International Journal of Business, Human and Social Sciences
ISSN: 2517-9411
Vol:4, No:7, 2010

Value–based Group Decision on Support Bridge Selection

Christiono Utomo and Arazi Idrus

***Abstract*—**Value-based group decision is very complicated since many parties involved. There are different concern caused by differing preferences, experiences, and background. Therefore, a support system is required to enable each stakeholder to evaluate and rank the solution alternatives before engaging into negotiation with the other stakeholders. The support system is based on combination between value-based analysis, multi criteria group decision making based on satisfying options, and negotiation process based on coalition formation. This paper presents the group decision and negotiation on the selection of suitable material for a support bridge structure involving three decision makers, who are an estate manager, a project manager, and an engineer. There are three alternative solutions for the material of the support bridge structure, which are (a1) steel structure, (a2) reinforced concrete structure and (a3) wooden structure.

***Keywords*—**Value-based, group decision, negotiation support, construction.

I. Introduction

VALUE Analysis [1] (VA) has been widely adopted in many countries over several decades as a very effective tool to meet the increasing demands for value enhancement by clients [2]. VA aims to achieve essential function at the lowest life cycle cost through identifying opportunities to remove unnecessary costs while ensuring that quality, reliability, performance, and other critical factors. As a process involving multidiscipline and teamwork, negotiation becomes an important role in the value-based decision process. Therefore, a support to group decision and negotiation is required.

Many researchers [3], [4] suggested applying Game Theory in negotiation support. However the support model for VA has not been developed. The characteristic of value criteria cannot be applied on previous research. Existing models commonly accepted are optimization-based, such as aggregation methods but these are not able to solve the problem of value criteria. This paper applied satisfying games [5] where the function and costs of a solution technique of a support bridge as the value criteria can be formulated on group decision and negotiation.

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The research objective presented in this paper is to develop a value-based group decision model to the fundamental problem involving selection of support bridge material. The model is based on three schools of thoughts concerning negotiation on value-based design decision. The first considers the teamwork process in VA, the second consider group decision theory and the third considers automated negotiation theory.

II. Theoretical Background

A. Value

Miles [6], who was the first to introduce the term ‘value’ in to the industry, defined ‘value’ as ‘the relationship between function and cost’ using the following equation :

$$\text{Value} = \text{Function/Cost} \quad (1)$$

This equation was applied as mathematical ratio in many literatures. It is possible to increase the value of a product by increasing its function even when this results in greater cost, if the added function increases more than the additional cost. The meaning of value may be opened to interpretation but generally, the value of a product will be judged on some factors such as high level of performance, capability, emotional appeal, style, etc, relative to its cost [7]. The definition given above may be applicable to functions that are quantifiable; however, less tangible functions may influence a customer’s perception to the value of a product, e.g. those concerned with aesthetic quality.

B. Function Analysis

Understanding of functionality is important because it represents a part of the design rationale [8]. In a conceptual design stage, a designer decomposes a required function into sub function called functional decomposition. The word function is commonly used, and has many definitions. Kaufman [9] defined function as ‘an intent or purpose that a product or service is expected to perform’. There is a relationship between function and value, the solutions that yield such value and the functions such solution performs [10].

Function analysis consists of four sequential steps [9]-[12] which are: (1) determination of project function, (2) examination and sorting of these functions into categories, (3) selection of critical functions and arrangement into a logical order, and (4) analyzing the importance of the function. There are several methods of function analysis, one of the most important and useful is FAST (Function Analysis System Technique) by [11].

Using the verb-noun rules in function analysis FAST creates a common language. It allows multi-disciplined team members to contribute equally and communicate with one another while addressing the problem objectively without bias [12]. Regarding to [11] and [12], the team members must discuss and reconfigure the FAST model until consensus is reached and all participating team members are satisfied that their concerns are expressed in the model.

C. Life Cycle Cost

The term 'life cycle cost' means a process for evaluating the total economic worth of a usable project segment by analyzing initial costs and discounted future costs, such as maintenance, and user costs over the life of the project [13]. Life cycle cost (LCC) is an essential design process for controlling the initial and future cost of building ownership [14]. LCC can be implemented at any level of the design process and can be an effective tool for evaluation of existing building systems [15]. LCC equation can be broken down into three variables: the pertinent costs of ownership, the period of time over which these costs are incurred, and the discount rate that is applied to future costs to equate them with present day costs [16]. For calculation of LCC, the following equation is used.

Present worth (Pw) of LCC
= Investment cost
+ Pw of operation cost
+ Pw of maintenance cost
+ Pw of energy cost
+ Pw of replacement cost
+ Pw of salvage value (2)

Present worth (Pw) can be calculated using theory of time value of money by Equations (3) and (4) as follows:

$$P = \left[\frac{1}{1+i}\right]^N = F(1+i)^{-N} \quad (3)$$

$$P = A\left[\frac{(1+i)^N - 1}{i(1+i)^N}\right] \quad (4)$$

Where P = present value; F = future value; A = annual value; i = rate (%) per period; N = number of periods (years).

III. METHODOLOGY

The methodology for value-based group decision [17] combines value-based processes, multi-criteria decision-making process, negotiation base coalition process and agent-based negotiation development. Fig. 1 represents these processes. It consists of three stages base on the process. The first two stages are referred to [18] and the last stage is based on coalition formation on Game Theory [3], [4].

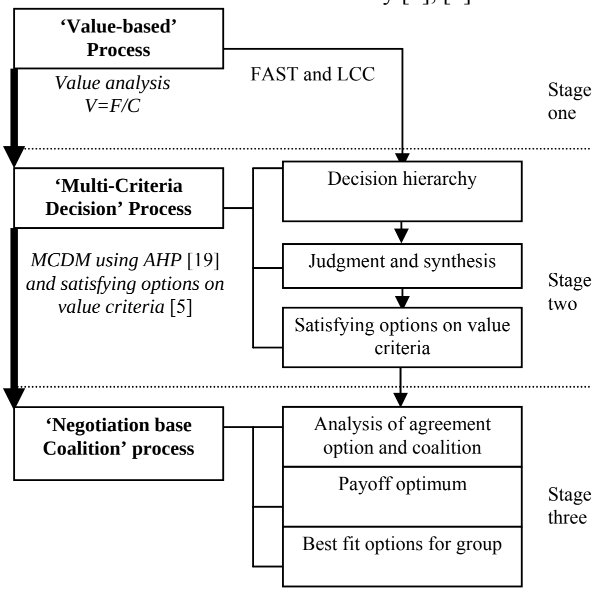

Fig.1 The methodology for automated negotiation on value-based decision

The selection of Support Bridge in this paper undergoes the following steps:

Stage 1: Determining the function and cost of each technical solution for Support Bridge.

Stage 2: Each decision maker sets the weight of each criterion (win condition). Using Analytical Hierarchy Process (AHP) [18], every decision maker evaluates and ranks the support bridge options based on his/her win conditions.

Stage 3: Identifying agreement options that reflect the combined preferences of all decision makers by coalition. Finally, determining the 'best fit' options for each coalition on first negotiation round.

IV. RESULT AND DISCUSSION

The selection criteria of value-based decision are taken from the basic theory of VA namely function and cost. Function will be determined by Function Analysis System Technique (FAST) and Cost will be calculated by the concept of Life Cycle Cost (LCC). The main reason for using FAST is the ontology of design, that every design of technical solution should have a function [8]-[11]. The functions will make the technical solutions worth considering, and proceed to become attributes of the decision. By following process presented on Fig. 1, the results are discussed as follow:

A. Stage One: Value-based

In this stage, function analysis and life cycle cost of the Support Bridge were determined as a basis for decision hierarchy and pair-wise comparison among technical solutions.

1) Function Analysis of the Support Bridge

Based on the FAST, the function of the Support Bridge can be identified. Fig. 2 shows the FAST diagram. Further, the identified function will become the attributes for decision (f1-f8). The FAST diagram reflect combination of the perception of engineer (support bridge design), the project manager (manage the construction) and the estate manager (manage the operation and maintenance).

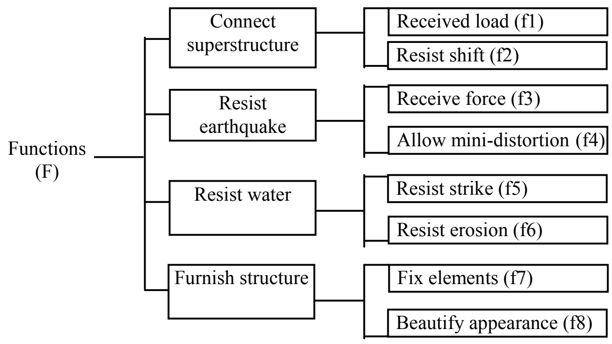

Fig. 2 FAST diagram for the support bridge

2) Life Cycle Cost of the Support Bridge

The costs of the Support Bridge were calculated; here the energy cost was not calculated because its cost is not involved in a Support Bridge. TABLE I presents LCC and initial cost (including investment cost). Equation (4) was used to calculate the O&M cost since these costs have annual basis and Equation (3) was used for replacement cost since this cost has variability in period.

TABLE I
COST OF THE SUPPORT BRIDGE

Cost category	Present Worth (1000USD)		
	a1	a2	a3
Initial	8102	5600	3720
LCC	40135	22625	55320

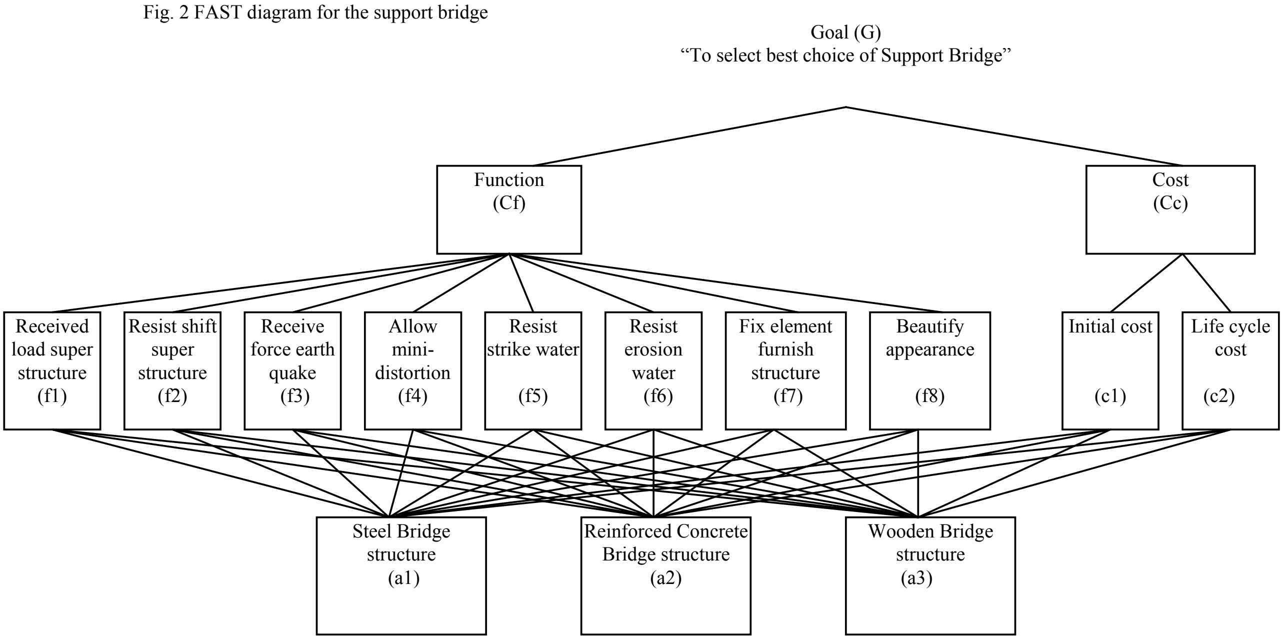

Fig.3 Decision hierarchy to select Support Bridge

TABLE II
WEIGHTING FACTOR OF EACH ALTERNATIVE TO EACH STAKEHOLDER

		Synthesis from AHP judgment and calculation on 3 Stakeholders										
		(f1)	(f2)	(f3)	(f4)	(f5)	(f6)	(f7)	(f8)	(c1)	(c2)	Weight
Stakeholder 1 (Estate Manager)	a1 (steel structure)	0.045	0.024	0.027	0.086	0.114	0.046	0.006	0.023	0.004	0.038	0.414
	a2 (reinforced concrete)	0.023	0.009	0.007	0.037	0.025	0.016	0.049	0.013	0.009	0.146	0.334
	a3 (wooden)	0.008	0.005	0.014	0.023	0.053	0.010	0.028	0.059	0.029	0.024	0.252
Stakeholder 2 (Project Manager)	a1 (steel structure)	0.020	0.016	0.013	0.021	0.003	0.011	0.008	0.026	0.093	0.021	0.232
	a2 (reinforced concrete)	0.012	0.006	0.005	0.012	0.015	0.035	0.040	0.021	0.410	0.080	0.634
	a3 (wooden)	0.004	0.004	0.006	0.006	0.002	0.005	0.021	0.023	0.053	0.011	0.134
Stakeholder 3 (Engineer)	a1 (steel structure)	0.046	0.031	0.034	0.051	0.030	0.065	0.012	0.045	0.002	0.020	0.335
	a2 (reinforced concrete)	0.027	0.014	0.008	0.025	0.005	0.030	0.079	0.023	0.010	0.096	0.317
	a3 (wooden)	0.008	0.009	0.013	0.013	0.010	0.020	0.044	0.217	0.004	0.012	0.349

B. Stage Two: Multi-Criteria Decision

Stage two consists of three steps which are decision hierarchy, judgment and synthesis and satisfying options on value criteria

1) Decision Hierarchy

Fig.3 shows four levels of the decision hierarchy. The goal (G) of the problem is "To select the best choice for Support Bridge". The goal is addressed by some alternatives (A = a1; a2; a3) which are steel bridge structure, reinforced bridge structure, and wooden bridge structure respectively. The problem is split into two value criteria namely Function (Cf) and Cost (Cc), which are divided further into respective sub-criteria f1, f2, f3, f4, f5, f6, f7, f8, and c1and c2.

2) Judgment and Synthesis

TABLE II presents the process to rank the Support Bridge options for each decision maker or stakeholder. Analytical Hierarchy Process (AHP) method [19] is used to determine the ranking. Decision before coalition revealed the result of weighting each alternative for each decision maker. The estate manager chose steel bridge as the best solution, meanwhile project manager chose reinforced concrete and engineer chose wooden as best solution for support bridge.

TABLE III
COST AND FUNCTION OF SUPPORT BRIDGE OPTIONS

	Cost				Function								Normalization	
	c1	c2	∑	Loss	f1	f2	f3	f4	f5	f6	f7	f8	Cost (Pr)	Function (Ps)
a1 (steel bridge)	0.10	0.18	0.28	0.91	0.60	0.62	0.57	0.59	0.59	0.64	0.08	0.24	0.57	0.49
a2 (reinforced concrete bridge)	0.21	0.70	0.91	0.28	0.30	0.24	0.14	0.25	0.13	0.23	0.59	0.14	0.18	0.25
a3 (wooden bridge)	0.69	0.11	0.80	0.40	0.10	0.14	0.29	0.16	0.28	0.14	0.33	0.62	0.25	0.26

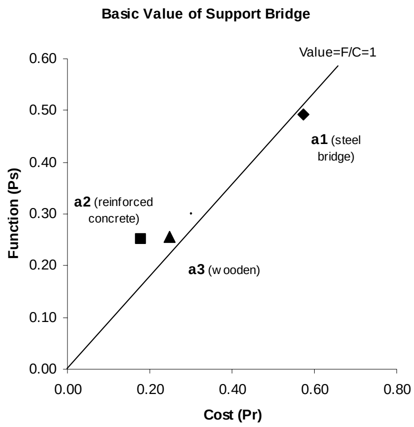

Fig.4 Basic value of Support Bridge options

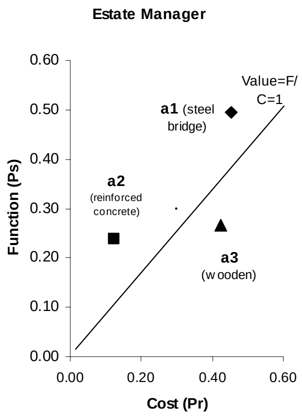

Fig.5 Value of Support Bridge options for estate manager

3) Satisfying Options on Value Criteria

In this paper, initial cost and LCC are identified as 'Cost' and all eight other functions which are 'received load', 'resist shift', 'receive forced', 'allow mini distortion', 'resist strike', 'resist erosion', 'fix elements', and 'beauty appearance' are identified as 'Function'. TABLE III shows the selectability (Ps) and rejectability (Pr) that represent function and cost of support bridge solutions. An option will be a rejectability options if the value of the options is below F/C=1 or the cost is higher than the function. In other word it can be said that there is unnecessary cost in the technical solution option.

Fig.4 provides a cross plot of function of the technical solution options. The figure is based on the result from TABLE III. Observe that although a1 has the highest function, it also has the high cost which resulted in its value below F/C=1. In this case, the highest value is a2 since it gives the highest satisfaction due to its low function and low cost

Fig. 5 provides cross plots of function and cost of the estate manager. Observe the influence of the estate manager's preference on a1.Basically that a1 is a rejected option since it has a value less than F/C=1. The estate manager's preference changes it to a value more than F/C=1, which made it to fall into selectability options.

C. Stage Three: Negotiation base Coalition

Three steps are conducted for this stage which are analyze agreement options and coalition, determine payoff optimum, and determine the best options for group stakeholders.

1) Agreement Options and Coalition

Identification of agreement options acts as second-level filter of the technical solution selection process. The first is the screening of technical solution products, which is usually based on the limits applied on the search criteria, while the second filter is based on stakeholders' preference. This second filter on the alternative technical solution products limits the tedious work for trade-off analysis, however, it should be noted that the set of agreement option changes as the negotiation progresses.

Agreement options are determined by identifying the potential stakeholders sub-group (estate management, project managements' client, and design management), followed by determining the optimal solution for each sub-group. First is determining the weighting factor (weight of preferences) of each criterion for each stakeholder and the aggregation. Based on the pair wise comparison of each criterion, Fig.6 reveals the different preferences among the three stakeholders.

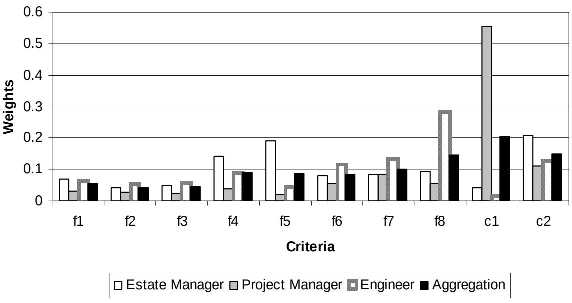

Fig. 6 Weight of preferences for each stakeholder

Second is grading alternative for each evaluation criteria. Fig.7 shows that a1 is the 'best fit' for f1, f2, f3, f4, f5, and f6. The 'best fit' solution for c1 and f8 is a3, and a2 for c2 and f7.

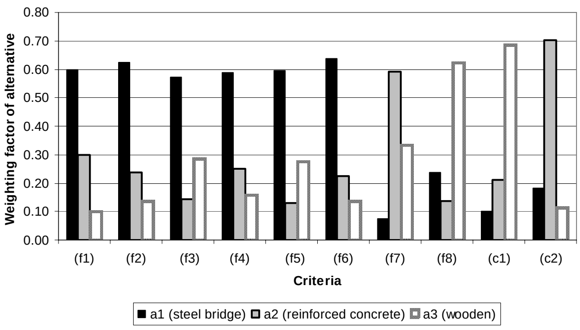

Fig.7 Weighting factor of every alternative for each criteria

Third is scoring every alternative for every stakeholder. TABLE II shows that each stakeholder has different best option as the solution alternative.

2) Determining payoff optimum

The determination of the optimal solution for each stakeholder in a coalition is based on a cooperative multi-person games with complete information in which coalition-formation among sub-group members are allowed [3], [4]. In the context of Game Theory, the formation of coalitions among subsets of negotiating entities (stakeholders) provides a means for achieving Pareto optimality, since every member in a coalition acts in such a way to benefit the entire coalition.

The payoff optimum for every stakeholder and every alternative on each coalition was determined tabulated on TABLE IV for Cost and Function respectively.

TABLE IV
PAYOFF OPTIMUM FOR EACH COALITION

COST						
Coalition		Alternatives			Payoff Optimum	
SH1+2+3		a1	a2	a3	Max-min	Optimum
	SH1	0.455	0.123	0.422	0.331	0.455
	SH2	0.443	0.064	0.493	0.429	0.461
	SH3	0.450	0.072	0.477	0.405	0.477
		1.348	0.260	1.393		
SH1+2		a1	a2	a3	Max-min	Optimum
	SH1	0.455	0.123	0.422	0.331	0.455
	SH2	0.443	0.064	0.493	0.429	0.461
		0.897	0.188	0.915		
SH1+3		a1	a2	a3	Max-min	Optimum
	SH1	0.455	0.123	0.422	0.331	0.455
	SH3	0.450	0.072	0.477	0.405	0.450
		0.905	0.195	0.900		
SH2+3		a1	a2	a3	Max-min	Optimum
	SH2	0.443	0.064	0.493	0.429	0.493
	SH3	0.450	0.072	0.477	0.405	0.477
		0.893	0.136	0.970		
FUNCTION						
Coalition		Alternatives			Payoff Optimum	
SH1+2+3		a1	a2	a3	Max-min	Optimum
	SH1	0.495	0.239	0.267	0.256	0.388
	SH2	0.352	0.436	0.212	0.224	0.436
	SH3	0.366	0.246	0.389	0.143	0.389
		1.212	0.920	0.867		
SH1+2		a1	a2	a3	Max-min	Optimum
	SH1	0.495	0.239	0.267	0.256	0.411
	SH2	0.352	0.436	0.212	0.224	0.436
		0.847	0.674	0.479		
SH1+3		a1	a2	a3	Max-min	Optimum
	SH1	0.495	0.239	0.267	0.256	0.471
	SH3	0.366	0.246	0.389	0.143	0.389
		0.860	0.484	0.655		
SH2+3		a1	a2	a3	Max-min	Optimum
	SH2	0.352	0.436	0.212	0.224	0.436
	SH3	0.366	0.246	0.389	0.143	0.282
		0.718	0.681	0.601		

The payoff optimum in both tables refers to each stakeholder in each coalition. The value of (max-min) payoff for a stakeholder is used to determine the payoff optimum by applying the coordinating scenario. This means that no one stakeholder has higher importance than others. This scenario can be changed depending on the situation of a project.

3) Analyzing the best fit options

On this research the process is applied to both value criteria namely function and cost. There are two categorize of best options which are best for function and best for cost. Based on the two categorize, a best option for all stakeholders can be determined by value equation which is function/cost. For both value criteria, the best selectability option is the one with the least negative value. However, if two alternatives have the same negative value, then the one with higher positive value of is better. The rationale is that if the negative value is close to zero, then most stakeholders earn a payoff close to their Pareto optimum. A high negative value means that some stakeholders earn higher than their Pareto optimum.

In the context of negotiation during the selection process for a technical solution of building system, the negative value of the grand coalition represents the amount of risk associated with the corresponding alternative building system. The results from the process and calculation for the best-fit solution of each coalition in the first round of negotiation are presented in Tables V.

TABLE V
RANKING OF SUPPORT BRIDGE OPTIONS FOR EVERY COALITION

Alternative ranking and coalition	Priorities		
	a1	a2	a3
SH 1 (Estate Manager)	1st	2nd	3rd
SH 2 (Project Manager)	2nd	1st	3rd
SH 3 (Engineer)	2nd	3rd	1st
Aggregation	2nd	1st	3rd
Coalition SH1 and SH2	2nd	3rd	1st
Coalition SH1 and SH3	2nd	1st	3rd
Coalition SH2 and SH3	1st	2nd	3rd
Grand coalition	1sd	2nd	3rd
RESULT	1st	2nd	3rd

Firstly, individually all stakeholders have their own best solution. Finally, as shown on TABLE V, steel structure (a1) is found to be the 'best fit' solution for all stakeholders after coalition. The best solution based on aggregation is different with the best solution after coalition formation. This finding is supported by the result in Fig.7. This figure shows that a1 have the highest weighting factor on the six criteria from the ten criteria. As the 'best fit' solution, a1 is contrary to the best option selected by the project manager, who chose a2 and engineer who chose a3. On the process of trade off in the next negotiation round, the project manager and engineer can propose a new preference if he or she did not accept a1 as the best option.

V. CONCLUSION

A 'Value' in Function/Cost is the basis for the methodology presented on this paper. On the value-based process, function and life cycle cost are analyzed. On multi-criteria decision-making, a satisfying option is used by correlating the function and cost to get the value of a technical solution option. Value in term of Function/Cost is the only criterion for the support bridge selection. On agent-based negotiation process, the payoff optimum and best fit options are based on the criterion of value, which are function and cost.

ACKNOWLEDGMENT

The writers would like to thanks Universiti Teknologi Petronas for supporting this research. The writers is also indebted to group managers from Ciputra Surya Tbk responding to the questionnaire of the decision by AHP in which the project was based.

REFERENCES

[1] J. Kelly and S. Male, *Value Management in Design and Construction: The Economic Management of Projects*, London: Spon Press, 1993.
[2] G. Lin and Q. Shen, "Measuring the performance of value management studies in construction: critical review," *Journal of Management in Engineering* vol. 23, no. 1, pp. 2-9, 2007.
[3] S. Kraus, *Strategic Negotiation in Multi-agent Environment*, MA: MIT Press, 2001.
[4] T. Wanyama, and B.H. Far, "A protocol for multi-agent negotiation in a group-choice decision-making," *Journal of Network and Computer Applications,* vol. 30, pp.1173-1195, 2007.
[5] W.C. Stirling, *Satisfying Games and Decision Making with Applications to Engineering and Computer Science*. Cambridge: Cambridge University Press, 2003.
[6] L. D. Miles, *Techniques of Value Analysis and Engineering*, 3rd ed. NY: Eleanor Miles Walker, 1989.
[7] K. Yang, *Voice of Customer, Capture and Analysis*. NY: McGraw Hill Proffesional, 2007.
[8] Kitamura, Y. and Mizoguchi, R, "An ontology of functional concept of artefacts". *AI-TR*, no.1, 1999.
[9] J.J. Kaufman, *Value Management: Creating Competitive Advantage*. Kent: Financial World Publishing, 2001.
[10] R. Woodhead, "Concepts of value in value management: the relationship between function and value". *Value World* summer, SAVE International, 2007.
[11] C.W. Bytheway, *FAST Creativity and Innovation: Rapidly Improving Processes, Product Development and Solving Complex Problems*. Florida: J.Ross Publishing, 2007.
[12] J.J. Kaufman and R. Woodhead, *Stimulating Innovation in Products and Services with Function Analysis Mapping*, New Jersey: John Wiley&Sons. 2006.
[13] S.J. Kirk and A. Dell'Isola, *Life Cycle Costing for Design Professionals*, 2nd ed. New York: McGraw-Hill, 1995.
[14] P. Barringer, "A life cycle cost summary". *The International conference of Maintenance Societies*. Maintenance Engineering Society of Australia, Perth, 20-23 May, 2003.
[15] J.W. Bull, *Life Cycle Cost for Construction*, London: Blackie Academic & Professional, 1993.
[16] H. Liu, V. Gopalkrishnan, K.T.N Quynh, W-K. Ng "Regression models for estimating product life cycle cost". *Journal of Intelligent Manufacturing*. Springer Science+Business Media. DOI 10.1007/s10845-008-0114-4, 2008.
[17] C. Utomo, A. Idrus, M. Napiah and M.F. Khamidi, "Agreement options and coalition formation on value-based decision". *Symposium on Computational Intelligence in Multi criteria Decision-Making.* IEEE Society Nashville, TN, March 30 – April 2, 2009, pp.118-125.
[18] ASTM, *ASTM Standards on Building Economics*, 5th edition. ASTM International, 2004.
[19] T.L. Saaty, "Decision making – the analytical hierarchy process and network process (AHP/ANP)", *Journal of System Science and System Engineering*, vol.13, no.1, pp.1-34, 2004.

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