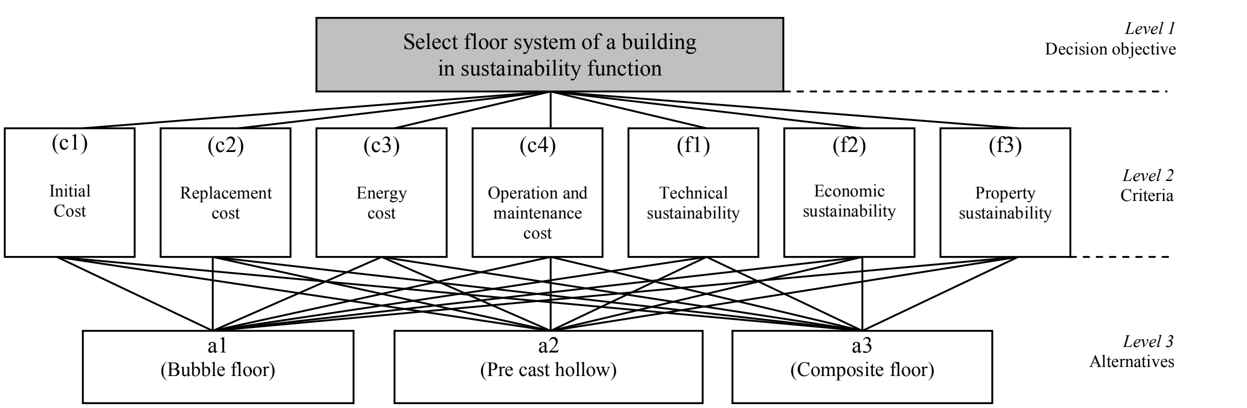

Figure 4. Decision hierarchy of building floor system selection

ALTERNATIVES 1: BUBBLE FLOORS / BUBBLE DECKS

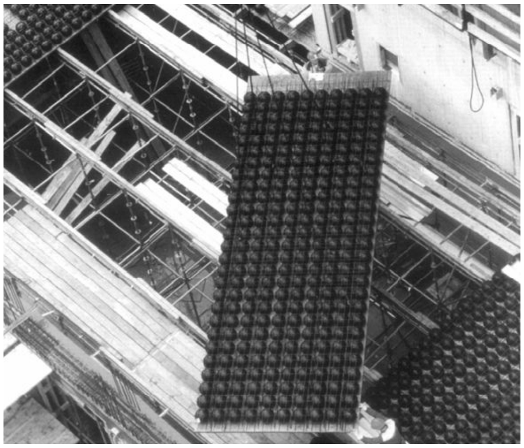

Figure 1. Bubble floor
(Source: http://www.eng.upm.edu.my/hrc/pc/handouts/precast%20frame%20-%203%20floors.pdf).

(a) Plastic spheres (about the size of footballs) are the weight saving medium. The spheres are fixed at the factory between two layers of spot welded reinforcement.
(b) May be manufactured to a wide ranges of sizes, the maximum being about
(c) 6 x 3 m, which weighs only 2.2 ton.
(d) Depth of the floor is tailored to suit structural requirements as the floor may be designed as continuous by the addition of in-situ top (and some bottom) reinforcement before the in-situ concrete.

ALTERNATIVES 2: HOLLOW CORE SLABS

Figure 2. Hollow core slabs
(Source: http://www.epmsb.com.my/hlc.html)

(a) Designed to BS 8110: 1997, simply supported Class 2 Member
(b) Fire resistance of 2 hours
(c) Concrete strength for slab at 28 days = 50.0 N/mm^2
(d) Standard hollow core slab design width is 1200mm

ALTERNATIVE 2: HALF SLABS / COMPOSITE PLANKS

Figure 3. Half slabs
(Source: http://www.eng.upm.edu.my/hrc/pc/handouts/precast%203%20floors%20pdf.pdf)

(a) Suitable as floorings for building, bridge decks, and permanent formworks.
(b) Span: 2m to 6m
(c) Width: 2 to 2.4m and customized widths.

3.2 Satisfying Option on Value Criteria

The technical solution options for building floor system were categorized into 'Cost' identified by initial cost, replacement cost, energy cost, and operation and maintenance cost; and 'Function' by all three functions which are technical sustainability, economic sustainability and property sustainability. Table 2 shows the selectability (Ps) and rejectability (Pr) that represent function and cost of technical solution for building floor system. Figures 5, 6, and 7 provide a cross plot of function and cost of facility management, design management, and project management respectively. Observe the influence of project management preference influence on a2.

Table 1. Weighting factor of each alternative for individual stakeholder

Alternatives	c1	c2	c3	c4	f1	f2	f3	WEIGTH
Stakeholder 1 (Facility Management)								
a1 (Bubble Floors)	0.0033	0.0081	0.0507	0.0632	0.0147	0.1233	0.0541	0.3175
a2 (Pre cast hollow)	0.0173	0.0146	0.0127	0.2079	0.0409	0.0233	0.0343	0.3510
a3 (Composite floor)	0.0061	0.0265	0.0254	0.1147	0.0300	0.0438	0.0851	0.3316
Stakeholder 2 (Design Management)								
a1 (Bubble Floors)	0.0049	0.0083	0.1724	0.0145	0.0316	0.1437	0.0354	0.4109
a2 (Pre cast hollow)	0.0262	0.0150	0.0431	0.0478	0.0876	0.0271	0.0224	0.2692
a3 (Composite floor)	0.0093	0.0272	0.0862	0.0264	0.0642	0.0510	0.0557	0.3199
Stakeholder 3 (Project Management)								
a1 (Bubble Floors)	0.0422	0.0038	0.0420	0.0065	0.0471	0.1020	0.0271	0.2708
a2 (Pre cast hollow)	0.2238	0.0069	0.0105	0.0215	0.1307	0.0192	0.0172	0.4299
a3 (Composite floor)	0.0794	0.0126	0.0210	0.0119	0.0957	0.0362	0.0426	0.2994

Table 2. Basic value of technical solutions for floor system

	Cost						Function			Normalization	
	c1	c2	c3	c4	∑	Loss	F1	F2	F3	Cost (Pr)	Function (Ps)
a1 (Bubble Floors)	0.12	0.16	0.57	0.16	1.02	1.63	0.17	0.65	0.31	0.412	0.377
a2 (Pre cast hollow)	0.65	0.30	0.14	0.54	1.63	1.02	0.48	0.12	0.20	0.259	0.266
a3 (Composite floor)	0.23	0.54	0.29	0.30	1.35	1.30	0.35	0.23	0.49	0.329	0.357

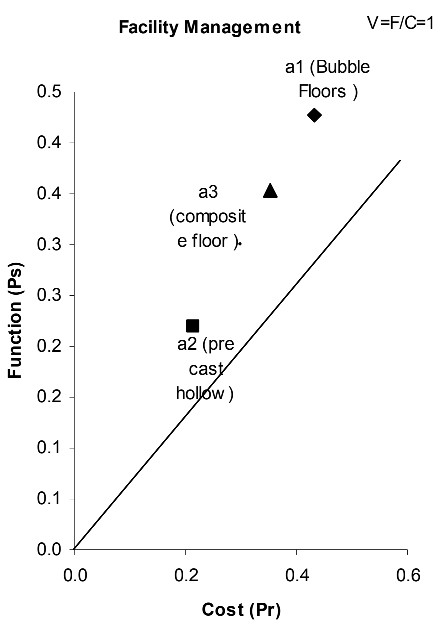

Figure 5. Value of floor system alternatives for facility management

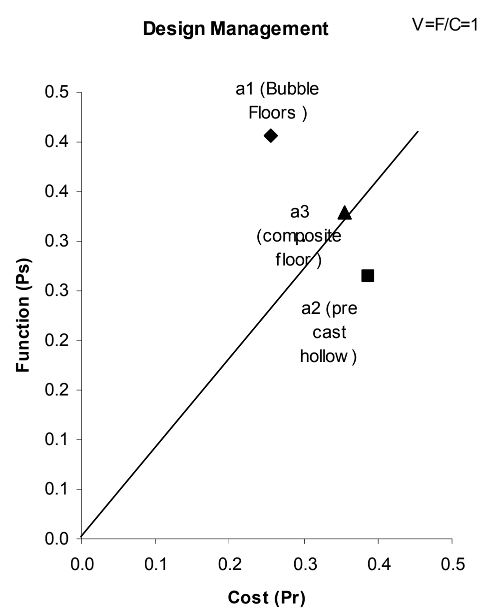

Figure 6. Value of floor system alternatives for design management

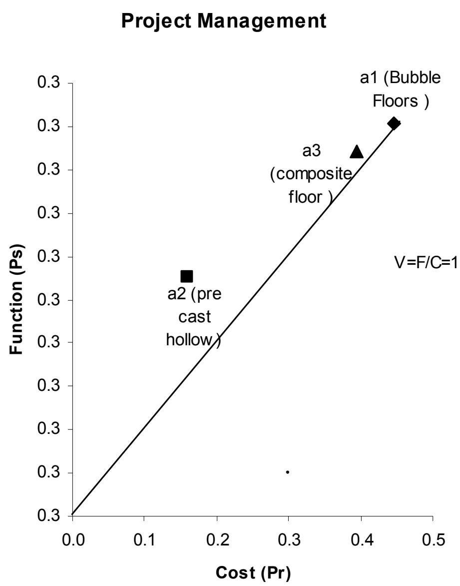

Figure 7. Value of floor system alternatives for project management

3.3 Agreement Options and Coalition

Three Steps are conducted which are determining the weighting factor (weight of preferences) of criteria for each decision-maker, grading alternative for each evaluation criteria, and scoring every alternative for every decision-maker. Figure 5, 6, and 7 show that every stakeholder has different alternative solutions. The result of payoff optimum and best fit options is presented on Table 3. It also presents the result of priorities of the technical solution for building energy system selection in the first negotiation round.

Table 3. Ranking of floor system solution on each coalition

Alternatives ranking for each stakeholder and coalition	Ranking of alternatives		
	a1	a2	a3
SH1 (Facility Management)	3rd	1st	2nd
SH2 (Design Management)	1st	3rd	2nd
SH3 (Project Management)	3rd	1st	2nd
Coalition SH1 and SH2	1st	2nd	3rd
Coalition SH1 and SH3	2nd	1st	3rd
Coalition SH2 and SH3	1st	2nd	3rd
Grand Coalition	2nd	1st	3rd
RESULT	2nd	1st	-

4 CONCLUSION

In this case, a composite floor (a3) is not an option because no one or coalition selects this solution as an option. The 'precast hollow' (a2) is the best solution. It is a best fit option for all coalitions of stakeholders. Future research in the application of this methodology in many fields of decision will build a wide range of knowledge to solve the theoretical and practical gap in automated design and automated negotiation. In the context of automated design based on an agent system, an artificial neural network can be applied to give learning to the system for the coalition algorithm on computer program.

REFERENCES

Angiz L, M.Z., Emrouznejad, A., Komijan, A.R. (2009). "Selecting the most preferable alternatives in a group decision making process using DEA." *Expert System with Applications: an International Journal* 36(5): 9599-9602.

Aziz, S.N. and Rauzan, N.F. (2003). *IBS Survey 2003: Survey on the usage of Industrialised Building Systems (IBS) in Malaysian Construction Industry*, Construction Technology Division, Construction Industry Development Board, Report. Kuala Lumpur, Malaysia

Barry, B. (2008). "Negotiator affect: the state of the art (and the science)," *Group Decision and Negotiation* 17: 97 - 105.

Baron, R. and Kerr, N. (2003). *Group Process, Group Decision, Group Action*, Open University Press, Buckingham.

Brandenburger, A. (2007). *Cooperative Game Theory: Characteristic Functions, Allocations, Marginal Contribution*, Http://pages.stern.nyu.edu/abranden/ coop-01-04-07.pdf. Accessed 2 April 2012.

CIDB (2003). *Industrialized Building System (IBS) Survey 2003*, CIDB Publications.

Contreras, J. (1997). "A cooperative game theory approach to transmission planning in power system," *Ph.D. Thesis*, University of California Berkeley.

Couger, J.D. (1995). *Creative Problem Solving and Opportunity Finding*, Boyd and Fraser, Thompson Publishing, NY

Davey, A. and Olson, D. (1998). "Multiple criteria decision making models in group decision support," *Group Decision and Negotiation* 7: 55-75. Kluwer Academic Publisher

DeSanctis, G. and Gallupe, R.B. (1987). "A foundation for the study of group decision support system," *Management Science* 33: 589-609.

Du, T.C. and Chen, H-L. (2007). "Building a multiple criteria negotiation support system," *IEEE*

Transactions on Knowledge and Data Engineering 19(6): 904-817.

Hunt, J. (1992). *Managing People at Work*. McGraw Hill, London

IBS Digest (2007). *IBS Digest @ malbex2007*, September, Kuala Lumpur.

Junid, S. (1986). "Industrialized building system," *Proceeding of UNESCO/FEISEAP regional workshop*.

Kamar, K.A.M and Hamid, Z.A. (2011). "Supply chain strategy for contractor in adopting Industrialized Building System (IBS)," *Austratlian Journal of Basic and Applied Science* 5(12): 2552-2557.

Khosrowshahi, F. and Howes, R. (2005). "A framework for strategic decision making based on a hybrid decision support tools," *ITcon* 10: 111-124.

Lin, Y-H., Lee, P-C., Chang, T.P., Ting, H.I. (2008). "Multi-attribute group decision making model under the condition of uncertain information," *Automation in Construction* 17: 792-797

Lu, J., Zhang, G., Ruan, D., Wu, F. (2007). *Multi Objective Group Decision Making: Methods, Software and Applications with Fuzzy Set Techniques*. Imperial College Press. London, UK, pp. 39-51.

McCain, R.A. (2004). *Game theory: A Non Technical Introduction to the Analysis of Strategy*. Southwestern Thomson Learning, Ohio.

Peniwati, K. (2007). "Criteria for evaluation group decision making methods," *Mathematical and Computer Modeling* 46: 935-947.

Provenzano, P. (2003). "A fuzzy-neural network method for modeling uncertainties in soil-structure interaction problems," *Computer-Aided Civil and Infrastructure Engineering* 18(6): 391 – 411.

Rao, R.V. (2007). *Decision-making in the Manufacturing Environment Using Graph Theory and Fuzzy Multiple Attribute Decision Making Methods*. Springer, London.

Scott, M.J. (1999). "Formalizing negotiation in engineering design," *Ph.D. Thesis*, California Institute of Technology, Pasadena, California.

Sen, P. and Yang, JB. (1998). *Multi Criteria Decision Support in Engineering Design*. Springer, London.

Tah, J.H.M. and Carr, V., (2000). "A proposal for construction project risk assessment using fuzzy logic," *Construction Management and Economics* 18(4): 491-500.

Thorpe, A., Tah, J. and McCaffer, R. (1992). "A knowledge based decision support system for drainage cost estimating," *The International Journal of Construction Information Technology* 1(1): 11-28.

Triantaphyllou, E. (2000). *Multi Criteria Decision Making Methods: A Comparative Study*. Kluwer Academic Publisher, Dordrecht The Netherlands.

Vetschera, R. (2005). "Strategic manipulation of preference information in multi criteria group decision methods," *Group Decision and Negotiation* 14: 393-414.

Waleed, A.M.T., Peng, L.W., Kadir, M.R.A., Jaafar, M.S. and Salit, M.S. (2003). "The essential characteristics of industrialized building system," *International Conference on Industrialised Building Systems*, Kuala Lumpur, Malaysia, pp.283-295.

Wanous, W. (2000). "A neuro fuzzy expert system for competitive tendering in civil engineering," *Ph.D. Thesis*, Liverpool University, UK.

Syahrul Nizam Aziz and Nor Fazliyana Rauzan (2003) IBS Survey 2003: Survey on the usageof Industrialised Building Systems (IBS) in Malaysian Construction Industry, ConstructionTechnology Division, Construction Industry Development Board, Report.Kuala Lumpur, Malaysia.

[this page intentionally left blank]