SEOUL TOLL PLAZA VALUE ENGINEERING STUDY CONSIDERING PERFORMANCE MEASUREMENT AND LIFE-CYCLE COSTS

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ABSTRACT : Recent increases in construction costs on Korean public works projects, largely due to change orders caused by poorly elaborated design, become a motivation of applying VE process in Korean construction industry.
The Seoul Toll Plaza project, recently value analyzed by four VE teams, demonstrates how value management helps save time, money and increase functional performance. The objective of this project is to upgrade and expand existing pay and ticket booths system on "Kyungboo Express Highway", the main artery for the Korean peninsula linking Seoul to Pusan. The value management study generated several innovate alternatives capable of saving up to 50% of project cost from the baseline project plan.

Key words : VE(VA), LCC, Function, Performance, Highway Toll Plaza

1. INTRODUCTION

A government study titled "Strategies for Achieving Efficiency in Public Construction Projects" requires that government agencies utilize value engineering (VE) to improve project performance and reduce life cycle costs on infrastructure projects. The subsequent federal statute, "Management of Construction Technology," required that value engineering be performed on all major projects with a budget of more than USD $40 million and has subsequently been reduced to USD $10 million. This requirement has led the Korean Ministry of Construction and Transportation (KMOCT) to study the best practices and procedures, in order to standardize the implementation of the value engineering methodology into the project development process (planning, design and construction). This effort led to the KMOCT publication, titled the "Manual and Guideline for Value Engineering for Constructed Facilities" and to the development of a "Database for Value Engineering Suggestions" which will allow public/private institutions and agencies to share data. In response to these efforts, construction companies and academic institutions have actively conducted research on value engineering and life cycle cost (LCC) analyses applicable to the design and construction of public works projects.

This study required a case study to be carried out within the Korean construction industry to demonstrate the effectiveness of the VE methodology in saving lowering capital costs and increasing values.

2. VE METHOD AND PROCESS

The Seoul Toll Plaza Upgrade Project used the methodology developed by George Hunter, in his tenure as the Caltrans VA program manager, to analyze and reduce the traffic delay caused by the toll booth. This methodology, follows the SAVE value methodology with the addition of some unique tools that apply to public works projects. One key distinction is the measurement of the baseline project by the project stakeholder by the definition, weighting and rating of project performance criteria that explicitly measure the project scope and schedule. This "Multi-attribute Decision Making Method" accommodates project attributes that may require trade-offs

3. CASE STUDY: SEOUL TOLL PLAZA

Kyungboo Express Highway is the main artery of the Korean peninsula, while the Seoul Toll Plaza serves as an entrance gate to metropolitan Seoul for motorists traveling on this highway. Due to high traffic volumes, the highway users experience approximately 30 minutes of queuing delays at peak periods and with planned highway expansions this delay time is expected to grow significantly. The current location of the toll plaza severely restricts the space available to add new toll booths. Therefore innovation was required to solve the project's objectives to reduce the queue time while maintaining collection of toll revenues.

Seoul Toll Plaza

Seoul Toll Plaza has a total of 32 booths, 19 of them are pay booths (Seoul direction) and 13 of them are ticket booths (Pusan direction). 7 out of 32 booths are reversible (pay or ticket) to accommodate peak periods. Also, 10 out of 19 pay booths utilize double booths system to increase their capacity. Figure 1 shows the layout of the existing Seoul Toll Plaza.

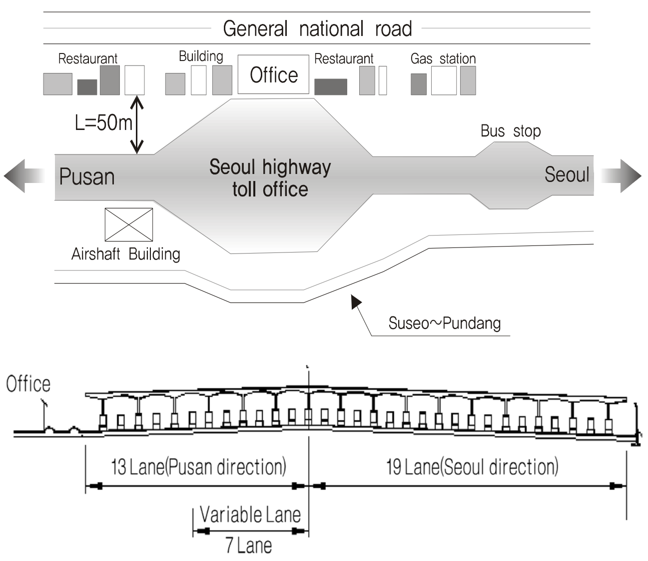

Figure 1. Seoul Toll Plaza Details

Project Performance Criteria

During the information phase the project stakeholders established 7 project performance criteria for this project in order to evaluate the effectiveness of the VE alternatives to be developed. Qualitative and quantitative parameters are used to increase the objectivity in the application. The criteria used are shown below:

- Travel delay (A): The time required to travel through the booth. Defined by the time that driver began slowing down from freeway operating speed to when driver required freeway operating speed.
- Safety (B): No. of accidents and aggregate severity of those accidents per year.
- Operational efficiency (C): Ease of operations of the pay and ticket booths, maintenances.
- Air quality (D): Amount of pollution encountered by the local community due to congestion caused by the toll booth.
- Socioeconomic (E): Farmland and other economic activities with community affected by the toll plaza (businesses, local transportation system, housing, etc).
- Project schedule (F): Time required to deliver the project (improvement in delay to highway user) to the public.
- Constructibility (G): Ease of construction. The likelihood of constructing the facility with minimal impacts to the local community, existing transportation systems, highway users. Also, ease of construction for the contractors.

Once the criteria were established, the VE teams applied the Analytic Hierarchy Process(AHP) method to determine weights. Table 1 shows the weights determined by AHP analysis, including “travel delay” and “safety” carrying the highest orders of importance.

Table 1. Weight determination by AHP method

Criteria	A	B	C	D	E	F	G	Weight
A. Travel delay	1.0	1.2	1.4	3.2	4.2	5.1	2.0	26
B. Safety	0.8	1.0	1.2	3.0	4.0	4.9	1.8	23
C. Operational efficiency	0.7	0.8	1.0	2.8	3.8	4.7	1.6	20
D. Air quality	0.3	0.3	0.4	1.0	2.0	2.9	0.5	8
E. Socioeconomic	0.2	0.3	0.3	0.5	1.0	1.9	0.3	5
F. Project schedule	0.2	0.2	0.2	0.4	0.5	1.0	0.2	3
G. Constructibility	0.5	0.6	0.6	2.2	3.2	4.1	1.0	15
λmax = 7.1241, C.I. = 0.0207 C.R. = 0.01568								

Assessment of performance rating according to performance criteria

This study adopts the following assessment for performance rating by selected performance criteria for reasonable assessment.

Table 2. Standard of Performance Measure For Travel Delay and Safety

Grade	Travel Delay	Safety
10	Below 1 min.	Accident not occurring
9	Below 2 min	A little occurrence than the main line
8	Below 4 min	As equal as main line
7	Below 6 min	More than about 2 times of the main line
6	Below 8 min	More than about 3 times of the main line
5	Below 10 min	More than about 4 times of the main line
4	Below 15 min	More than about 5 times of the main line
3	Below 20 min	More than about 6 times of the main line
2	Below 25 min	More than about 8 times of the main line
1	Below 30 min	More than about 10 times of the main line

- Travel delay applied delay time of upper echelon which approach to place of business by measure.
- Safety applied safety of the main line unit length and forecasting accident occurrence ratio of each place of business alternative about traffic accident occurrence by measure

Table 3. Standard of Performance Measure For Operational Efficiency and Air Quality

Grade	Operational Efficiency	Air Quality
10	Increase more than 40% than project which is not executed	Air pollution not occurring
9	Increase about 40% than project which is not executed	Much a little occurrence than the main line
8	Increase about 30% than projects which is not executed	A little occurrence than the main line
7	Increase about 20% than projects which is not executed	As equal as main line
6	Increase about 10% than project which is not executed	More than about 2 times of the main line
5	Project which is not executed	More than about 3 times of the main line
4	Decrease about 10% than project which is not executed	More than about 4 times of the main line
3	Decrease about 20% than project which is not executed	More than about 5 times of the main line
2	Decrease about 30% than project which is not executed	More than about 6 times of the main line
1	Decrease more than 30% than project which is not executed	More than about 7 times of the main line

- When project is not execute, operational efficiency by standard (grade 5) and applied.
- Air quality applied forecasting air pollution ratio of each place of project alternative about air pollution degree of the main line unit length by measure.

Table 4. Standard of Performance Measure For Socioeconomic, Constructibility and Project schedule

Grade	Socioeconomic and Constructibility	Project schedule
10	Very positive	2004 year
9	↑	2005 year
8	↑	2006 year
7	Positive	2007 year
6	↑	2008 year
5	Normal	2009 year
4	↓	2010 year
3	Negative	2011 year
2	↓	2012 year
1	Very negative	2013 year

- Socioeconomic and constructibility divide them into 5, such as, very positive - positive - normal (Project which is not executed) - negative - very negative and applied qualitative factor by quantification.
- Presuming scheduled public use year from present considering scheduled public use opening year when the feasibility study is executed and degree of difficulty of project apply to assess index of project schedule.

Performance measurement for original design

Using the established definitions and weights the performance criteria, the current design was measured for project performance. The current design scored 475 performance points, out of a minimum of 100 points and an ideal performance of 1000 points. This will be used as a comparison baseline to alternative values. Table 2 shows the performance evaluation result for the current design.

Table 5. Result of performance evaluation

Criteria	Weight	Rating	Performance
A. Travel delay	26	5	156
B. Safety	23	4	92
C. Operational efficiency	20	3	60
D. Air quality	8	4	32
E. Socioeconomic	5	6	30
F. Project schedule	3	5	15
G. Constructibility	15	6	90
Total	100	33	475

Functional Analysis

"Reduce Storage Time" was the basic function identified for this project. "Figure 2" shows the function analysis of Seoul Toll Plaza project and theirs relationships with cost as established on the FAST Diagram.

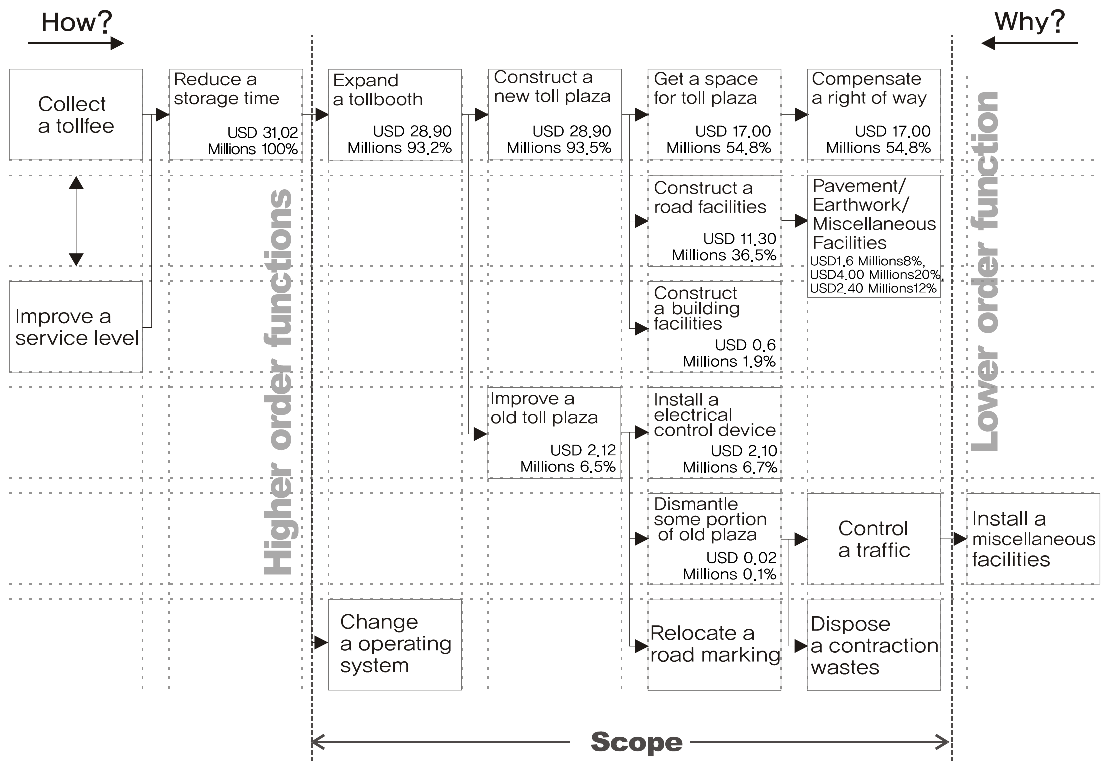

Figure 2. Function Analysis Diagram

Creativity and Evaluation

A total of 143 alternative ideas were proposed throughout the team brainstorming process. In the next step, evaluation, ideas with the greatest potential to improve the current design have to be established.

Table 3 shows one of the "out of the box" ideas that were generated in the creativity session, a overheard toll booth that does not consume scarce and expensive roadbed.

Table 6. Alternative ideas

No.	Alternative Ideas	Ranking
S-1	Make additional toll plaza	4
S-3	Change Toll Booth layout	4
S-5	Apply "Hi-Pass" lane (4 lane → 6 lane)	4
S-7	Apply "Touch and Go" system	3
S-8	Double Booth (all booths)	3
S-10	Reorganize lane marking in toll plaza	3

The evaluation process ranked VE ideas from 5 (significant value improvement) to 1 (significant value degradation) by considering their performance and cost. The evaluation phase paired down the 143 ideas down to 26 potential alternatives to be developed. Table 3 shows 6 out of 26 alternative ideas.

Value Measurement by considering Performance and Cost

The 26 surviving alternatives were developed in technical and cost detail in the development phase by the VE teams.

As a conclusion to this development each alternative had to be compared back to the baseline performance and cost basis. Value was checked by using basic formula below:

$$V = \frac{P}{C}$$

where,

V: Value
P: Performance (of given functions)
C: Cost

Also, Life Cycle Cost (LCC) models were applied to the alternatives. The LCC model used in this study show in below:

NPV= IC + PVORM + PVD

where,

NPV = net present value
IC = initial cost
PVORM = present value of maintenance cost
PVD = present value of disposal cost

The economic analysis brought all cost to the present, i.e. applied the "present value method" using 4.5% interest rate for a 20-year period.

Combination of alternatives

To obtain best value, several alternatives were combined. This study suggested 8 combinations of alternatives and Table 4 shows the best two combinations of alternatives, Set 4 and Set 6. Set 4 includes S-1(Make additional toll plaza), S-5(Apply "Hi-Pass" lane), S-7(Apply "Touch and Go" system) + S-8(Double Booth), and S-10(Reorganize lane marking in toll plaza). Set 6 includes S-3(Change Toll Booth layout), S-5(Apply "Hi-Pass" lane), S-7(Apply "Touch and Go" system) + S-8(Double Booth), and S-10(Reorganize lane marking in toll plaza).

Table 7. Example of combined alternatives

	Combination of Alternatives
Original	Extend From 32 toll booths to 46 toll booths (Pusan direction.: 16, Seoul direction.: 30)
VA Set 4	S-1 + S-5 + S-7 + S-8 + S-10
VA Set 6	S-3 + S-5 + S-7 + S-8 + S-10

Comparison of VA sets' performance

After forming the combination of alternatives, the performance of the sets was determined. The VA sets were measured against the criteria and weights established for the baseline project. Table 5 indicates that VA Set provides a 44% improvement and a 19% improvement for VA Set 6 when compared to the current design.

Table 8. Comparison of performance

Criteria	Weigh	Origin		VA Set 4		VA Set 6	
		R	P	R	P	R	P
A. Travel delay	26	5	130	10	260	10	260
B. Safety	23	4	92	5	115	4	92
C. Operational efficiency	20	3	60	4	80	4	80
D. Air quality	8	4	32	5	40	5	40
E. Socioeconomic	5	6	30	6	30	6	30
F. Project schedule	3	5	15	5	15	5	15
G. Constructibility	15	6	90	7	105	6	15
합 계	100	33	449	42	645	40	532

R : Rating P : Performance

Comparison of Cost

After the comparison of performance, we need to consider LCC for different ideas. Because of the uncertainties and noisiness of input variables, this study applied Monte Carlo Simulation (MCS) method. From this analysis, we found that VA Set 4 has 12 %, and VA Set 6 has 31 % lower LCC when compared to original plan. So, the result shows VA Set 6 is better in cost. Table 6 shows the comparison of LCC cost between origin and alternatives. Notice that the spread between the original and proposed VA recommendations were narrowed when the maintenance costs were accounted fore.

Table 9. Comparison of LCC (Billion won)

	Original	Alt. 4	Alt. 6
Initial cost	315	242	157
% Change I.C.	-	23%	50%
Maintenance cost	133	151	154
NPV	448	393	311
% Change NPV	-	12%	31%

Comparison of alternative value

Finally, this study compares the values between original plan and alternatives. VA Set 6, based on established performance measurement and cost differences, is identified as the better value choice. Table 7 shows the comparison of values between the original design and the VA alternatives.

Table 10. Comparison of values

	Original	VA Set 4	VA Set 6
Performance	44.9	64.5	53.2
Initial Cost	315	242	157
% Change	-	23%	50%
Value Index (P/C)	0.14	0.27	0.34
Value % Change	-	87%	138%

The change in spread between the LCC analyses, indicated in Table 6, and the Value Indices, shown in Table 7, can be explained by the more comprehensive list of attributes accounted for in the performance measurements.

This delineates the difference in approach in project analysis using value indices versus life cycle costing. The project performance measurements are well suited for project-decision making in the earlier project development stages to define and measure large variances in project scope and schedule.

Figure 3 shows the layout of recommended design for VA Set 6 for upgrading Seoul Toll Plaza project. The solution stresses that projects can be improved by not just removing project costs but by improving performance of the project objectives.

4. CONCLUSION

The quality and costs of highway and other public work sector projects can benefit by the application of well-elaborated VA methodologies. Specifically the VA methodology provides a sound methodology for analyzing the project objectives and attributes which, in turn, focuses the development of alternatives in the value study. This study applied methodology espoused by George Hunter (Caltrans' VA Methodology) to analyze the project, establish a value baseline and generate competing alternatives.

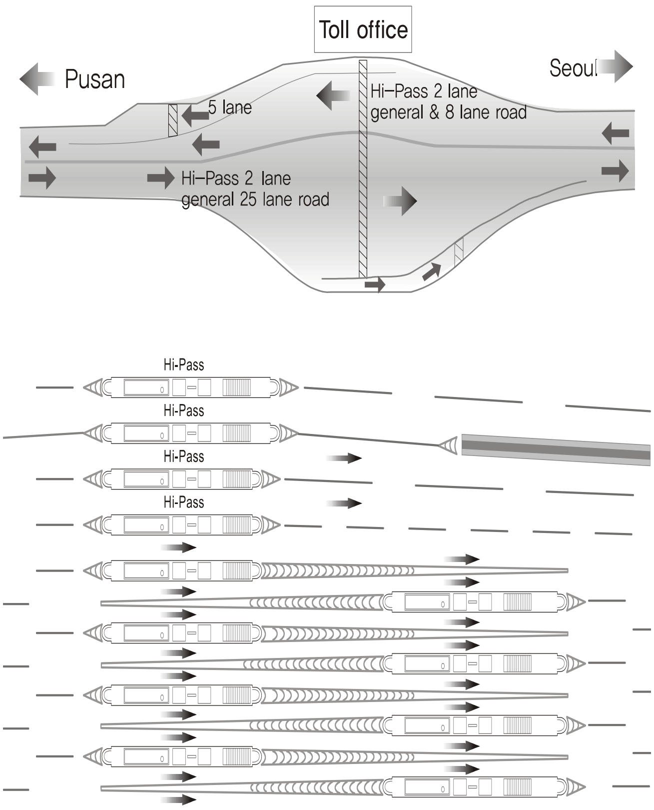

Figure 3. Recommended design

As a conclusion, the authors found that alternative ideas obtained from VE analysis provided up to 50% of project cost comparing to baseline project plan while significantly increasing the performance of the project functions In conclusion, the authors offer the following suggestions to implement a successful value engineering program in the public works sector:

- VE responsibilities must be clearly delineated within the organization.
- VE guidelines and manuals should be developed, used and maintained.
- VE training should being provided.
- VE specialists and consultants should be utilized.
- Program evaluation and auditing must be provided.

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