Value-based Design Decision on Building System Selection

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Abstract—This paper presents a decision model for technical solution options on building system selection. There are many studies on design decision making using multicriteria, such as in assessment of exterior building wall system; selection of steel structure; structural alternatives of prefabricated concrete and metal clad; and roof system selection. The characteristic of value criteria has not been widely used to previous research. Existing models that are commonly accepted are optimization-based models, for example aggregation methods, but these are not able to solve the problem of value criteria on design decision. The model is based on a satisficing function/cost preferences. It is multi-attribute, and the environment is in a Value Management (VM) process. Since "value" is the main single objectives for the decision model of VM, the attributes for this decision model therefore is function and cost. This also provides the method to construct the Life Cycle Cost (LCC) analysis for the cost attributes and the Function Analysis System Technique (FAST) for the function attributes. This research applies the satisficing game method where function and cost of solution techniques for a building system is formulated and the reduction of the technical solutions based on function/cost preferences can be made. Therefore solving the problem on computerizing the creativity of human/decision participant helps to elaborate on every possibility of the technical solutions and reduce them before choosing the best solution. Keywords— design decision; value; cost; function; building system.

1. Introduction

Value has been affected by the evolution of its own techniques. The evolution can be traced from typical definitions of three value terms in literature to provide a good understanding. They are value analysis (VA), value engineering (VE), and value management (VM) [1]. Miles [2] started with VA as a philosophy implemented by the use of a specific set of techniques, a body of knowledge, and a group of learned skill. It has a purpose to identify unnecessary cost. Zimmerman and Hart [3] defined VE as "a systematized approach to seek out the best functional balance between the cost, reliability, and performance or a product or project". Kelly and Male [1] described VM as "a structured, organized team approach to identifying the function of a project, product, or service with recognized techniques and provide the necessary functions to meet the required performance at the lowest overall cost". VM is a methodology, whereas VE and VA describe the application of this methodology. Value criteria describe the efforts to establish performance standards and approach for governing the effective application of the value disciplines. VM evolved from the traditional paradigm of VA and VE [4]. VM is used to resolve soft, dynamic and multifaceted problems on strategic level. Liu [5] illustrated the VA and VE as subsets of the total VM figure. In design and construction process, the scope of VM covers all phases of construction from inception to operation, VE scope covers design and construction phase while VA scope covers the construction/operation phase. How to applied concept of value on design decision in term of building system selection is the objective of this research presented in this paper.

2. Conceptual

Decision making in general, and engineering decision making, in particular, often involve the balancing of multiple, potentially conflicting requirements [6]. The performance attributes of the chosen solution meet some functional requirements in an engineering design. Decision making of all kinds involves the choice of one or more alternatives from a list of options. The list of options would normally be more or less acceptable solutions for the problem at hand and consequences, both good and bad, flow from the exercise of choice. Design in engineering crosses all the disciplinary domains. A building system design theory can consist of theories of function, proportion, etc.

Design decision is one of the decision making processes with multiple criteria that rank a number of alternatives, each of which is ranked separately by several ranking of criteria. This problem of multiple criteria is different with social choice problems. The difference makes decision with multiple criteria has deep implications for the applicability of the theorem to design decision making. Viewing design as a decision making process recognizes the substantial role that decision theory can play in design [7]. The definition does not clearly indicate the relation between decision making and design. Tate [8] stated that 'in design, decision making is most important. This is because designer must make many types of decisions, the development of a set of suitable requirements'. Many researchers supported Tate argument and suggested the role of decision making in engineering design. Li [8] derived from Hazelrigg, noted that decision making is the core of all design activities. It starts at problem definition stage by deciding the customer/client's requirements, and defining constraint and targets and at alternative generation phase by exploring design space and selecting concept [9].

3. Value-Based Process

3.1 Background

As one of the most important system in a building, wall system selection can be part of the building design. The selection process is difficult because of the large number of factors, many of which are unrelated or conflicting with one another, and the lack of key data (such as realistic design service life). Like in high-rise building column selection, a computer integrated knowledge based system would also greatly benefit to wall system selection process. Building system decomposes a building project into a collection of systems and system components.

3.2 Function Analysis of Wall System

The function of building wall system can be identified using the function analysis system technique (FAST). Fig. 1 shows the FAST diagram. There are eight functions identified on the wall system which are structural stability; exclusion of rain and water; thermal properties; acoustics properties; protection to occupant's asset; fire safety; satisfy and user convenience; image and aesthetic. The main reason for using FAST is the ontology of design, that every design of technical solution should have a function [10]. The functions will make the technical solutions worth considering, and proceed to become attributes of the decision.

3.3 Life Cycle Cost of Wall System

Cost drivers of the wall system which are initial cost and operation maintenance cost are identified. Operation and maintenance (O&M) costs have annual basis, Table I presents the cost of the wall system for each technical solution which are a1 (reinforced brick wall), a2 (Precast wall concrete), a3 (Metal frame wall), a4 (Timber wall panel), and a5 (Glass wall). The cost drivers namely c1 (initial cost) and c2 (operation and maintenance cost) become evaluation criteria in the selection of wall system solution.

3.4Wall System Selection

In order to obtain a good representation of the problem, it has to be structured into different components called activities. Fig. 2 shows that the goal of the problem (G ="To select wall system") is addressed by some alternatives (A = a1; a2; a3, a4, a5) which are metal frame wall, precast wall concrete, glass wall, timber wall panel, and reinforced brick wall respectively. The problem is split into value criteria namely function and cost and sub problem (f1, f2, f3, f4, f5, f6, f7, f8, c1, c2) which are the evaluation criteria. In this paper, initial cost and O&M cost are identified as 'Cost' and the other eight functions are identified as 'Function'.

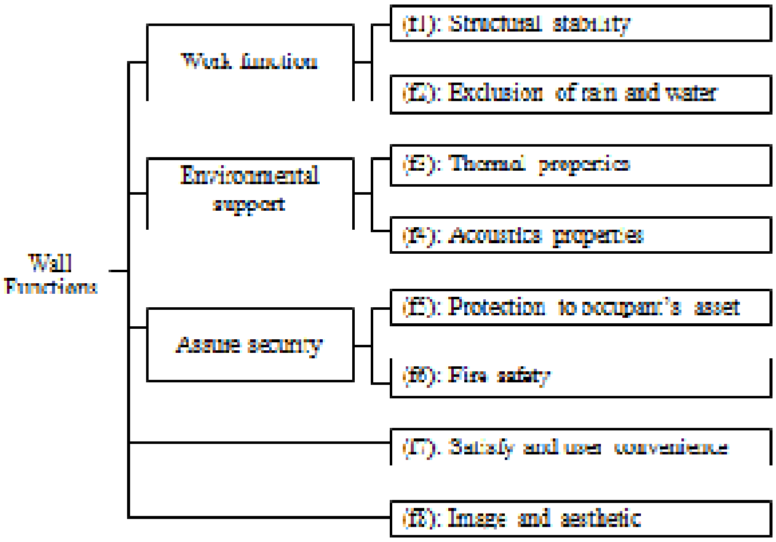

Figure 1. FAST diagram of the building wall system

Table 1. LCC OF Wall Building System

Cost category	Present Worth (1000USD)				
	a1	a2	a3	a4	a5
(c1) Initial	250	1600	800	1600	1200
(c2) Operation & maintenance	800	200	400	2000	800

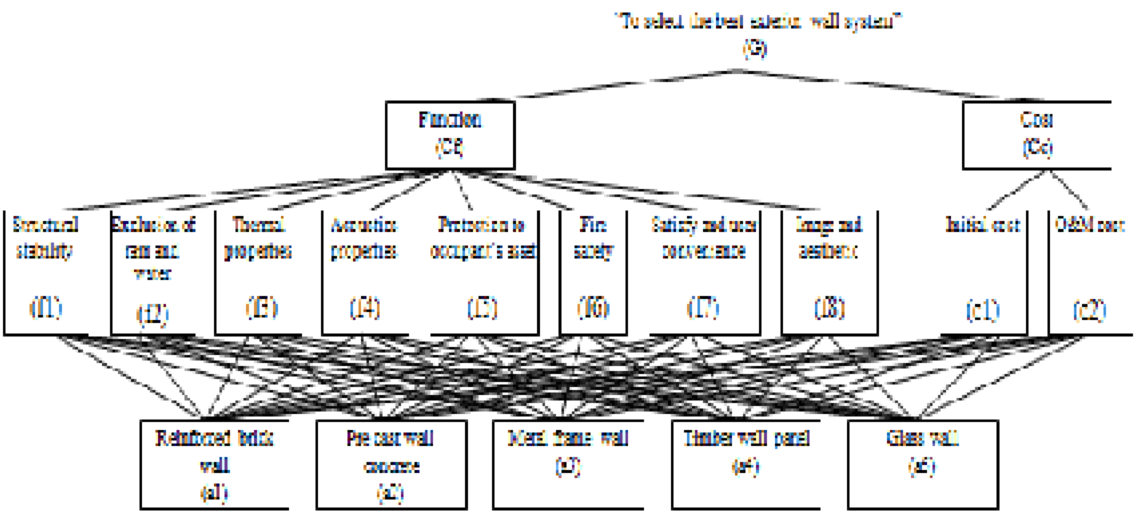

Figure 2. Decision hierarchy to select the best wall system

Table 2. Judgment Synthesis for Each Alternative Solution

Alternative solutions	Aggregation										Weight
	f1	f2	f3	f4	f5	f6	f7	f8	c1	c2	
	0.079	0.078	0.053	0.034	0.087	0.141	0.095	0.101	0.218	0.116	
a1	0.005	0.008	0.022	0.015	0.020	0.058	0.024	0.020	0.121	0.018	0.3107
a2	0.005	0.010	0.016	0.010	0.040	0.044	0.006	0.014	0.011	0.056	0.2130
a3	0.010	0.019	0.007	0.005	0.014	0.023	0.007	0.007	0.057	0.026	0.1767

a4	0.020	0.003	0.006	0.002	0.008	0.004	0.038	0.004	0.008	0.004	0.0963
a5	0.038	0.037	0.002	0.003	0.004	0.012	0.019	0.055	0.021	0.011	0.2033

Table 3. Satisficing For Cost and Function

Alternative solutions	Cost		Function								Normalization	
	c1	c2	f1	f2	f3	f4	f5	f6	f7	f8	Cost (Pr)	Function (Ps)
a1	0.554	0.158	0.058	0.103	0.411	0.437	0.234	0.412	0.255	0.202	0.037	0.264
a2	0.051	0.486	0.069	0.132	0.311	0.288	0.463	0.310	0.059	0.140	0.128	0.222
a3	0.261	0.227	0.132	0.249	0.133	0.139	0.163	0.164	0.079	0.074	0.154	0.142
a4	0.037	0.034	0.253	0.037	0.105	0.056	0.091	0.030	0.402	0.037	0.372	0.126
a5	0.096	0.096	0.487	0.480	0.040	0.080	0.048	0.085	0.205	0.547	0.309	0.247

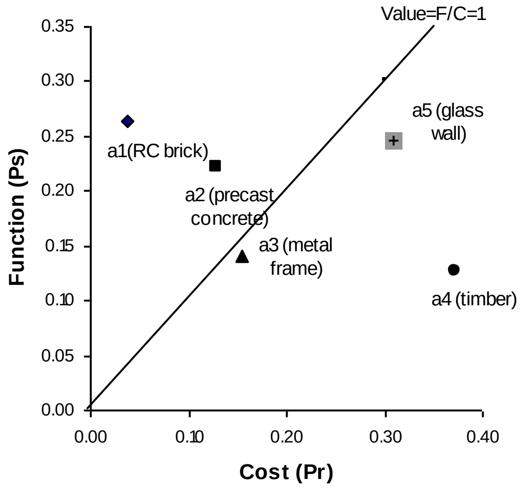

Figure 3. Basic value of wall system options

In this case the highest value is a1. It gives the highest satisfaction since it has high function and low. Based on the result presented on Table II and Table III provides a cross plot of function of the technical solution options (Fig.3).

4. Conclusion

The result indicated that higher value can be achieved without necessarily incurring higher costs. The value-based can help designer achieve a balanced overall strategy and a balance between short-term and long-term performance goals of the building system design. The future research should review the criteria used to measure and evaluate performance, as excessive emphasis on short-term financial performance may limit the effectiveness of value-based design decision.

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