Characteristics for Leveraging Value Management Processes on Capital Facility Projects

Hee Sung Cha, A.M.ASCE[1]; and James T. O'Connor, M.ASCE[2]

Abstract: A more competitive business environment requires that a variety of value management process (VMP) options be continuously introduced into the construction industry. Project stakeholders and managers are highly concerned about value maximization through implementation of one or more beneficial VMP options. The objective of this study is to identify the most leveraging project characteristic factors (PCFs) in need of VMP implementation. Furthermore, the levels of importance of each PCF in association with the optional VMPs are quantified to effectively assess the applicability of VMP implementation using the fuzzy-based analytic hierarchy process method. Four real-case validation tests provide robust research findings. The proposed project assessment tool is useful in evaluating individual projects in terms of whether the subject project is leveraged or has much to be improved by implementing the optional VMPs. The results of this study can facilitate a rigorous evaluation of a project and eventually help the decision-making process in selecting the most beneficial VMP options to maximize the optimum project value.

DOI: 10.1061/(ASCE)0742-597X(2006)22:3(135)

CE Database subject headings: Facilities; Fuzzy sets; Value engineering; Construction industry; Business management; Theories.

Introduction

Providing better solutions or benefits to clients by increasing the value of a project is the foremost objective in the construction industry. Not only the clients but also the project participants are always concerned about project value improvement, but investment capital is a scarce commodity, and clients are striving to use their available capital in the most efficient and effective ways. For example, facility owners and their consultants/contractors are constantly seeking greater value from capital facility investment, whether they are pursuing performance improvements in security/safety, cost efficiency, quality, schedule, environmental stewardship, or risk containment.

Although the term "value" is defined by the *2003 Oxford English Dictionary* as "that amount of some commodity, medium of exchange, etc. that is considered to be an equivalent for something else," the meaning of value is not well defined but rather is used from various perspectives because the concept is so abstract and difficult to define (Gage 1967; Clawson 1970; Miles 1972; Macedo et al. 1978; Dell'Isola 1982; Kelly and Male 1993; Kirk and Spreckelmeyer 1998). A recent empirical study by Koga (2000) provided various interpretations of value from project management's perspective, for example, (1) the mixture of function, aesthetics, quality, time, and cost from the owner's perspective; (2) whether or not the owner's expectations are met; (3) the assembly that meets the owner's needs and provides a good level of quality without depriving the owner of any benefits; and (4) the reflection of what owners want. Thus it is noteworthy that value in the context of project management has to be regarded as the compilation of an owner or client's expectations and objectives.

On the other hand, in an effort to achieve value maximization, many innovative management processes, which are also interchangeably termed *best practices, value improving practices*, and *value management*, have shown successful results in achieving better performance in terms of owner (or client) value objectives, including time, cost, quality, and safety (O'Connor et al. 2003). One example is the Construction Industry Institute's (CII) best practices (BPs), which are reported to effectively enhance both project cost and schedule performance (Oey 2001; Lee 2001). Another example is the Independent Project Analysis (IPA)'s value improving practices (VIPs), which are increasingly being introduced into construction projects to improve project profitability (Collins 2001).

In recent years, the most common challenge confronted by industry has been too many *value management process (VMP)* options to choose from. Furthermore, project practitioners have difficulty understanding which VMP options are best for a particular project because there is no guidance for making such a decision (CII 2003). With so many VMP options confronting project teams, the selection of one or more of them is too often more likely to depend on a random process than on a systematic approach, thereby causing project stakeholders to fail to select the best VMP options. Varying project characteristic factors, which include resource availability, site conditions, and project objectives, presumably determine the level(s) of suitability in maximizing the benefits from the implementation of one or more VMP options. A thorough understanding of both the project characteristic factors and their related VMP options should result in maximum project value enhancement.

[1]Assistant Professor, Dept. of Architectural Engineering, Ajou Univ., Woncheon-Dong, Yeongtong-Gu, Suwon, 443-749, Korea. E-mail: hscha@ajou.ac.kr

[2]C. T. Wells Professor of Project Management and Professor of Civil Engineering, Dept. of Civil Engineering, Univ. of Texas at Austin, Austin, TX 78712-0276. E-mail: jtoconnor@mail.utexsas.edu

Note. Discussion open until December 1, 2006. Separate discussions must be submitted for individual papers. To extend the closing date by one month, a written request must be filed with the ASCE Managing Editor. The manuscript for this paper was submitted for review and possible publication on August 1, 2005; approved on November 29, 2005. This paper is part of the ***Journal of Management in Engineering***, Vol. 22, No. 3, July 1, 2006. ©ASCE, ISSN 0742-597X/2006/3-135–147/$25.00.

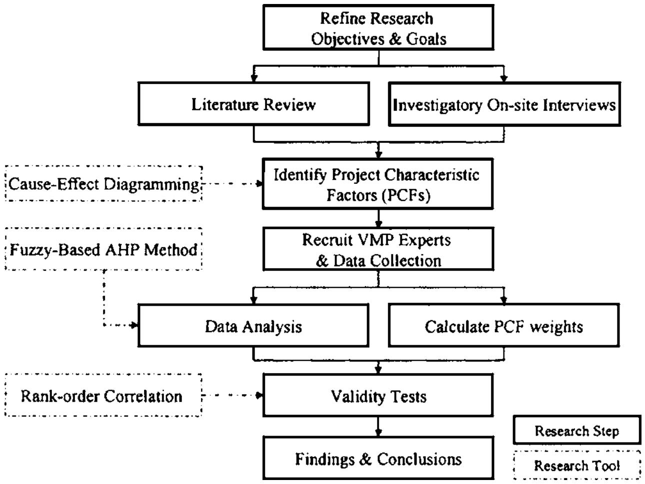


Fig. 1. Study methodology

For the purpose of this study, value is defined as a measure of how well the owner or client's objectives are met and is typically documented as a set of project objectives. The owner or client's ability to understand, prioritize, and articulate project value objectives is critical to overall project success because the right combination of project value objectives is the set of objectives that will provide optimum value to the owners or clients (Kerzner 1984). In other words, the concept of value in the context of a capital project should be established by the project owner or client in order to reflect unique business goals, project objectives, need, and desires (Leung et al. 2002).

The main objective of this study is to identify the most leveraging factor(s), or project characteristic factors (PCFs), in need of VMP implementation, assuming that dominant project circumstances exist that justify implementation of the VMP option(s). To achieve this objective, the study quantifies the degree of association between the identified PCFs and their related VMP options. In addition, this research provides an assessment tool in which a particular project can be evaluated effectively in terms of the suitability for implementation of individual VMP options in enhancing the value of the project. The quantitative approach should provide the industry with guidance in selecting and/or implementing the best VMP options in considering various project circumstances.

Research Methodology

The main topic of the VMP options in this study is limited to the CII's 44 VMPs, each of which was initially identified from an industrywide investigation and finalized through brainstorming and a literature search in collaboration with CII Project Team 184. These VMP options in association with their purpose and objectives are provided in Appendix I. For more details, the writers refer the reader to CII Research Report 184-11. The study methodology in conducting this research is provided in Fig. 1.

As shown in Fig. 1, the study consists of three major activities: preliminary investigation (Step 1), expert survey (Step 2), and validity test (Step 3). Each step is elaborated in the following sections.

Step 1: Preliminary Investigation

To identify any factors that trigger implementation of VMPs on capital projects, the writers not only conducted a rigorous literature review, but also proceeded with industry-wide on-site interviews. Based on these two investigations, the writers identified a variety of PCFs. In this step, a graphical tool, relationship diagramming, was used to effectively elicit those factors (Salas M. 2002). One example of these diagrams is presented in Fig. 2.

In developing those diagrams, a comprehensive collection of

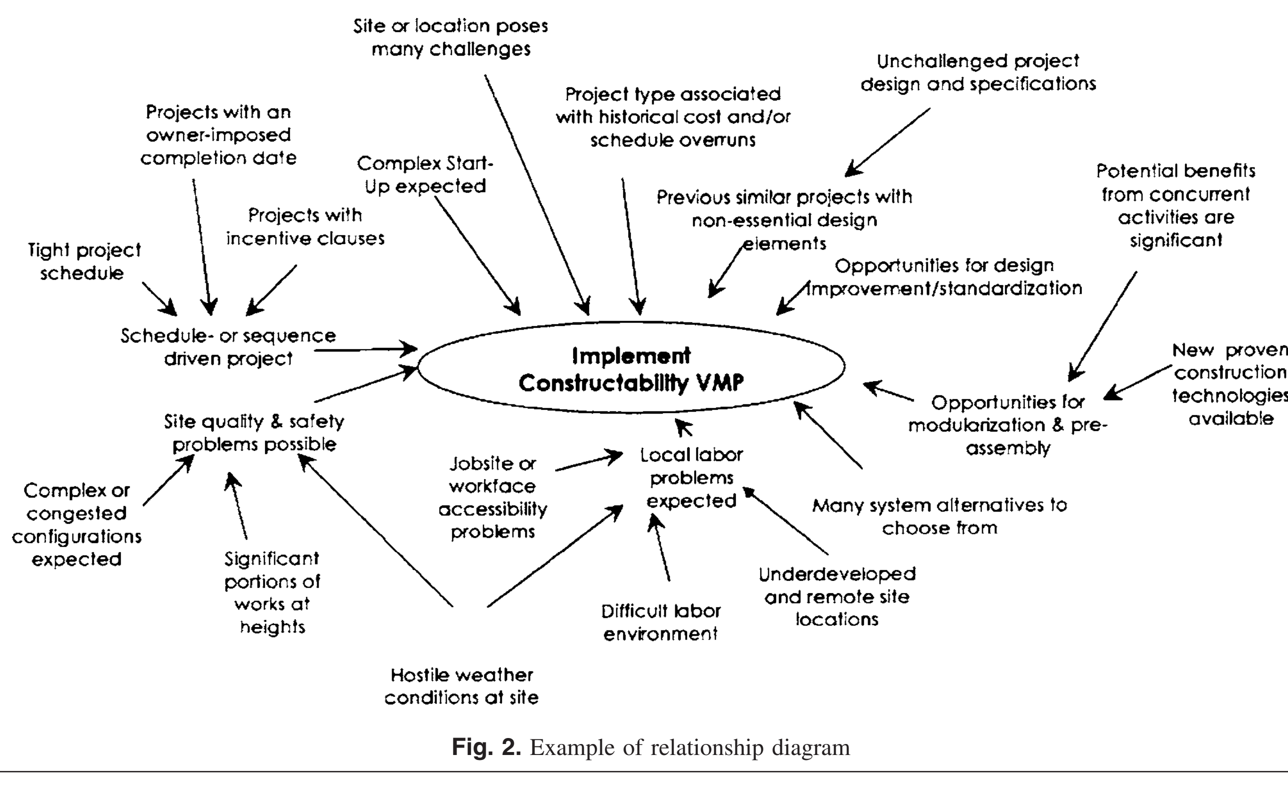


Fig. 2. Example of relationship diagram

Table 1. Organizations of Survey Participants

Organization	Owner	Contractor	Institute/ association	University	Total
Number of organizations	12	4	4	8	24
Number of individuals	30	6	4	11	51

both academic and in-practice publications, including various types of documents, was incorporated. Finally, the literature review in the form of relationship diagramming effectively produced 149 PCFs, as provided in Appendix II.

The resulting factors were then categorized and each was classified into 12 classes, which include owner characteristics (A), project objectives/performance (B), budget/cost/economics (C), contracts/organization (D), site conditions/existing facility (E), facility scope and characteristics (F), technologies/manufacturing process (G), project design (H), facility operations/maintenance (I), materials/equipment/procurement/supply chain (J), site labor (K), and procedures and communications (L).

Step 2: Expert Survey

For the purpose of investigating the relative importance of the PCFs, many experts' input was surveyed. Because most of the PCFs were identified based on the literature review and knowledge-based experience, they should be verified based on experts' point of view. Once the complete list of the PCFs was constructed, a survey instrument was developed. To avoid the survey results being affected by any biased data, only the VMP experts, who are either VMP consultants or VMP practitioners, were allowed to participate in the survey. The writers recruited VMP experts from both industry and academia who should either be knowledgeable of any of the VMPs or involved in the implementation of any of these VMPs. The expert survey was performed from September 2002 through June 2003, and a total of 51 respondents, representing 24 organizations, participated, as shown in Table 1.

As the complete list of 149 PCFs, however, was too long to allow any respondent to complete the survey in a reasonable amount of time, a preliminary screening process was required to eliminate some of the less important PCFs. By doing this, each list for the reduced set of the VMP PCFs could effectively include the candidate factors for the corresponding VMPs. To expedite the data collection process, a survey instrument, called a VMP ballot, was developed, as shown in Fig. 3 (Cha 2003).

Using these VMP ballots, the respondents' degree of agreement could be effectively obtained regarding whether the candidate PCFs were important in implementing the particular VMP. For each VMP ballot, a 5-point Likert scale (0=no importance, 1=low importance, 3=moderate importance, 5=high importance) was used to quantify the relative importance of the PCFs within each VMP.

Step 3: Validity Case Studies

The primary objective of this study was to determine the association between VMPs and their PCFs. To verify whether this objective was met, real-case validity tests were conducted, each of which comprised two different experiments; VMP rank order by a manually based approach, and VMP rank order by a weight-based approach. In the manually based approach, the 44 VMPs were prioritized and rank ordered by an in-house project team in terms

VMP: Risk Management

Name of Voter:		**Phone:**	
Company Affiliation:		**Fax:**	
E-mail:		**Date:**	

Factor No.	Potential Project Characteristic Factor	Relative Importance of Factor in Selecting This VMP				
		None (0)	Low (1)	Moderate (3)	High (5)	Don't Know
B1	Project objectives, functional requirements, and/or priorities are unclear or have not been agreed upon					
B12	Poor environmental performance of project could have potentially adverse effects on public health and safety					
C5	There is a need for a more accurate estimate of cost contingency					
D5	Major portions of the work are being or will be subcontracted to various parties					
D8	Project involves geographically dispersed personnel					
E1	The project is outside of U.S.					
E2	The project involves uncertain pre-existing conditions					
E4	There is or will be hostile weather conditions at the site					
F1	Project has unique challenges: structural, environ'l, etc.					
F2	Project type is relatively new, at least for this owner					
F7	Project involves potential liabilities with waste disposal					

Fig. 3. Example of VMP ballot

Table 2. Participant Project Profile in Validation Tests

Participant projects	Project size	Project location
Desulfurization unit	$100 million	Corpus Christi, Tex.
Gas-oil separation plant	300 K BPD	Haradh Field, Saudi Arabia
Chemical plant	$7 million	Midland, Mich.
Power plant	550 megawatts	Las Vegas

Table 3. Experts' Survey Results

VMP	Number of respondent experts	Number of key factors included	Average score: Mean	Average score: Standard deviation	Average score: P-value ($\alpha=0.05$)
01	5	6	3.30	0.39	0.02
02	4	8	4.13	0.64	—
03	4	6	3.54	0.68	—
04	6	6	4.07	0.42	—
05	9	11	4.23	0.48	—
06	4	7	4.25	0.69	—
07	5	9	3.41	0.03	0.02
08	4	9	4.00	0.35	—
09	7	7	4.06	0.63	—
10	5	7	3.74	0.43	—
11	4	7	4.04	0.82	—
12	10	6	3.77	0.87	—
13	3	7	4.05	0.52	—
14	5	7	3.16	0.86	0.003
15	10	8	3.54	0.94	—
16	6	8	3.73	0.53	—
17	9	8	3.71	0.69	—
18	3	9	4.56	0.47	0.005
19	5	8	4.05	0.51	—
20	5	10	4.37	0.43	0.036
21	9	8	4.36	0.53	—
22	9	7	3.13	0.32	0.002
23	5	10	3.79	0.58	—
24	7	10	4.49	0.42	0.009
25	4	8	4.06	0.56	—
26	4	10	4.55	0.28	0.003
27	7	8	4.11	0.39	—
28	5	9	4.29	0.71	—
29	5	8	3.63	0.65	—
30	9	9	3.86	0.42	—
31	3	9	3.74	0.85	—
32	5	8	3.87	0.47	—
33	5	8	4.01	0.63	—
34	7	8	3.85	1.03	—
35	5	8	4.40	0.37	0.046
36	5	8	3.45	0.40	0.046
37	5	8	3.03	0.78	0.0002
38	4	7	3.86	0.69	—
39	3	6	4.00	0.70	—
40	4	8	4.19	0.37	—
41	5	10	3.68	0.42	—
42	11	9	4.04	0.48	—
43	9	8	3.49	0.78	—
44	7	8	4.30	0.58	—
Total	—	—	3.93	0.67	—

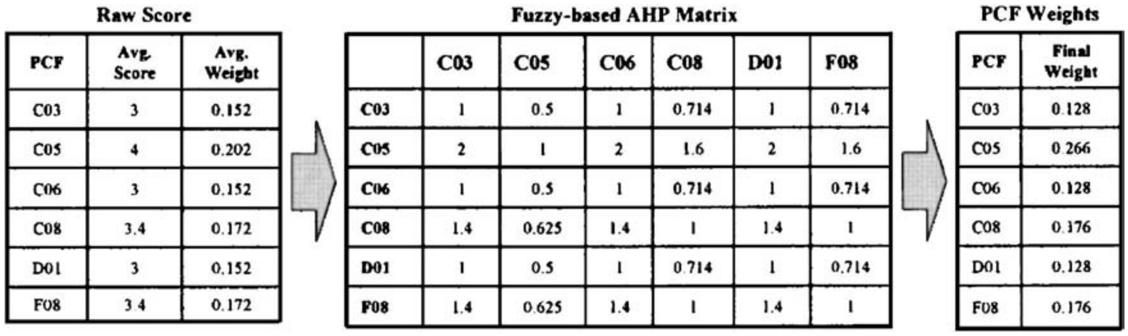
Table 4. VMP Factors and Weights (Partial)

VMP	PCF	Average score	Factor weight
01	C03	3	0.128
	C05	4	0.266
	C06	3	0.128
	C08	3.4	0.176
	D01	3	0.128
	F08	3.4	0.176
02	A01	3.5	0.076
	A02	3.5	0.076
	B01	5	0.204
	B06	4.5	0.150
	B09	5	0.204
	D06	4	0.107
	D08	4	0.107
	D13	3.5	0.076
03	B06	3.5	0.16
	G06	4	0.19
	G08	4	0.19
	G16	3.5	0.16
	H01	4	0.19
	L10	2.25	0.11
04	A02	4	0.152
	A03	3.4	0.099
	B01	4.67	0.249
	B06	4.33	0.197
	B08	4	0.152
	B09	4	0.152
05	B10	4.33	0.095
	B13	4.78	0.131
	E03	4.33	0.072
	E04	4.56	0.115
	F01	3.44	0.051
	F03	3.44	0.051
	F08	4.33	0.095
	F11	4.11	0.08
	H12	4.11	0.08
	H13	5	0.151
	K01	4.11	0.08

of suitability for the case-study project, while in the weight-based approach, the VMP factors were evaluated in terms of whether the project team agreed on the PCFs established in this study. In this approach, the resulting weights were used in ranking the order of the VMPs by summing the corresponding factor weights. By comparing the two rank orders and investigating any substantial difference between them, the study results (i.e., the VMP factor weights) were considered effectively verified. Four volunteered projects participated in the case studies, and brief project profiles are presented in Table 2.

Data Profile and Analysis

Table 3 shows the results of data collection from the expert survey. The sample size of data varies according to the different VMP options, and thus some VMP options got a larger number of experts involved than did others. The average number of experts who participated in the survey was 6, ranging from 3



Raw Score

PCF	Avg. Score	Avg. Weight
C03	3	0.152
C05	4	0.202
C06	3	0.152
C08	3.4	0.172
D01	3	0.152
F08	3.4	0.172

Fuzzy-based AHP Matrix

	C03	C05	C06	C08	D01	F08
C03	1	0.5	1	0.714	1	0.714
C05	2	1	2	1.6	2	1.6
C06	1	0.5	1	0.714	1	0.714
C08	1.4	0.625	1.4	1	1.4	1
D01	1	0.5	1	0.714	1	0.714
F08	1.4	0.625	1.4	1	1.4	1

PCF Weights

PCF	Final Weight
C03	0.128
C05	0.266
C06	0.128
C08	0.176
D01	0.128
F08	0.176

Fig. 4. Example of fuzzy-based weight computation

(VMP Nos. 13, 18, 31, and 39) to 11 (VMP No. 42). Out of 149 factors, those most likely to be important, or candidate PCFs, were initially included in the survey. During the data collection process, however, the low-scored factors were regarded as insignificant and effectively screened out of the analysis by comparing the average scores obtained by the experts with the mean value of average scores within each VMP.

The mean value of the average PCF scores within each VMP ranged from 3.03 (VMP No. 37) to 4.56 (VMP No. 18). Although the targeted number of the factors within each VMP was eight, the finalized numbers of VMP factors were different from one another, an inconsistency that resulted from the small sample size. Therefore, for some VMPs, the difference in relative importance among the factors was unclarified in this survey. On the other hand, the average PCF factor scores for all 44 VMPs were ANOVA tested to analyze whether the resulting data did not differ in terms of mean variance. The hypothesis that there is no difference between the individual VMP mean scores and the total mean score was tested, and the resulting p-values for all VMPs are provided in Table 3.

The ANOVA tests prove that 33 VMPs have no variance in their mean values, while 11 VMPs have significant variance in their sample data, as shown in Table 3. These test results are interpreted to show that the averaged raw scores (scale of 0 to 5) are insufficient to use in the form of factor scores, and therefore the raw scores should be converted into an appropriate format in order to be used as a meaningful value.

Factor Weighting: Fuzzy-Based AHP Method

The fuzzy set theory developed by Zadeh (1965) is an effective quantification tool in dealing with linguistic terms such as "good" or "important." Since the characteristic of data gathered for this research is linguistic and the pool of data providers is so limited, the writers chose a fuzzy-based analytical hierarchy process (AHP) method in computing the weights of each PCF (Saaty 1980; Zayed and Halpin 2004). The averaged raw score obtained from the VMP experts ranged from 0 (no importance) to 5 (high importance). In comparison with a simple statistical approach, the fuzzy-based AHP method requires an interim process of pairwise comparison (Tam et al. 2002). Once the AHP weights in each pairwise matrix for a particular VMP are computed, each raw score can effectively be converted into a fuzzy-embedded weight, as shown in Table 4.

For detailed computing procedure, refer to fuzzy logic (McNeill and Thro 2002). All AHP weights were converted into a meaningful value since the finalized consistency index for all 44 VMPs was less than 0.1. Fig. 4 illustrates how the PCFs in the activity-based costing VMP were converted into the finalized fuzzy weights. Since the weight-converting process was time consuming, a computer software program (Fuzzy Decision Maker) was used in calculating the whole PCF weights for all 44 VMPs in this study.

Because the factors and their weights are completely dependent on the expert survey, the data should be beneficial in making a constructive decision to select the best VMP options for a particular capital project. The most salient findings from the data analysis are the key project characteristics that drive the need for VMP implementation. These factors are regarded as the dominant project conditions that should be considered as crucial factors in deciding whether to adopt any of the VMPs for a particular project. By summing up the final weights from all 44 VMPs, the high-ranked key project characteristics were determined as follows:

Table 5. Top 20 Project Characteristics That Drive Need for VMP Implementation

Rank	Factor	Sum weight	VMPs affected[a]
1	B01	1.252	02, 04, 12, 13, 21, 22, 27, 31
2	B07	1.235	08, 09, 11, 14, 17, 18, 26, 28, 42, 44
3	A01	1.046	02, 14, 21, 22, 23, 27, 29, 30
4	F08	0.989	01, 05, 12, 13, 24, 30, 37, 42
5	B06	0.969	02, 03, 04, 12, 21, 31, 41
6	B11	0.886	07, 14, 16, 22, 24, 30, 34
7	B09	0.827	02, 04, 12, 21, 31, 41
8	B02	0.782	07, 15, 18, 23, 25, 27, 41
9	F05	0.777	15, 24, 27, 28, 30, 33, 40
10	L03	0.749	07, 15, 23, 25, 35, 41
11	B10	0.749	05, 20, 24, 29, 34, 36
12	B13	0.679	05, 06, 22, 29, 34
13	C08	0.674	01, 10, 19, 33, 37
14	F01	0.650	05, 07, 13, 23, 32, 42
15	B04	0.642	10, 19, 29, 36, 43
16	B08	0.637	04, 07, 21, 31, 41
17	C05	0.616	01, 32, 33, 37
18	B05	0.588	10, 16, 23, 36, 42
19	G02	0.557	11, 39, 40, 42
20	I11	0.548	18, 24, 26, 34, 41

[a]See Appendix I.

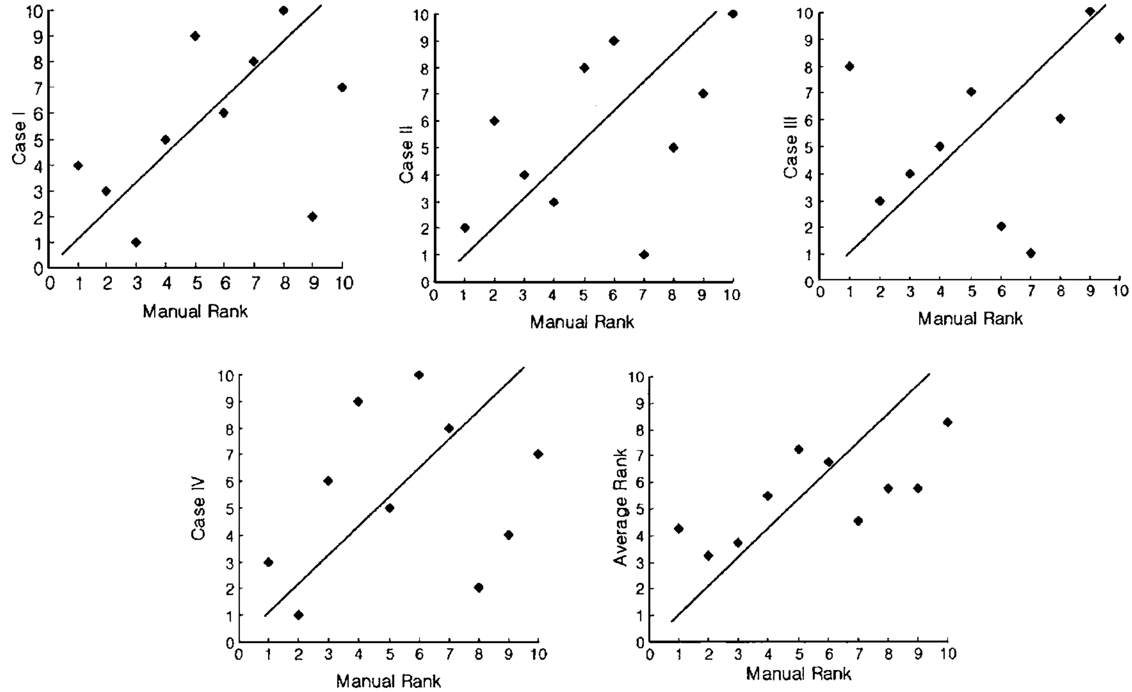


Fig. 5. Real-case validation test results

- Project objectives, functional requirements, and/or priorities are unclear or have not been agreed upon (B01);
- Reducing facility life-cycle cost is an important objective (B07);
- Owner lacks in-house resources for project development and execution (A01);
- Project is very complex (F08); and
- Owner objectives/expectations are often in conflict (B06).

Including the above, the top 20 high-ranked key factors associated with their corresponding VMPs are provided in Table 5.

Validation of Findings

For the purpose of verifying the established VMP factor weights, real-case projects were analyzed in terms of whether the resulting weights provide valid outcomes in implementing the VMP options. Because of the large number of VMP options and related PCFs, a strategic approach was developed in the validation process. Using this approach, two types of VMP rank orders were compared to check whether there is any substantial difference between the two results, one based on manual selection and the other on weight-based selection. In the manual selection, the project participants were asked to rank the candidate VMP options by potential benefits in implementing the options on their project, but in the weight-based selection, the VMP ranks were automatically computed using the PCF weights provided in this study.

Comparison of the manually based with the weight-based outcome should effectively prove the validity of the findings. Four real-case projects participated in this validation. The detailed steps in the validity test are listed as follows.

1. Organize core project team and limit candidate VMPs by team;
2. Manually rank order candidate VMPs in terms of suitability for subject project in consideration of project characteristics;
3. Evaluate subject project in terms of whether PCFs are matched with subject project;
4. Rank order candidate VMPs by summed weights of matched PCFs; and
5. Compare two ranking results and compute rank-order correlation.

Fig. 5 depicts the validity test results. Each graph shows the relationship between two different top 10 rank orders and is interpreted as showing that if the points in each plot are located near the 45 degree line, the two ranks are relatively well matched with each other. The fifth graph shows the combined or averaged rank orders of the four cases.

When the two ranking results are highly correlated, the findings of this study should be concluded to be verified. The

Table 6. Real-Case Validation Test Results

Manual rank	Case I	Case II	Case III	Case IV	Average rank
1	4	2	8	3	4.25
2	3	6	3	1	3.25
3	1	4	4	6	3.75
4	5	3	5	9	5.5
5	9	8	7	5	7.25
6	6	9	2	10	6.75
7	8	1	1	8	4.5
8	10	5	6	2	5.75
9	2	7	10	4	5.75
10	7	10	9	7	8.25
Spearman's rho (rank-order correlation)	0.43	0.48	0.31	0.24	0.53
Significance (two tailed)	0.21	0.16	0.39	0.51	0.12

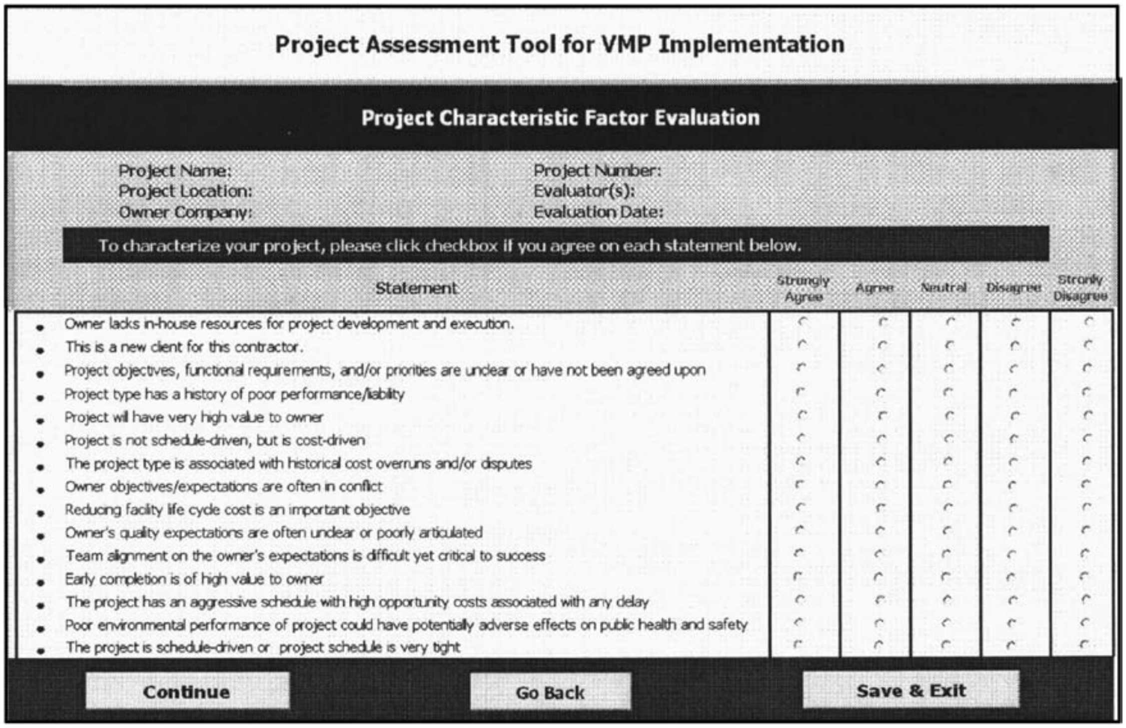


Fig. 6. Screenshot of project assessment tool

hypothesis test was conducted for the four individual case projects. The null hypothesis was that there is no relationship between the manual rank order and the weighted rank order. Table 6 provides both the individual and combined (averaged) results of the hypothesis test.

The interesting findings of these results include that the correlation coefficient between the manual ranks and the averaged weighted ranks of the four cases (0.53) strongly support the positive relationship with the significance of the p-value of 0.12. Although the p-value may not be small enough to draw the conclusion that the null hypothesis should be rejected statistically, this value sufficiently justifies a strong relationship between the manual- and the weight-driven rank orders. Once the tests were completed, the two ranking results were provided to the test participants, who were requested to input any ideas in explaining the discrepancy between the two results. The test participants recognized that if they were more committed to evaluating the VMP factors, the results would be more improved because the main reason for the difference came from misunderstandings or lack of awareness of the VMP options and their factors.

Project Assessment Tool for VMP Implementation

The PCF weights are useful indicators in deciding a strategy for implementation of one or more of the VMP options. Using the PCF weights, the optional VMPs are evaluated in terms of how much the subject project has to be improved. In other words, project stakeholders or participants can effectively forecast the project status by matching the PCFs with the project circumstances. To expedite the evaluation process, the project assessment tool (PAT) was developed via Excel-based Visual Basic programming, as shown in Fig. 6.

With this tool, each weight of the PCFs in a particular VMP is effectively combined with degree of agreement when quantifying the project leverage status. In a range of 0 (strongly disagree) to 10 (strongly agree), each PCF is assessed in terms of how much the subject project is associated with the specific PCFs. Thus, the project leverage score is computed by the following equation:

$$\text{VMP project leverage score} = \sum_{i=1}^{j} W_i \cdot A_i \tag{1}$$

where W=weight of project characteristic factor (in a range of 0 to 1); A=degree of agreement (in a range of 0 to 10); and j=number of PCFs in a particular VMP.

Fig. 7 illustrates how the VMP project leverage scores are computed. In this example project, two VMPs (nos. 1 and 2) are supposed to be selected for project assessment. VMP 1 (activity-based costing) has six PCFs, and VMP 2 (chartering project teams) has eight PCFs (Table 4). The selected PCFs are then

VMP: Activity Based Costing

PCF	Weight	Agreement
C03	0.128	3
C05	0.266	0
C06	0.128	5
C08	0.176	7
D01	0.128	10
D08	0.176	7

Project Leverage Score= 4.768

VMP: Chartering Project Teams

PCF	Weight	Agreement
A01	0.076	3
A02	0.076	0
B01	0.204	5
B06	0.15	7
B09	0.204	7
D06	0.107	5
D08	0.107	7
D13	0.076	10

Project Leverage Score= 5.77

Fig. 7. Example of computing project leverage score

reviewed for the purpose of scoring the degree of agreement in terms of how much a particular PCF is agreed on the subject project. Using Eq. (1), each project leverage score is computed as shown in Fig. 7.

The project leverage score (PLS) is useful in determining the project circumstance because any project can be assessed in a quantifiable scale. As the equation shows, the higher the score, the worse the project. Although a more rigorous analysis is needed in interpreting the score, a basic guideline is provided based on pilot tests of the tool. The test results prove that any VMP with a score larger than 7.0 is highly leveraged. More detailed guidance in using the tool is provided as follows:

- More than 7.0: strongly recommended for implementation;
- Between 5.0 and 7.0: recommended for implementation;
- Between 3.0 and 5.0: may be recommended for implementation, but additional analysis is needed; and
- Less than 3.0: not recommended for implementation.

Conclusions and Recommendations

Faced with a challenging business environment, project stakeholders have long been striving to achieve an optimum value increase. Implementation of one or more VMP options is an important strategy in maximizing the value of a project. Although many VMP options are available in the industry, little research has been conducted on the overall strategic approach for these options. Recognizing that project characteristics play an important role in differentiating the magnitude of impact on VMP options, the purpose of this study was to quantify the degree of association between the established 44 VMPs and 149 leveraging project characteristics. This was accomplished by a thorough literature review and an industrywide expert survey. The resulting data were further converted into a meaningful measure of VMP factor weights. Four real-case validity tests using these weights proved the applicability of the study findings. Findings from this study are helpful to companies in deciding whether to adopt certain types of VMP options and providing useful guidance in implementing the most beneficial VMPs for a particular project.

The fundamental conclusions from this study are as follows:

- A wide range of VMPs should be more frequently considered for application on projects: most project teams consider only a few limited VMPs.
- Selection of VMPs should be a rigorous and thorough undertaking that considers various project characteristic factors, such as owner characteristics, project objectives and performance, resource availability, and site conditions.
- There are dominant project characteristics that drive the implementation of one or more VMPs, and their respective weights as drivers of VMP applicability in large part establish magnitude of benefits from implementing the associated VMPs.
- VMP factor weights are effective for selecting the most applicable VMPs for particular projects and thereby increase the optimum value of a project.

The established 44 VMPs represent the current state of practice of value management in the construction industry. Since value management is a continuous, ever-evolving aspect of management (Macedo et al. 1978), any VMP that becomes assimilated into standard project management can no longer be on the list; instead, new innovative management processes or efforts should be included in the collection of VMP options. In parallel with updating the VMP listings, data collection from VMP expert groups should be expanded and the degree of association (or the factor weights) should be updated and modified accordingly.

Acknowledgments

The writers would like to thank the Construction Industry Institute, the Alfred P. Sloan Foundation, and the Center for Construction Industry Studies for their financial support. This work is also supported by the new faculty research fund of Ajou University. Many individuals who have contributed to this research through surveys and the reviewers of this paper are also appreciated.

Appendix I. CII's 44 Value Management Processes

	VMP number and title	Purpose and objectives
01	Activity-based costing	Quantitatively measure cost and performance of activities, resources, and cost objects, including appropriate overhead
02	Chartering project teams	Develop resource manning plan defining team's membership, roles, and responsibilities
03	Choosing by advantages	Enhance decision-making process by making consistent, congruent, and effective decisions
04	Classes of facility quality	Articulate and prioritize facility performance characteristics needed to meet manufacturing business goals
05	Constructability	Achieve overall project objectives by integrating construction knowledge and experience into front-end planning, designs, and procurement phase
06	Construction simulation	Employ computer-based work process simulation to optimize design of construction operations for high-volume cyclical construction activities
07	Design effectiveness	Establish goals and benchmarks for tracking performance of design activities and to evaluate performance against prescribed benchmarks
08	Design for maintainability	Improve ease, effectiveness, safety, and economy in performance of maintenance action by including relevant maintenance input during all phases of facility delivery process
09	Design to capacity	Minimize excess capacity in major pieces of equipment and systems while being careful not to create a bottleneck situation; set the lowest practical overdesign factors
10	Design to cost	Enhance affordability of program (project, products, systems, or services) over its life cycle by making design converge on cost instead of allowing cost to converge on design
11	Energy optimization	Optimize manufacturing process by linking energy and process changes to profit improvement
12	FAST diagramming	Clarify business project and assist organizations to develop clear statement of their performance requirements in strategic function terms

	VMP number and title	Purpose and objectives
13	Function analysis concept development	Efficiently and quickly “rough out” agreed-upon conceptual design for facility and resolve all significant design and budget issues through intense 2-week workshop involving all key stakeholders and design personnel
14	Individual value engineering	Identify areas that should be investigated by VM study team or considered for design simplification/elimination
15	Knowledge management/lessons learned systems	Enable individuals to share their learning experiences with others effectively and to develop work processes that capture these experiences for benefit of future endeavors
16	Lean construction	Employ technologies to maximize reliability of work flow within construction process
17	Life-cycle costing	Optimize facility design decisions over life cycle of facility through economic assessment of competing design alternatives, considering all significant costs of ownership over economic life of each alternative
18	Mechanical reliability modeling	Quantitatively assess availability of all or part of process and identify major contributors to forced downtime
19	Minimum standards and practices	Establish minimum acceptable standards, codes, and specifications that align with owner’s project objectives to obtain optimum life-cycle costs
20	Modularization/mass customization	Achieve efficient assembly-line mass production of components that can lead to industrywide increases in economic productivity
21	Owner‘s values and expectations	Articulate owner’s value parameters for project as first step for helping achieve project success
22	Partnering	Understand each project participant’s objectives, priorities, and expectations and identify common goals
23	Peer review	Improve efficiency of construction process, quality of constructed product, and credibility of organization’s decision making
24	Planning for startup	Help to plan facility startups in more thorough, effective, and efficient manner, recognizing that project success relies heavily upon startup success
25	Postoccupancy evaluation	Help owners determine if facility is meeting its original goals and objectives and satisfying customer expectations to improve the quality of future projects and/or make modifications to the facility
26	Predictive maintenance	Incorporate into plant design those technologies which optimize equipment useful life and maintenance efforts
27	Preproject planning	Maximize the chance for a successful project by developing sufficient strategic information with which owners can address risk and decide to commit resources
28	Process simplification	Combine, simplify, technologically update or eliminate one or more chemical or mechanical processing steps; increase NPV through systematic functional review of major components of process design; and lower life-cycle cost of plant
29	Project delivery methods	Select an overall project strategy that will meet capital project objectives and provide the best value
30	Project execution plan	Ensure that all tasks are identified and carried out in timely manner
31	Quality functional deployment	Help companies assure that product design and manufacturing functions can actually deliver to the customer’s quality expectations
32	Risk management	Develop a plan for controlling risk based on thorough analysis
33	Risk-based estimating	Employ probability distributions, correlations, and risk analysis to improve accuracy and risk assessment of conceptual-level cost estimate
34	Schedule optimization	Provide schedule acceleration tools to enable project teams to meet project objectives
35	Six sigma	To increase productivity or reduce waste by improving capability of work processes (transactional, production, or product development processes) through rigorous application of performance benchmarking data collection and analysis
36	Sourcing strategies	Enable optimum resource allocation throughout assessment of organization’s strengths and weaknesses
37	Successive estimating	Employ cost statistics to maximize accuracy of conceptual-level cost estimate for amount of effort invested
38	Sustainable design and construction	Achieve longer-term facility life-cycle benefits by integrating environmental stewardship into way facilities are planned, designed, constructed, and operated
39	Technology gatekeeper	Improve business prospects and quality of organizational decision making by supporting individuals and groups who rigorously seek out information about potentially implementable technologies and direct such information to appropriate individuals within organization
40	Technology selection	Search and evaluate technologies for specific purpose through formal, systematic process
41	Total quality management	Make quality driving consideration in each phase of engineering and construction work process
42	Value engineering	Achieve necessary functions and essential characteristics in most cost-effective manner through organized effort directed at analyzing functions of goods and services
43	Value engineering change proposal	Benefit from contractor expertise and marketplace economies by allowing contractor to submit proposals for alternative ways to perform work more economically.
44	Waste minimization/pollution prevention	To reduce waste production as part of everyday plant-level manufacturing to reduce liability, promote positive public image, and lower waste treatment, disposal, and production costs

Appendix II. Project Characteristic Factors That Drive Need for VMPs

A. Owner characteristics	
A01	Owner lacks in-house resources for project development and execution.
A02	This is a new client for this contractor.
A03	Owner sometimes gets a facility that it doesn't want/need.
A04	Owner has strong commitment to sustainable/green design, construction, and operation.
B. Project objectives/project performance	
B01	Project objectives, functional requirements, and/or priorities are unclear or have not been agreed upon.
B02	Project type has a history of poor performance/liability.
B03	Project will have very high value to owner.
B04	Project is not schedule driven but is cost driven.
B05	Project type is associated with historical cost overruns and/or disputes.
B06	Owner objectives/expectations are often in conflict.
B07	Reducing facility life-cycle cost is important objective.
B08	Owner's quality expectations are often unclear or poorly articulated.
B09	Team alignment on owner's expectations is difficult yet critical to success.
B10	Early completion is of high value to owner.
B11	Project has aggressive schedule with high opportunity costs associated with any delay.
B12	Poor environmental performance of project could have potentially adverse effects on public health and safety.
B13	Project is schedule driven or project schedule is very tight.
B14	Project type has history of schedule overruns and/or disputes.
B15	Contractor has had or will have difficulty in achieving planned field progress.
B16	Project has long design life.
B17	Expected overall project life cycle is short.
B18	Project is part of overall capital program.
C. Budget/cost/economics	
C01	Project budgetary objectives are not established early in project cycle.
C02	Project budget is very tight and additional financing is not likely or possible.
C03	Conceptual cost estimates are too uncertain; bases for cost estimate contain too many uncertainties; and need to reduce uncertainty is associated with cost estimate.
C04	Current cost forecast is significantly over budget.
C05	More accurate estimate of cost contingency is needed.
C06	Traditional cost-estimating techniques have been deficient for this project type.
C07	Reliable cost estimate is needed in short amount of time.
C08	Project economics are marginal and/or management has no tolerance for any cost overrun.
D. Contracts/organization	
D01	Conflicts or disputes may escalate; litigation is likely.
D02	Selecting project execution strategy is difficult.
D03	Project will be design/build.
D04	Project participants have never worked together before.
D05	Major portions of work are being or will be subcontracted to various parties.
D06	Project team lacks trust, teamwork, and/or effective working relationship.
D07	One or more very large organizations is involved.
D08	Project involves geographically dispersed personnel.
D09	Contractor-bidders are prescreened or of very high quality.
D10	No VE study team is available.
D11	Getting adequate planning input from facility operators is usually difficult.
D12	Owner has no formal project delivery/contract method selection process.
D13	Project team involves many young, inexperienced personnel.
D14	Several stakeholder organizations have never worked together before.
D15	Much interest exists in training or becoming learning organization.
D16	Key project stakeholders are not sure VE would work.
E. Site conditions/existing facility	
E01	Project is outside of United States.
E02	Project involves uncertain preexisting conditions.
E03	Site or location poses many challenges.
E04	There are or will be hostile weather conditions at the site.
E05	Local transport infrastructure is available.

E06	Existing plant contains “hidden” capacity.
E07	Existing plant has had recent decrease in reliability or availability.
E08	Existing plant has history of plant maintenance problems and costs.
E09	Existing plant has seen increase in treatment, disposal, or recycling costs.
E10	Existing plant has seen increasing frequency of unexpected equipment breakdowns.
E11	Existing plant has history of difficulty in complying with certain governmental regulations.
E12	Local environmental activists have significant political and/or media influence.
E13	Site of existing plant is geographically isolated with limited availability of spare parts.
F. Facility scope and characteristics	
F01	Project has unique challenges: structural, environmental, etc.
F02	Project type is relatively new, at least for this owner.
F03	Project involves repetitive construction processes.
F04	Project is outside organization’s strongest experience.
F05	Project involves many new features, processes, or approaches.
F06	Project is regulatory or permit driven.
F07	Project involves potential liabilities with waste disposal.
F08	Project is very complex.
F09	Project involves numerous facility operating systems.
F10	Project involves maintenance-intensive equipment.
F11	Several opportunities exist for modularization and/or preassembly.
F12	Plant capacity objectives are not understood or agreed upon.
F13	Scope definition is incomplete.
F14	High likelihood exists of changes during project.
F15	Plant involves multiple feed stocks and products with many repeating elements.
F16	Project risks are not understood.
F17	Recent significant turnover occurred in owner organization.
F18	Project type is either building or light industrial.
G. Technologies/manufacturing process	
G01	New implementable project technologies have emerged that could replace old.
G02	Project could benefit from new technologies.
G03	Project involves new manufacturing technology.
G04	Project construction methods may involve or benefit from recent innovations.
G05	Project type will be significantly affected by technological change.
G06	There is no apparent leading technology, but several alternatives from which to choose.
G07	There has been no recent research and review of technology alternatives.
G08	Selecting most appropriate technology is difficult.
G09	Only a few technologies are usually considered.
G10	Technology transfer is too often unsuccessful.
G11	Mature manufacturing process has not been rigorously challenged.
G12	Relatively new manufacturing process has not been optimized.
G13	Manufacturing process has evolved incrementally.
G14	New potentially beneficial equipment monitoring technologies have become available.
G15	High degree of process reliability is required.
G16	Project involves mutually exclusive alternatives.
G17	Project involves repetitive processes.
H. Project design	
H01	Many system alternatives exist from which to choose.
H02	Equipment sizing parameters are somewhat uncertain.
H03	Design is largely driven by safety factors.
H04	Designers are too distant from relevant cost data and cost feedback.
H05	Designers need feedback on quality of service/product.
H06	Relationships between equipment cost and capacities are not well understood.
H07	Additional opportunities exist for design standardization.
H08	Design process has not emphasized functional need.
H09	Designs are often gold plated or contain excessive redundancy.
H10	Project involves performance-based specifications.
H11	Project solution is very conventional.
H12	Project involves some new/untried materials and/or construction methods.
H13	Project involves many highly congested configurations.

H14	Standardization in plant components is lacking.
H15	Excessive variation in spare parts is needed.
H16	High degree of or opportunity exists for design repetition.
H17	Feedstock and product logistics are very complex.
H18	Front-end or design phases will be or have been rushed.
H19	Contractor preferences regarding materials/methods may result in significant cost savings.
I. Facility operations/maintenance	
I01	Project involves costly equipment-monitoring technologies.
I02	Plant preferences are highly variable or inconsistent.
I03	Plant reliability is too uncertain.
I04	Project must have very high availability.
I05	Facility has very high energy consumption.
I06	Plant produces excessive amount of waste material.
I07	Facility is very expensive to operate.
I08	Project operation/maintenance costs will be very high and cost-saving innovations could be significant.
I09	Facility type involves frequent maintenance or repairs.
I10	Major contributors to forced plant downtime are not understood.
I11	Production unit is highly profitable with very costly downtime (opportunity cost).
I12	Accessibility for maintenance is/will be limited or difficult.
I13	Waste disposal or recycling capacity is very limited.
I14	Facility has symptoms of underperformance, such as occupant dissatisfaction or excessive energy consumption.
I15	Opportunities for maintainability efficiency improvements are suspected.
I16	Agreed-upon and reliable facility performance indicators are lacking.
I17	No effective process exists for identifying where and when facility component needs upgrading or replacing
J. Materials/equipment/procurement/supply chain	
J01	Inventory and/or backlog levels are excessively high.
J02	Large fluctuations do or will exist in the daily demand for resources.
J03	Timing of delivery of fabricated components is often unreliable.
J04	Economic conditions limit resource availability.
K. Site labor	
K01	Local skilled labor is or will be scarce.
K02	Local labor productivity is relatively or often low.
K03	Labor productivity is highly variable.
K04	Local labor wage rates are relatively high.
L. Procedures and communications	
L01	Some key players lack communication skills.
L02	Successful innovations are seldom repeated or reused.
L03	Mistakes or errors are repeated too often.
L04	Feedback on designer/contractor performance is rarely provided.
L05	A key work process is inefficient, performing below specification or with unacceptable variation in quality.
L06	A key work process has long cycle time or excessive cost.
L07	No recent, thorough review has been made of specifications, standards, and/or industry practices.
L08	Project team has no established comprehensive start-up planning procedures.
L09	No established procedure exists for integrating maintenance planning into planning, design, or construction.
L10	Need quick turnaround on VE recommendations.

References

Cha, H. S. (2003). "Selecting value management processes for implementation on capital facility projects." Ph.D. thesis, Univ. of Texas, Austin, Tex.

Clawson, R. H. (1970). *Value engineering for management*, Auerbach, New York.

Collins, P. M. (2001). "Adding true business value through value practices." *Proc., Society of American Value Engineers*, SAVE, Dayton, Ohio.

Construction Industry Institute (CII). (2003). "Introduction to the value management toolkit." *Research Summary No. 184-1*, Austin, Tex.

Dell'Isola, A. J. (1982). *Value engineering in the construction industry*, Van Nostrand Reinhold, New York.

Gage, W. L. (1967). *Value analysis*, McGraw-Hill, Berkshire, U.K.

Kelly, J., and Male, S. (1993). *Value management in design and construction*, E&FN SPON, New York.

Kerzner, H. (1984). *Project management: A systems approach to planning, scheduling and controlling*, Van Nostrand Reinhold, New York.

Kirk, S. J., and Spreckelmeyer, K. F. (1998). *Enhancing value in design decisions*, Kirk Associates, Grosse Pointe Park, Mich.

Koga, J. E. (2000). "Does value management have a place in project management?" *Proc., Society of American Value Engineers*, SAVE, Dayton, Ohio.

Lee, S. H. (2001). "Discriminant function analysis for categorization of best practices." Ph.D. thesis, Univ. of Texas, Austin, Tex.

Leung, M.-Y., Ng, S. T., and Cheung, S.-O. (2002). "Improving satisfaction through conflict stimulation and resolution in value management in construction projects." *J. Manage. Eng.*, 18(2), 68–75.

Macedo, M. C., Dobrow, P. V., and O'Rourke, J. J. (1978). *Value management for construction*, Wiley, New York.
McNeill, F. M., and Thro, E. (1994). *Fuzzy logic: A practical approach*, Academic, New York.
Miles, L. D. (1972). *Techniques of value analysis and engineering*, McGraw-Hill, New York.
O'Connor, J. T., Cha, H. S., and Salas, M. (2003). "Development of the value management toolkit." *Research Rep. 184-11*, Construction Industry Institute, Austin, Tex.
Oey, M. (2001). "Effects of selected practices on the cost performance of building projects." Ph.D. thesis, Univ. of Texas, Austin, Tex.
Saaty, T. L. (1980). *The analytic hierarchy process*, McGraw-Hill, New York.
Tam, C. M., Tong, T. K. L., Leung, A. W. T., and Chiu, G. W. C. (2002). "Site layout planning using nonstructural fuzzy decision support system." *J. Constr. Eng. Manage.*, 128(3), 220–231.
Zadeh, L. A. (1965). "Fuzzy sets." *Inf. Control.*, 8, 338–353.
Zayed, T. M., and Halpin, D. W. (2004). "Quantitative assessment for piles productivity factors." *J. Constr. Eng. Manage.*, 130(3), 405–414.