THE STUDY OF MULI-LEVEL PERFORMANCE MEASUREMENT APPROACH FOR VALUE MANAGEMENT OF CIVIL INFRASTRUCTURE PROJECTS

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ABSTRACT: Best value in value engineering has relation to cost and performance. But a severe problem in VE study of a project is to reduce value due to loss of performance, caused by focusing on cost reduction. Also a lack of understanding performance concept, no trial VE workshop as well as cost saving-based policy have not satisfied customer needs. A efficient and practical methodology for accomplishing best value in construction projects is proposed. This study developed a more objective approach for performance measurement approach of mega projects and suggested a systematic process of performance quantitative analysis verifying value improvement. The proposed performance measurement method would be very useful for better communication and consensus between stakeholders and VE team especially through value engineering.

Keywords: VE, Best Value, Value Management, Performance Evaluation

1. INTRODUCTION

A variety of bidding processes are being used for efficient implementation of construction projects. As part of an effort to improve performance of structures and reduce costs, this is in line with the objectives of design VE which focuses on increasing customer satisfaction and enhance value. The Ministry of Land, Transport and Maritime Affairs(MLTMA) requires that any construction project that is worth 10 billion won or more be subject to an economic feasibility study for its design. To this end, the Ministry recently set up a standard bidding process and related evaluation criteria[7], which will allow more efficient implementation of VE.

Talks of best value design are getting around among the local media, which places an emphasis on both the performance and the costs of structures, as the system where the bidder who offers the lowest price wins the contract proliferates nationwide.

Despite such a trend, too much focus of the client and the VE team on performance in large scale projects often leads to excessive pursuit of cost reduction, resulting in unduly selection of an alternative that does not meet performance requirements. This is largely caused by factors like lack in understanding of VE measurement and analysis, non-implementation of VE workshop and cost reducing efforts focusing too much on performance and, as a result, brings down customer satisfaction. Repetition of such practices will likely lead to failure to make the best of VE activity and counter its further development.

The purpose of this study is to show the significance of the performance evaluation for large scale projects and the process of quantifying value improvement using it in order to achieve efficient design VE implemented as part of large scale state-led initiatives. The multi-level performance measurement method proposes in this study is expected to play a crucial role in coordinating the interests of different stakeholders including clients of large scale projects and VE team members, reaching agreements and achieve the best value.

2. LLC, PERFORMANCE AND BEST VALUE IN DESIGN VE

Design VE refers to a technique to help improve the value of the subject to be analyzed by providing means required to meet the performance of structures on minimum Life Cycle Cost(LCC) and distinguishing and evaluating the means so that an alternative to improve the value of the structures can be found. The value can be represented as a correlation between the performance made by the means and the costs required for it as shown in Equation (1) [5].

$$V = \frac{P}{C} \qquad \text{Equation (1)}$$

Where P is performance, C is cost, meaning Agency Life Cycle Costs to be borne by the manager. The costs are measured objectively through performance quantification and cost evaluation at the state of qualitative and quantitative VE implementation. A quantitative evaluation need to be made for the performance in times of VE implementation so that one can determine how much the value has increased in relation to the original plan. To this end, objective standards for performance measurement and justification for it must be secure. While the LLC, which is estimated by the manager, can be calculated accurately if objective data are provided as it consists of numbers, performance is mostly determined by a subjective judgment. This causes a situation where no serious considerations are made to more objective approaches to design VE, only implementing it for the purpose of cost reduction. Such an attitude often makes it more difficult to perform appropriate evaluation for large scale projects like infrastructure. The section to follow will propose a multi-level performance measurement approach which can help ensure rational valuation for design VE by improving the existing methods.

3. MULTI-LEVEL PERFORMANCE MEASUREMENT APPROACH

3.1 Methodology Information

Caltrans introduces a method to measure quantitatively the performance of design VE for construction projects for the first time[3]. The method is based on the value metrics developed by Robert Stewart[2]. Existing methods like the Stewart's identifies 7 to 9 areas to evaluate and determine weights and grades for them. But the 7 to 9 evaluation areas for large scale projects like infrastructure have a risk of failing to evaluate the overall performance of the project including project characteristics and resulting in losing objectivity in the evaluation. For example, when performance attributes(PA) is defined as constructability, the category of constructability includes a variety of criteria to evaluate performance reflecting project characteristics. Though specific performance attributes including rationality and negotiation easiness in regard to the construction plan, construction period and structure installation plan are incorporated in the criteria, individual grading cannot be performed.

Table 1. Example of using the multi-level performance measurement method

Entire project				Sub-projects for each component			
Step 1 (Category)		Step 2 (Element)		Sub-project 1		Sub-proejct 2	
Attribute	Weight	Attribute	Weight	Significance	Weights	Significance	Weights
P-01	(A1)	p-1.1	(B1)	(C1)	(D1)	(E1)	(F1)
		p-1.2	(B2)	(C2)	(D2)	(E2)	(F2)
		p-1.3	(B3)	(C3)	(D3)	(E3)	(F3)
:	:	:	:	:	:	:	:
Significance	0= No effect / 1= not Important / 2= Not much Important / 3= Important / 4= A bit Important / 5= Very Important						

The existing method used by WS DOT[8] and the Deaprtment of Transportation of California[1], which considers only one factor, constructability, poses serious threat to the accuracy and communication failure among stakeholders. Existing methods like that not only fails to incorporate project characteristics but also causes over- or underestimate performance, resulting in less objectivity and ultimately less reliability about VE. All these combine to call for a need to quantify performance by defining more detailed measurement criteria for infrastructure which requires a wide scale of evaluation.

The Multi-Level Performance Measurement Approach proposed in this paper, as shown in Figure 1, allows rational measurement of performance by defining 7 to 9 attributes as categories (P-N), which are in turn classified into 20 to 30 elements(p-n) so that grading of the individual attributes can be performed, depending on the project. It can also a tool to carry out measurement for project components such as process, structures and tools as well as the project as a whole. The project components can be defined according to the project characteristics.For a large scale project, section can be used while for a unit project, fields or structures can be used.

Such categorized measurement of a project is out of the client or user's need not only to calculate the value of the project as a whole but also to reflect the performance and costs associated with it in the valuation. Since performance attributes of the whole project can be different from those of its components, derivation of the components' attributes from the categorized attributes can be used for the evaluation of the components.

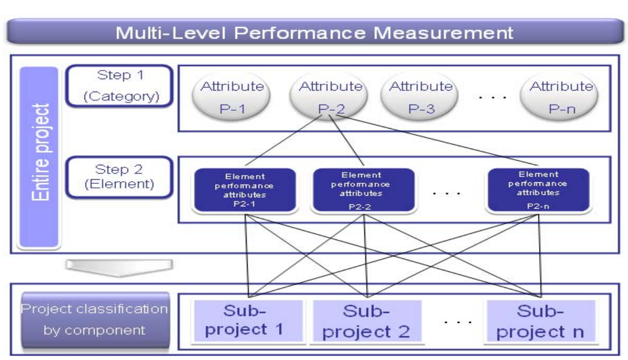


Figure 1. Multi-Level Performance Measurement Approach

Figure 1 shows the improved multi-level performance measurement method. The individual measurement criteria will calculate individual weights through a series of process. The most commonly used calculation is the Simple Paired Comparison Matrix. Calculation of the weights for this paper's new measurement approach will use the matrix to produce the results in two stages, and the weights for the elements of the components of the project will be calculated as shown in Table 1 according the significance proposed in this study. As shown in Figure 1, the weights for the sub-projects will be calculated using Equation 2 considering the significance of individual attributes in the segment in relation to the weights for the categories. In this way, performance attributes that reflect the characteristics of the sub-projects and their weights can be derived.

$$D_j = A_i \times C_j / \sum_{j=1}^{n} C_j \qquad \text{Equation(2)}$$

Where, D_j: Element attribute weights

A_i: Attribute weights of the category which the element attribute belongs to

C_j: The significance of the category attribute to the family attribute

n: The number of element attributes in the category which it belongs to

3.2 Process of measuring the multi-level performance

Communication and discussion among the design VE team members is critical in deciding the criteria for the multi-level performance measurement. To this end, understanding of constrains, requirements from stakeholders and required structure performance through pre-inspection in preparation step is required to produce a quality model, as shown in Figure 2.

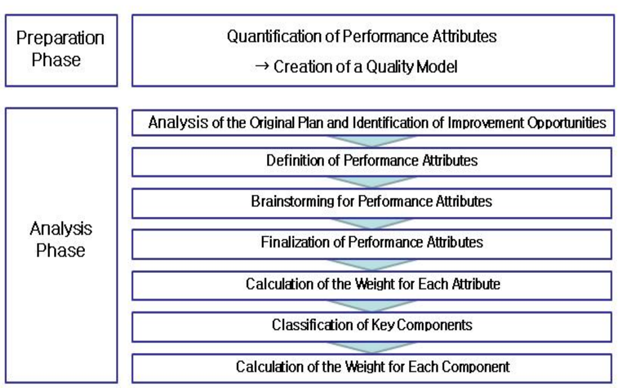


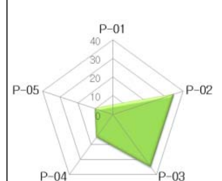
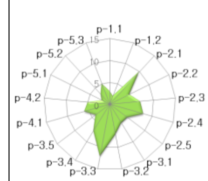
Figure 2. Process of measuring the multi-level performance

In the stage of VE Workshop, individual and group brainstorming will be used to defining performance attributes and the relationship among them based on the findings from the pre-inspection. The number of attributes for categories and elements will be recommended at 7 to 9 and 20 to 30 respectively. Weights for individual performance attributes will be calculated as described in 3.1 and applied according to the characteristics of the components.

3.3 Comparative evaluation of improved criteria for performance measurement

So far the process of applying the criteria for the multi-level performance measuring approach and the method of calculating the weights have been described. Table 2 summaries the differences between the criteria for the multi-level approach and the existing ones.

Table 2. Comparison between the criteria for existing approaches and that for the multi-level approach

	Existing approaches	Multi-level approach
Number of PA	7~9	20~30
Criteria for quantification of performance measurement	Subjects	Individual components
Accuracy	Overestimation	Rational
Communication among project participants	Good	Good + exchange of opinions
Satisfaction of participants	Moderate	High
Implementation of measurement	Difficulty in quantitative measuring Low Understanding	Quantitative measuring Increased understanding
Measurement diagram (example)		

Compared to the existing measurement approach which used with ambiguous and multi-meaning expressions and little objectivity, the multi-level approach visulize the dependency among attributes and defines segment measurement attributes, resulting in higher understanding of the attributes and better communication among participants. In addition, stages in the attributes allow derivation of attributes that can be measured quantified for more objectivity in the performance measurement.

4. EXAMPLE

As an example, this study will perform a design VE review for a railway project using the multi-level approach.

4.1 About the project

The project costs 6.1370 trillion won and covers 233.19km. VE workshop was performed on the vertical alignment for 4 days starting October 4, 2007. The workshop was conducted using Caltrans's VE process as shown in Table 3.

The process consists of 8 stages as shown in Table 3 and involves a workshop. The criteria proposed in this study incorporated project constraints and various interests of stakeholders to define the scope of the attributes and rationalize evaluation areas.

4.2 Setup of measurement criteria

The measurement criteria consist of 8 categories in 2 stages. Under each of the categories lie 29 elements classified according to the characteristics of the project as shown in Table 4.

Table 4. Performance attributes in Level 1 and 2 for the railroad project

Level-1	Level-2
Railroad Operation efficiency	Efficiency of the wiring in stations*
	Energy efficiency
	Train operation on the main track
	Efficiency in the entry and exit points of stations*
	Connectivity with existing lines*
Safety	Response to disasters during construction
	Response to disasters during operation
	Track safety
Constructability	Appropriateness of construction period
	Appropriateness of civil work plan
	Minimizing civil complaints during construction
	constructability within the site
	Accessibility to the site
	Constructability in proximity to operation lines
	Appropriateness of construction methods
Operational environment	Minimal civil complaints during operation
	Lease segregation in the regions
	Lease vibration and noise during operation
Maintenance	Location of service workshops *
	Easiness of maintenance for facilities
	Accessibility for maintenance serive providers
User convenience	Convenience for users*
	Commercial speed
	Ride
View/landscaping	Harmony with the landscape
	Accommodation of future urbanization
	Local symbolic factors
Consistency with superior plans	Consistency with a land use plan
	Consistency with urban plans

* : To be applied for individual sections

The 8 categories in Level 1 include railroad operation efficiency, safety, constructability, operation environment, maintenance, user convenience, view/landscaping, and consistency with the superior plans. The criteria for individual section measurement are defined based on the criteria for the entire project to include the existence of platform, repair station or connection with the existing line in a section . As shown in Table 5 the weights for the selected measurement criteria are calculated using the Simple Paired Comparison Matrix which provides a balanced approach for comparison for the attributes in Level 1 and 2. The weights calculated are then used to derive the weights for the criteria for element attributes according to the impact on each section.

Calculation results reveal that user convenience, which is the most important requirement for user satisfaction in regard to facility utilization, has the largest share. Consistency with superior plans is found to be the least significant. The weights for the measurement criteria for the categories are distributed according to the significance of each element criteria and then used to determine the weights for the measurement criteria for the element attributes as shown in Table 6.

4.3 Performance measurement

After the criteria for performance measurement and their weights are defined 20 alternatives were identified through brainstorming and evaluation and development of the ideas. As a result of application of those alternatives, there has been 6.1% of improvement in relative to the original plan.

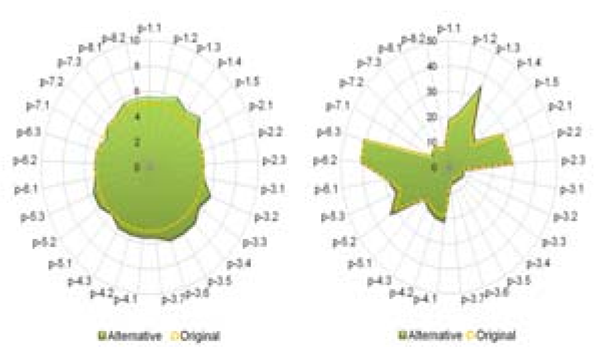


Figure 3. Result of performance measurement for individual areas

Table 5. Calculation of weights to determine the significance of the attributes in Level 1

Performance attribute matrix												
Criteria		A	B	C	D	E	F	G	H	Total	Weights	Finalized weights
A	Railroad operation efficiency		a	a	a	a	f	a	a	7	19.4	19
B	Safety			b	b	b	f	b	b	6	16.7	17
C	constructability				d	e	f	c	c	3	8.3	8
D	Operational environment					e	f	d	d	4	11.1	11
E	Maintenance						f	e	e	5	13.9	14
F	User convenience							f	f	8	22.2	22
G	View/landscaping								g	2	5.6	6
H	Consistency with superior plans									1	2.8	3
Total										36	100.0	100

Finalized weights for measurement areas

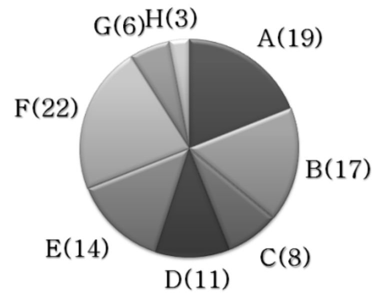


Table 6. Calculation of weights for performance measurement criteria

Category criteria	Element criteria	Weights: category	Element	Section 1 I	Section 1 W	Section 2 I	Section 2 W	Section 3 I	Section 3 W	Section 4 I	Section 4 W	Section 5 I	Section 5 W	Section 6 I	Section 6 W
Railroad operation efficiency	Efficiency of the wiring in stations	19	3.4	3	3.8	-	-	4	3.8	5	4.5	5	4.3	3	3.8
	Energy efficiency		3.9	4	5.1	1	3.8	4	3.8	4	3.6	4	3.5	3	3.8
	Train operation on the main track		5.8	4	5.1	4	15.2	4	3.8	4	3.6	4	3.5	3	3.8
	Efficiency in the entry and exit points of stations		3.3	4	5.1	-	-	4	3.8	4	3.6	4	3.5	3	3.8
	Connectivity with existing lines		2.6	-	-	-	-	4	3.8	4	3.6	5	4.3	3	3.8
Safety	Response to disasters during construction	17	5.6	3	5.7	3	5.1	4	5.7	3	5.7	3	5.7	3	5.7
	Response to disasters during operation		5.6	3	5.7	3	5.1	4	5.7	3	5.7	3	5.7	3	5.7
	Track safety		5.9	3	5.7	4	6.8	4	5.7	3	5.7	3	5.7	3	5.7
constructability	Appropriateness of construction period	8	1.2	4	1.4	4	1.5	3	1.0	3	1.0	3	1.0	4	1.3
	Appropriateness of civil work plan		1.2	4	1.4	4	1.5	3	1.0	3	1.0	3	1.0	4	1.3
	Minimizing civil complaints during construction		1.3	4	1.4	4	1.5	3	1.0	4	1.4	4	1.4	3	1.0
	constructability within the site		1.0	3	1.0	3	1.1	3	1.0	3	1.0	3	1.0	3	1.0
	Accessibility to the site		1.0	3	1.0	3	1.1	3	1.0	3	1.0	3	1.0	3	1.0
	constructability in proximity to operation lines		1.0	1	0.3	1	0.4	4	1.4	4	1.4	4	1.4	4	1.3
	Appropriateness of construction methods		1.2	4	1.4	3	1.1	4	1.4	3	1.0	3	1.0	4	1.3
Operational environment	Minimal civil complaints during operation	11	3.9	4	3.7	4	4.0	4	4.4	3	3.7	4	3.7	4	4.0
	Lease segregation in the regions		3.7	4	3.7	4	4.0	3	3.3	3	3.7	4	3.7	4	4.0
	Lease vibration and noise during operation		3.4	4	3.7	3	3.0	3	3.3	3	3.7	4	3.7	3	3.0
Maintenance	Location of service workshops *	14	3.3	2	4.7	-	-	-	-	4	4.7	3	4.7	3	6.0
	Easiness of maintenance for facilities		5.9	2	4.7	3	10.5	3	7.0	4	4.7	3	4.7	2	4.0
	Accessibility for maintenance serive providers		4.8	2	4.7	1	3.5	3	7.0	4	4.7	3	4.7	2	4.0
User convenience	Convenience for users*	22	5.7	4	11.0	-	-	-	-	3	7.3	4	8.8	3	7.3
	Commercial speed		8.1	2	5.5	3	11.0	3	11.0	3	7.3	3	6.6	3	7.3
	Ride		8.1	2	5.5	3	11.0	3	11.0	3	7.3	3	6.6	3	7.3
View/landscaping	Harmony with the landscape	6	1.9	2	1.7	3	2.0	3	2.0	3	1.8	3	2.0	3	2.0
	Accommodation of future urbanization		2.0	2	1.7	3	2.0	3	2.0	4	2.4	3	2.0	3	2.0
	Local symbolic factors		2.1	3	2.6	3	2.0	3	2.0	3	1.8	3	2.0	3	2.0
Consistency with superior plans	Consistency with a land use plan	3	1.5	3	1.5	4	1.5	4	1.5	4	1.5	4	1.5	4	1.5
	Consistency with urban plans		1.5	3	1.5	4	1.5	4	1.5	4	1.5	4	1.5	4	1.5

※ I(Important Fator) : Significance (0~5) ※ W(Weight) : Weights for the measurement criteria for elements

Figure 3 shows the results of performance measurement for individual areas. Railroad operation efficiency and constructability are the two areas that have show the greatest improvement while the view/landscaping area shows a little bit of decrease. The momentum behind the increase in the family attributes which cannot be measured objectively can now be quantified using the multi-level performance measurement approach. This allows the VE team to have rapid decision making and smooth communication based on agreement.

4.4 Valuation

During implement workshop, five alternatives rejected from 25 alternatives and 20 were selected, which show a decrease in the value and low rationality in incorporation of plan. Based on the result, the Life Cycle Cost(LCC) was reduced by 3.8% in relation to the original plan and the performance showed 3.8% of increase as shown in 4.3. Measurement using Equation 1 to determine the value of the project in terms of performance and cost reduction shows a increase of 10.3% as in Figure 4. The value can be quantified and a successful VE activity can be achieved with no decrease in the performance. Smooth communication can also be achieved not only within the VE team but also among the original design team, the client, VE department and stakeholders.

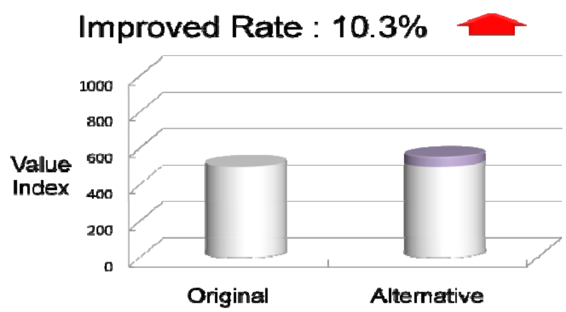


Figure 4. Design VE review for OO railroad project

5. CONCLUSION

In this study, a method for efficient design VE implementation is explored, which can be used for a large scale project such as infrastructure and a measurement approach for performance quantification for best value is proposed.

1) We propose a rationalized multi-level performance measurement approach for efficient and fast decision making based on consensus for a large scale project after exploring the drawbacks in the existing measurement approach.
2) A new VE job plan using the multi-level approach is analysed and compared in relation to the one derived from existing approaches.
3) The multi-level approach is applied to the design VE for an actual railroad project titled OO.
4) The multi-level approach presented in this study will be very useful in coordinating opinions and reaching agreements among stakeholders like the client and the VE team members in case of the design VE activity of a large scale project by providing categorized performance criteria.

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