Optimizing Implementation of Value Management Processes for Capital Projects

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Abstract: A variety of innovative management processes are increasingly being introduced into the capital facility projects, thereby causing a great concern about which to implement on a particular project among project stakeholders. It is essential to identify the most effective process because varying circumstances on each project determine the level of suitability. This paper details a new systematic approach to determining the best process from among the 44 value management processes (VMPs) that can proactively achieve the articulated 12 project value objectives (PVOs). Throughout this paper, identifying and quantifying the selection principles (e.g., targeted PVOs, timing of initiation, project characteristics, and relative impact), the detailed research methodology and the findings from industry survey and VMP expert input are also illustrated. A computerized tool, programmed by Visual Basic Application on MS Excel, is described, and its ongoing validation process is also discussed. As a first-ever research, this paper contributes to a growing area of research, not only by providing a comprehensive and structured knowledge on the subject of VMPs, but also by developing a new method to effectively select the most beneficial VMPs. From the industry perspective, the results of this study, specifically the computerized selection tool, facilitate the implementation of the VMPs on the construction industry and maximize the potential benefits to a particular project.

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Introduction

Labor shortages, tight budgets, and rigid construction schedules are continuously creating a highly competitive business environment. To overcome these hardships, many management efforts have focused on project performance in terms of both construction project effectiveness and efficiency. One example is the Construction Industry Institute's (CII) best practices (BPs). If properly implemented, CII's BPs have been shown to enhance both project cost and schedule performance (Lee 2001; Oey 2001). Another example is the Independent Project Analysis' (IPA) value improving practices (VIPs). These VIPs are being increasingly introduced to construction projects to improve project profitability (McCuish and Kaufman 2002; Ruthven and Stripling 2002).

Although many innovative management processes are available in the industry, there has been remarkably little research on the subject of selection of these management processes. Furthermore, the selection method has been dependent on a manual system or an experienced individual's intuition. This approach, lacking in-depth analysis, fails to pinpoint the best management processes that can effectively maximize the value of a project. As a result, it has become a critical challenge to effectively select the most beneficial management processes for a particular capital facility project.

An alternative solution is to systemize the selection process in an analytic manner. This systematic selection process is advantageous for many reasons. First of all, the vast majority of available management processes are impractical to implement on a single project (Lenzer 2001; McCuish and Kaufman 2002). Individual organizations or agencies, as well as organizational institutions such as CII, IPA, and the Society of American Value Engineers (SAVE), are independently developing and supporting one or more management processes. Second, there are numerous factors to be considered when examining the magnitude of benefit of each management process. For example, the maximum benefit is leveraged by the circumstances which characterize a project. Third, the enhancement of efficiency has become a primary concern in the construction industry. A lean organization is a predominant pattern in the industry. As such, the identification of a limited number of qualified management processes is extremely significant.

This paper illustrates the "black box" of the selection process. Fundamental selection principles are described, and a detailed scheme for extracting the most suitable management process for a particular project is explained. The resulting computerized application tool is also described. With project information inputted into the system, the computerized tool generates the rank order of the potential management processes in terms of optimal project value.

The study methodology is primarily dependent on the effort of the CII Project Team (PT) 184. CII PT 184 was initiated in April 2001 to address the current status of value management processes

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Table 1. Value Management Processes by Context of Application

Broad application	Organizational	Planning	Design/construction	Operations/maintenance
Activity-based costing	Chartering project teams	Classes of facility quality	Construction simulation	Postoccupancy evaluation
Choosing by advantages	Knowledge management/ Lessons learned system	Constructability	Design effectiveness	
FAST diagrams	Minimum standards and practices	Design to capacity	Design for maintainability	
Individual value engineering	Partnering	Function analysis concept	Design to cost	
Life cycle costing	Quality functional deployment	Development Mechanical Reliability modeling	Energy optimization	
Peer review	Sourcing strategies	Modularization/Mass customization	Lean construction	
Risk-based estimating	Technology gatekeeper	Owner's values and expectations	Predictive maintenance	
Risk management	Total quality management	Planning for startup	Value engineering Change proposal	
Six sigma successive estimating		Preproject planning process Simplification		
Technology selection		Project delivery Methods		
Value engineering		Project execution Plan		
		Schedule Optimization		
		Sustainable design and construction		
		Waste minimization/ pollution prevention		

(VMPs) that have proven effective in the construction industry (Salas 2002). The members of CII PT 184 consisted of 17 project practitioners. Their experience and knowledge represented building and industrial projects from both private and public organizations.

For the purpose of this study, VMP is defined as any management effort or process that can proactively pursue articulated project value objectives (PVOs) (e.g., security/safety, cost efficiency, quality, schedule, environmental stewardship, and risk containment). This paper consists of six sections: Objectives and research limitations, background and literature review, VMP selection principles, VMP selection algorithm, selection tool validation strategy, and conclusions and recommendations.

Objectives and Research Limitation

The primary research objective in this study was to facilitate a VMP selection process for implementation on a particular capital facility project. To begin with, the selection principles were identified that might affect the magnitude of benefit from each VMP. Based on these principles, a new selection method was proposed with a computerized application tool.

During this research, four secondary objectives were also established. To increase the awareness of VMPs, one of these objectives was the development of structured knowledge of fragmentary VMPs. The second objective was the characterization of VMPs in terms of the timing benefit because each VMP has a different timing-benefit profile. The quantification of relative impact among the VMPs was the third objective. Finally, the identification of the project characteristics that trigger the implementation of one or more VMPs was included. The project characteristics are equivalent to project circumstances in need of one or more VMPs. Because not all the project characteristics have the same effect on the benefit of each VMP, it is also essential to assess the relative importance of each project characteristic in association with the VMPs.

Forty-four management processes are considered as the state-of-the-practice VMPs, based on the identification effort conducted by CII PT 184. Although some VMPs are interrelated with or overlapping one another, it is assumed that each VMP is independently applicable to a construction project. The complete list of VMPs is enumerated in Table 1. The listing covers the entire project's phases in its application, ranging from planning to maintenance.

Another research limitation regards the PVO. Although there are numerous PVOs customized to each individual project, there are 12 widely accepted PVOs considered in this paper. These PVOs are as follows:

- Security of personnel and facilities,
- Operations/maintenance safety and health,
- Construction safety and health,
- Regulatory compliance,
- Capital cost efficiency,
- Operating cost efficiency,
- Maintenance cost efficiency,
- Project/service quality,
- Construction quality,
- Schedule optimization,
- Environmental stewardship, and
- Containment of risk and uncertainty.

Finally, there is no existing standard in dividing the life cycle of a project. For the purpose of this study, five widely accepted categorizations are considered:

- Feasibility and planning,
- Detailed design,
- Procurement,
- Construction, and
- Operations/maintenance.

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Background and Literature Review

There is no single definition of value due to its abstract nature. Historically, value was classified by Aristotle into seven classes: Economic, political, social, aesthetic, ethical, religious, and judicial. However, economic value is the main concern of industry (Fasal 1972). Economic value consists of four types: Cost value, exchange value, esteem value, and use value (Clawson 1970; Fasal 1972). Cost value means the total monetary cost of a product or project. Exchange value refers to the scarcity of a product or project. Esteem value is highly subjective and difficult to measure, since it is determined by one's personal artistic feeling. Use value, the relationship of cost to function, is the fundamental element in economic value because the other value types are meaningless without this value (Clawson 1970; Fasal 1972).

From the practical perspective, "real value" is the relative outcome of conjoining different types of value (Fasal 1972). Miles (1972) defined value as the relationship between cost and performance. In other words, value is increased by enhancing performance or reducing cost. Clawson (1970) declared that value is the balance of the cost of essential function with quality, reliability, safety, appearance, and ease of maintenance. Accordingly, value can be defined as function with appropriate performance driven by its cost.

Value management is often interchangeably referred to as value analysis and value engineering in literature. An organized and creative approach to identify unnecessary cost (Miles 1972), value analysis focuses on analyzing a product or project to reduce its cost without affecting its function. Thus, sometimes value analysis is interpreted as a cost-reduction effort.

Value engineering, although it has the same root as value analysis, has evolved into a creative and systematic approach. In the literature, it is defined as an "organized and creative approach to optimize cost and performance of a facility" (Dell'Isola 1982; Zimmerman et al. 1982). Value management, however, is a continuously evolving dynamic concept (Macedo et al. 1978). One of the recent definitions of value management is a "systematic approach to maximize a client's value by continuously auditing throughout all project phases" (Kelly and Male 1993). For the purpose of this paper, value management is referred to as any management effort to meet a client's expectations in association with project value objectives.

As noted earlier, a set of 44 VMPs have been adopted by CII PT 184. Originally, the VMPs were based on widely accepted standard project management processes, derived from various resources. One resource is the benchmarking organizations in the construction industry, such as CII and IPA. Currently, CII recommends 13 BPs and 11 proposed best practices to be implemented in a project as the most beneficial VMPs. On the other hand, IPA supports 12 VIPs for the capital facility projects. The second category is VMP-related institutes; for example, the Lean Construction Institute, and the Quality Function Deployment Institute. These organizations strongly support a single VMP as being the most beneficial for a project. The final category is individual companies that solely develop their own innovative VMPs. The nominated VMPs, based on these categories, have been carefully and rigorously screened with four criteria.

The first criterion is that VMPs are nonconventional but innovative management processes. Accordingly, cost control, master scheduling, and safety management are excluded in the set of VMPs because of their conventionality in the area of project management. Second, the VMPs are optional, rather than essential, project management processes. Any of the VMPs can be a supplementary management process and selectively applicable to a project. The third criterion is that each VMP is a recognizably well-established process. The VMPs should follow a relatively well-documented process. As such, VMPs are either a successfully proven or demonstrable process. Finally, the 44 VMPs are significantly beneficial for capital facility projects. The complete list of 44 VMPs is enumerated in Table 1.

Because the VMPs are relatively new and innovative, it is necessary to define each VMP in a structured manner. This formalization summarizes key elements, such as objectives and leveraged project circumstances, while providing a standard body of knowledge on the context of value management in construction. An example of a formalized VMP, or VMP descriptive profile, is illustrated in the Appendix.

To document the VMP descriptive profiles, a rigorous literature review has been conducted. In addition, experiences of the project practitioners including CII PT 184 have been incorporated. Finally, the profiles were revised and refined numerous times. The descriptive profile of the identified 44 VMPs consists of nine elements as seen in the Appendix.

The first element of "Purpose and Objectives" describes why the VMPs should be implemented. Second, "Primary Benefits" details how the VMPs can benefit a project. The third element is "Key Output or Deliverable(s)" and deals with the end product of the VMPs. The fourth element, "Circumstances for Leveraged Application," describes the specific situations in which the VMPs have the highest impact. The fifth element, "Optimal Timing of Implementation," indicates the best initiation timing for the VMPs. The sixth element, "Lead Organization(s) for Implementation," suggests who should guide the effort of each VMP. Critical participants are described in the seventh element, "Other Participants." "References for More Information" is the eighth element and it explains where more information can be found. Finally, "Sequence of Steps in the Process" illustrates how the respective VMPs are implemented.

The definitions of value and value management and how the 44 VMPs have been identified and described in a structured manner have been previously discussed. The VMP selection issues are overviewed in the rest of this section. At the time of this writing, the VMP selection is completely dependent on a manual-based process. Moreover, only recently were the selection issues addressed in the construction industry. One of the pioneering efforts was conducted by McCuish and Kaufman (2002), who developed a "project matrix" to assess a project by comparing the base project value with the anticipated project value. A set of potential VIPs (or VMPs) was then extracted in a manual basis. It is noteworthy that only a limited number of VMPs are used in this selection method. In addition, this method fails to justify the outcome of the selection process.

Another selection method, conducted by Ruthven and Stripling (2002), introduced a team-based selection approach. The 12 VIPs (or VMPs) were categorized into five groups based on their relative impact on a pipeline project. Although they attempted to classify these VMPs in terms of their relative impact, this method is no more than a manual selection that lacks both an analytic and a systematic approach. As a result, none of the previous research has been successful in elaborating on the issues of VMP selection.

The project value objective is a fundamental component in the VMP selection process. It is critical that project objectives should be established at the initial stage of a project (CII 1989). For the purpose of effectively selecting the best-fit VMPs, 12 PVOs have been identified, and the relationship between each PVO and VMP has been determined. As a result of the group consensus reached

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by CII PT 184, this relationship is tabulated in Table 2. The 12 PVOs are briefly discussed:

- "Security of Personnel and Facilities," which is important especially if a project is open to the public, relates to the protection of the personnel and/or facility. It also relates to the acquisition of a higher-level safeguard for people and/or facilities.
- "Operations/Maintenance Safety and Health" relates to the protection of an end-user's safe operation and maintenance of a facility. It is oriented to reduce the possible innate accidents in operating and maintaining the facility.
- "Construction Safety and Health" relates to minimizing the occurrence of safety and/or health problems during a construction phase. It is beneficial to predict the unsafe construction methods that can otherwise cause a worker's safety and health problems.
- "Regulatory Compliance" relates to the identification of regulatory restrictions that has become a great concern in the construction project because of a growing number of regulatory agencies. It is mandatory to check whether the project violates the regulatory requirements, such as zoning and other ordinances.
- "Capital Cost Efficiency" focuses on the elimination of unnecessary cost items that negatively affect the total installed cost. Cost efficiency increases by omitting or replacing a variety of cost items with alternatives.
- "Operating Cost Efficiency" concerns high energy-consuming projects. It focuses on an optimization of operating costs required to operate the facility, such as energy and waste removal costs.
- "Maintenance Cost Efficiency" relates to the reliability of operating a facility. It is concerned with the repair and replacement of elements comprising a facility.
- "Project/Service Quality" focuses on the client's satisfaction with the final product or project. It is different from construction quality because it is related to the quality of a design.
- "Construction Quality" means the compliance of facility quality with design quality. Construction quality is strongly related to the right use of materials and methods that are associated with a given project.
- "Schedule Optimization" relates to a timely completion of a project with optimized resource allocation. It is considered to be significant if a delayed schedule negatively affects the success of a project.
- "Environmental Stewardship" relates to reducing any potential impact of a project on the environment and surrounding community. It involves the prevention of pollution and preservation of natural resources.
- "Containment of Risk and Uncertainty" relates to eliminating project risks and uncertainties. The risk and uncertainty can be fully contained by exact risk assessment and appropriate risk control planning.

As represented in Table 2, the frequently iterated PVOs are Capital Cost Efficiency (35) and Containment of Risk and Uncertainty (37). These results indicate that capital costs and risk containment are the primary concerns in implementing most of the VMPs.

In addition to PVOs, the timing of implementation affects the selection of VMPs because each VMP has an optimal timing in initiating the implementation. Just as many experts maintain that earlier effort is important to maximize the benefit (Gibson et al. 1995), the magnitude of benefit varies according to the initial timing of implementing VMPs. Because there is no existing standard in classifying a project life cycle, five major milestones are considered in this paper as follows:

- "Feasibility/planning phase" involves a conceptual project planning in which the project viability is determined by means of marketing, technical, and profitability studies.
- "Detail design phase" involves detail drawings, detailed construction specifications, and structural calculations that are needed to proceed with the construction process.
- "Procurement phase" involves a bidding process in which contractual proposals are prepared and a detailed project delivery method is planned and executed.
- "Construction phase" involves a construction execution in which jobsite monitoring and controlling are conducted.
- "Operation/maintenance phase" directly relates to the prolongation of a project's lifetime, and it continues until a project terminates.

Finally, the selection of VMPs depends on the leveraged project characteristics. Project characteristics are defined as project circumstances in need of implementing one or more VMPs. In other words, project characteristics are causal factors that trigger the VMP implementation on a given project.

Project characteristics for each VMP have been identified based on a trial-and-error approach in association with a rigorous literature review and experienced knowledge of experts. To effectively identify these characteristics, an influence diagram method has been employed. This technique is an effective tool to identify significant variables and to graphically model their interrelationship with each other.

As a result of identifying the project factors, 149 project characteristics have been finalized in an explanatory format and classified into 12 categories in terms of their relatedness. These categories include "owner characteristics (4 items)," "project objectives/performance (18 items)," "budget/cost/economics (8 items)," "contracts/organization (16 items)," "site conditions/existing facility (13 items)," "facility scope and characteristics (18 items)," "technologies/manufacturing process (17 items)," "project design (19 items)," "facility operations/maintenance (17 items)," "materials/equipment/procurement/supply chain (5 items)," "site labor (4 items)," and "procedures and communications (10 items)."

Value Management Process Selection Principles

In this section, the scoring metric systems and the findings from the weighting results are discussed. The schematic diagram of Fig. 1 illustrates the interrelationship among VMP selection principles.

The first selection principle is PVOs. The primary PVO of a project can effectively filter out any irrelevant VMPs from the set of 44 VMPs. Thus, the primary project objectives play an important role in generating core VMPs to be further analyzed.

The timing of VMP initiation is the second selection principle. Because each VMP has its own optimal timing of implementation, a discrepancy between the current phase of a target project and the optimal timing of VMP can reduce the magnitude of the maximum benefit. Nonetheless, it should not be neglected that if the current project phase is earlier than the optimal timing, the project can still have the maximum benefit.

Third, the relative impact among VMPs is included in the selection process. According to a recent study, the level of enhancement in terms of project performance varies with different types of VMPs (Lee 2001). In addition, it is a common belief that

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Table 2. Value Management Processes (VMPs) by Project Value Objectives

VMP title	Security of personnel or facilities	Operations/ maintenance safety or health	Construction safety and health	Regulatory compliance	Capital cost efficiency	Operating cost efficiency	Maintenance cost efficiency	Product or service quality	Construction quality	Schedule optimization	Environmental stewardship	Containment of risk or uncertainty
	Primary project value objectives											
Activity-based costing					√					√		√
Chartering project teams												√
Choosing by advantages					√	√	√	√	√			√
Classes of facility quality					√	√	√	√	√			√
Constructability			√		√				√	√		√
Construction simulation					√					√	√	
Design effectiveness								√	√	√	√	
Design for maintainability						√	√					
Design to capacity					√	√	√					
Design to cost					√							√
Energy optimization					√	√					√	
FAST diagrams	√			√	√	√	√	√			√	√
Function analysis concept development	√	√		√	√	√	√	√		√	√	√
Individual value engineering	√				√	√	√	√				√
Knowledge management/lessons learned system	√	√	√	√	√	√	√	√	√	√	√	√
Lean construction					√					√		√
Life cycle costing					√	√	√					√
Mechanical reliability modeling						√	√	√				√
Minimum standards and practices		√	√	√	√	√	√					
Modularization/mass customization			√		√		√		√	√		
Owner values and expectations	√	√	√	√	√	√	√	√	√	√	√	√
Partnering					√				√	√		√
Peer review	√	√	√	√	√	√	√	√	√	√	√	√
Planning for startup	√	√		√		√	√	√		√	√	√
Postoccupancy evaluation						√	√	√				√
Predictive maintenance						√	√					√
Preproject planning	√	√	√	√	√	√	√	√	√	√	√	√
Process simplification					√	√	√	√				√
Project delivery methods					√				√	√		√
Project execution plan			√	√	√	√	√	√	√	√		√

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Table 2. (*Continued.*)

	Primary project value objectives											
VMP title	Security of personnel or facilities	Operations/ maintenance safety or health	Construction safety and health	Regulatory compliance	Capital cost efficiency	Operating cost efficiency	Maintenance cost efficiency	Product or service quality	Construction quality	Schedule optimization	Environmental stewardship	Containment of risk or uncertainty
Quality functional deployment				√	√	√	√	√	√			√
Risk-based estimating					√							√
Risk management	√	√	√		√			√	√	√		√
Schedule optimization				√	√					√		√
Six sigma	√	√	√	√	√	√	√	√		√		√
Sourcing strategies					√			√		√		√
Successive estimating					√							√
Sustainable design and construction		√		√		√	√				√	√
Technology gatekeeper	√	√	√	√	√	√	√	√	√	√	√	√
Technology selection	√	√	√	√	√	√	√	√	√	√	√	√
Total quality management	√	√	√		√	√	√	√	√	√	√	√
Value engineering change proposal					√	√	√			√		√
Value engineering	√	√	√	√	√	√	√	√	√	√	√	√
Waste minimization/ pollution prevention		√		√		√					√	√
No. VMPs with benefit	14	15	14	17	35	29	28	23	18	24	16	37

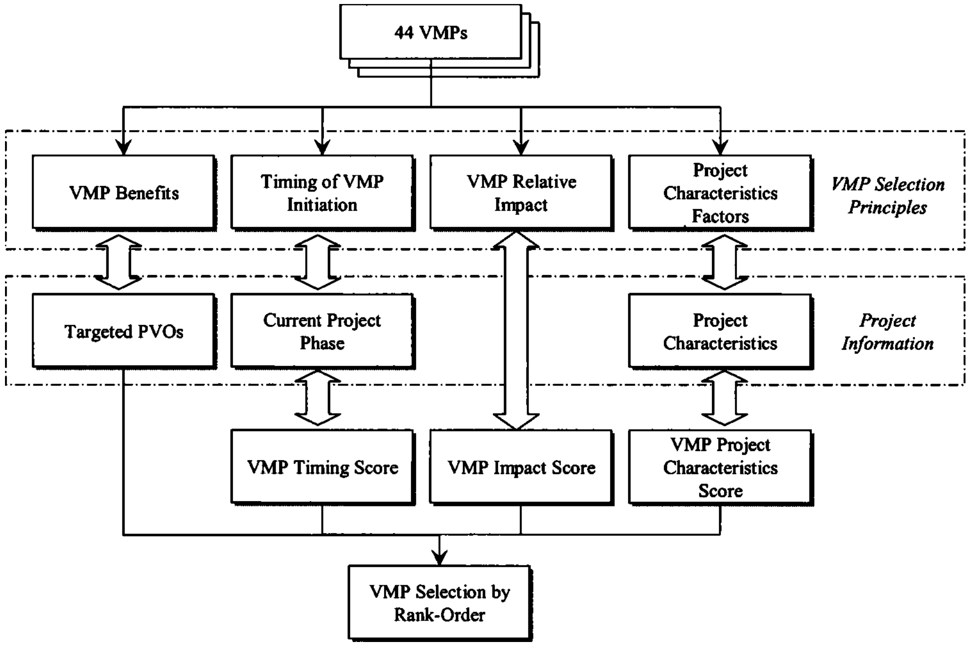

Fig. 1. Value management process selection principles and relationship

each VMP has a different magnitude of impact on a project. Consequently, the relative impact of each VMP should be considered to be a significant factor in the selection process. For the purpose of this study, it is assumed that the relative impact, or relative importance of VMP, is quantifiable, and these quantified impact scores are not affected by either the project phase or project circumstances.

The final selection principle is the project characteristics. Just as a prescription without a diagnosis is malpractice, the project characteristics (i.e., leveraged circumstances) must be included in the selection process. Moreover, how a project is characterized makes a big difference in the magnitude of a benefit from a particular VMP.

To effectively apply these four selection principles to the VMP selection, scoring metric systems have been developed for the timing, relative impact, and project characteristics associated with each VMP.

The timing metric system represents the maximum benefit that can be achieved at different project phases, such as planning, design, procurement, construction, and operation/maintenance. This scoring system has been developed by comparing VMPs in terms of relative benefit at each project phase. These metric scores are useful in rank-ordering VMPs based on the magnitude of benefit that a project can at most obtain given the current project phase.

Second, the relative impact metric system represents the magnitude of relative impact that can be fully achieved in implementing the respective VMPs. This system has been developed by pair-wise comparison among 44 VMPs. These metric scores are useful in rank-ordering VMPs regardless of the project phase or the project characteristics.

The final project characteristics metric system reveals the relationship between each VMP and its corresponding project characteristics. It also represents the relative importance of project characteristics associated with the VMPs. This system is useful in rank-ordering VMPs in terms of the degree of suitability to a given project.

The primary methodology used in developing these metric systems was iterative internal workshops conducted by CII PT 184. To create the timing scores, a trial-and-error approach was used to reach a group consensus. The maximum score of "10" was provided to the optimal timing of each VMP. On the contrary, the minimum score of "0" was provided given that a project phase gets no benefit from implementing a VMP. This 0 to 10 base scoring system applies to each project phase in terms of a relative importance of the respective VMPs.

On the other hand, the group consensus approach made it difficult to quantify the relative impact of each VMP. For this metric system, the top-ten-and-bottom-ten approach was introduced. Each PT member was required to group top-ten VMPs with a higher impact and to group bottom-ten VMPs with a lower impact. During this process, both experiences and personal preferences were incorporated. The top-ten VMPs were given the score "1" and the bottom-ten VMPs were given the score "−1." Then, for each VMP, the summed-up score was computed by adding up the scores that were provided by each member. Finally, by normalizing the summed-up scores, each VMP was given the relative impact score based on the scale of 0.6 to 1.0.

It was not simple, however, to develop the project characteristics metric system because both the number of VMPs and the number of the project characteristics were enormously large. In addition, some of the VMPs were relatively new to PT members. As a result, the Delphi technique was introduced to establish the project characteristics metric system. This technique is a useful tool to employ a pooled intelligence (Emory et al. 1991). At first, the VMP experts who were knowledgeable in one or more VMPs were identified. To facilitate the data collection process, the relatively significant project characteristics were selected instead of listing all 149 factors. Then, the data collection tool, or VMP ballot, was developed to collect the relative importance of each project characteristic within the respective VMPs. For each VMP, the five-point Likert scale (0: No importance, 1: Low importance, 3: Moderate importance, 4: Somewhat important, 5: High importance) was used. The final weights of the project characteristics were determined by averaging the scores given by each expert respondent. The total number in the expert respondents group was

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Table 3. Value Management Processes (VMP) Timing Scores

VMP	Feasibility and planning	Detailed design	Procurement	Construction	Operations/maintenance
Activity-based costing	10	9	4	4	0
Chartering project teams	10	3	3	3	0
Choosing by advantages	10	9	5	2	2
Classes of facility quality	10	0	0	0	0
Constructability	10	8	3	2	0
Construction simulation	0	0	0	10	0
Design effectiveness	0	10	0	0	0
Design for maintainability	10	9	0	0	0
Design to capacity	10	4	0	0	0
Design to cost	10	7	0	0	0
Energy optimization	10	6	0	0	0
FAST diagrams	10	9	3	2	2
Function analysis concept development	10	4	0	0	0
Individual value engineering	10	6	0	0	0
Knowledge management/LL systems	10	7	6	6	7
Lean construction	7	10	8	6	0
Life cycle costing	10	9	2	1	3
Mechanical reliability modeling	10	5	0	0	0
Minimum standards and practices	10	5	3	2	2
Modzn/mass custom.	10	5	0	0	0
Owners values and expectations	10	4	1	1	0
Partnering	10	9	8	7	2
Peer review	10	9	6	5	0
Planning for startup	10	9	3	2	0
Postoccupancy evaluation	0	0	0	10	10
Predictive maintenance	10	9	0	0	0
Preproject planning	10	3	0	0	0
Process simplification	10	0	0	0	0
Project delivery methods	10	0	0	0	0
Project execution plan	10	6	3	2	0
Quality Funl Deploy.	10	4	0	0	0
Risk management	10	8	5	3	3
Risk-based estimating	10	5	0	0	0
Schedule optimization	10	6	3	2	0
Six sigma	10	9	7	3	5
Sourcing strategies	10	8	4	3	0
Successive estimating	10	4	0	0	0
Sustainable design and construction	10	9	5	3	0
Technology gatekeeper	10	4	2	1	3
Technology selection	10	3	0	0	0
Total quality management	10	5	4	3	4
Value engineering	10	9	3	2	1
Value engineering	0	9	10	10	0
Waste minimum/pollution prevention	10	5	0	0	0

51. It is noteworthy, however, that the "outlier" data points were eliminated based on the frequency distribution, and only high-ranked project characteristics were involved in computing the weights of each VMP.

The weighting or scoring results of each metric system are discussed in the rest of this section. In Table 3, the results of the VMP timing scores are tabulated.

Most of the highest scores fall under the feasibility/planning phase although, for some featured VMPs, the highest score falls under a particular project phase. Once the timing scores of each VMP are accumulated and these summed-up scores are arrayed in terms of project phase, a timing-benefit curve of VMP can be derived as seen in Fig. 2.

This curve is remarkably consistent with the typical timing-influence curve that represents a significant low benefit at the construction and operation/maintenance phases compared with

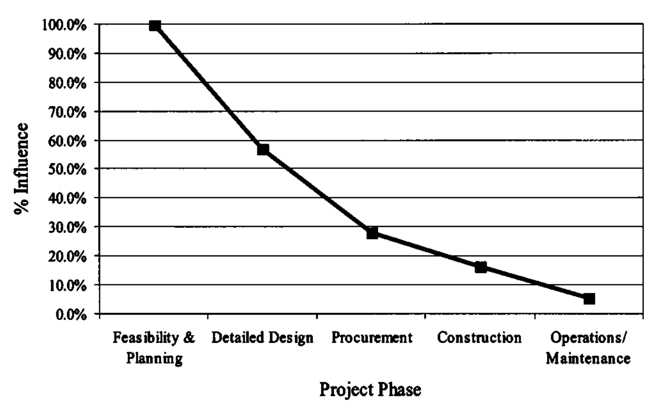

Fig. 2. Timing-benefit curve of value management processes

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Table 4. Value Management Processes (VMP) Impact Scores

VMP title	Impact score
Preproject planning	1.0
Owner values and expectations	1.0
Project execution plan	0.9
Value engineering	0.9
Risk management	0.9
Constructability	0.9
Life cycle costing	0.9
Schedule optimization	0.9
Function analysis concept development	0.9
Planning for startup	0.9
Process simplification	0.8
Knowledge management/lessons learned system	0.8
Design for maintenance	0.8
Design to capacity	0.8
Chartering project teams	0.8
Minimum standards and practices	0.8
Technology selection	0.8
Classes of facility quality	0.8
Modularization/mass customization	0.8
Energy optimization	0.8
Sustainable design and construction	0.8
Six sigma	0.8
Project delivery methods	0.7
Design effectiveness	0.7
Individual value engineering	0.7
Construction simulation	0.7
Value engineering change proposal	0.7
Waste minimum/pollution prevention	0.7
Lean construction	0.7
Peer review	0.7
Partnering	0.7
Mechanical reliability modeling	0.7
Sourcing strategies	0.7
Risk-based estimating	0.7
Postoccupancy evaluation	0.7
Predictive maintenance	0.7
Technology gatekeeper	0.7
FAST diagrams	0.7
Quality functional deployment	0.7
Total quality management	0.6
Choosing by advantage	0.6
Activity-based costing	0.6
Successive estimating	0.6
Design to cost	0.6

the planning and detail design phases. With this similarity, the timing scores can be interpreted to be fairly compelling.

The relative impact scores of each VMP are illustrated in Table 4. Compared with other VMPs, preproject planning and owner values and expectations have the highest impact score of "1.0." It is noted, however, that these scores require a rigorous validation because the scores do not represent the absolute magnitude of impact. In other words, the difference between two scores does not exactly account for the same amount of the difference in the magnitude of impact.

The partial weighting results of the project characteristics are shown in Table 5. As illustrated, each VMP is linked to different project characteristics in which a project can effectively benefit from the corresponding VMPs. These top-ten project characteristics are derived from the ranking order of the summed-up weightings of each project's characteristics. Accordingly, these characteristics are interpreted as the most significant factors in need of implementing most of the VMPs. As shown in Table 5, the life cycle cost is crucial in consideration of implementing VMPs. What follow next are the team alignment and the project objective setting. The complexity and new project features are also ranked high. It can be concluded that the benefit of VMPs increases when a project is placed in one of the previously described project circumstances.

Value Management Process Selection Algorithm

The metric systems regarding the VMP selection principles have been previously discussed. In this section, the proposed VMP selection algorithm is elucidated. In Fig. 3, the overview of the VMP selection logic is illustrated.

The selection methodology is aimed at ranking the VMPs in terms of the magnitude of benefit by combining four selection principles. The systemized selection process involves four VMP matrixes (e.g., PVO matrix, timing matrix, relative impact matrix, and project characteristics matrix) as described in the previous sections. These matrixes are all combined into the composite score to rank the suitability of VMPs for a project except for the PVO matrix. The PVO matrix is used in filtering high-potential VMPs. Thus, this matrix is optional in the selection process because it functions only if there are specific project value objectives. Nonetheless, this matrix curtails the whole selection process by limiting the number of VMPs in the beginning because the one or more selected PVOs automatically extract the candidate VMPs linked with this matrix.

Once the candidate VMPs are established by using the PVO matrix or ruling out the irrelevant VMPs, the current project phase is required to be input into the selection system. The timing matrix at this point is used to derive the timing scores of the candidate VMPs. It is also required that the system users single out the current project phase from five options (e.g., feasibility/planning, detailed design, procurement, construction, and operations/maintenance). The third matrix of the project characteristics functions to score the VMPs using the project characteristics metric system. Because the candidate VMPs vary project by project, the listing of the project characteristics which are related to one or more VMPs is also variable. Preventing the generation of the full set of 149 project characteristics, this matrix enables the selection of the relevant project characteristics linked to the candidate VMPs. If the list of the project characteristics is prepared, the system demands the users to evaluate each project characteristic with an option of either agreement or disagreement. The candidate VMPs are scored by summing up the weights of the project characteristics based on the user's characterization of a given project. The final relative impact matrix functions to score the candidate VMPs in terms of the relative magnitude of impact. The relative impact scores of each VMP are shown in Table 4.

A single score has to be created to combine the three VMP scores, i.e., timing score, relative impact score, and project characteristics score. This single score, or VMP composite score, is computed using the following equation:

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Table 5. Project Characteristics Score Matrix (Partial)

Rank		Project characteristics	Sum weight	Activity-based costing	Charactering project teams	Choosing by advantages	Classes of facility quality	Constructability	Construction simulation	Design effectiveness
1	B07	Reducing facility life cycle cost is an important objective	1.398	0.11						
2	B01	Project objectives, functional requirements, and/or priorities are unclear or have not been agreed upon	1.169		0.15		0.14			
3	A01	Owner lacks in-house resources for project development and execution	1.136		0.11					
4	F05	Project involves many new features, processes, or approaches	0.887							
5	B06	Owner objectives/expectations are often in conflict	0.861		0.14	0.14	0.13			
6	F08	The project is very complex	0.856	0.14				0.11		
7	B11	The project has an aggressive schedule with high opportunity costs associated with any delay	0.852							0.12
8	B09	Team alignment on the owner's expectations is difficult yet critical to success	0.844		0.15		0.12			
9	B02	Project type has a history of poor performance/liability	0.827							0.12
10	B10	Early completion is of high value to owner	0.764					0.11		

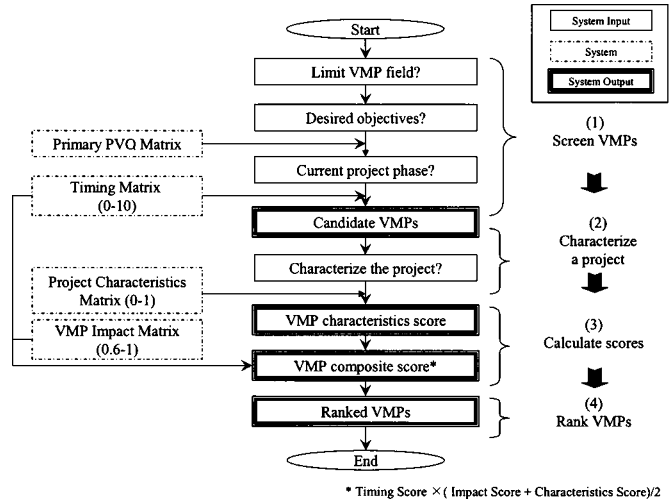

Fig. 3. Value management process selection tool logic flowchart

$$\text{Value Management Process Composite Score} = \text{Timing Score} \times (\text{Relative Impact Score} + \text{Project Characteristic Score})/2$$

With this equation, the VMP composite score can be derived ranging from 0 to 10. The timing score that is dependent on the current project phase considers the subsequent project phases. For example, if the current project phase is feasibility and planning, the timing score is equivalent to the maximum value among the five timing scores. The earlier a project is put into place, the greater the chance the project gets to earn a higher VMP score.

The average score of relative impact and project characteristics can be interpreted as how powerful the VMP is for a given project. As previously described, the relative score is based on the minimum of 0.6 and the maximum of 1.0, and the project characteristics score ranges from 0 to 1, according to the results of the project characterization.

A computerized application tool was designed for the purpose of enhancing the efficiency of the selection process. Microsoft Excel Visual Basic Application software version 6.3 was used in the tool development. The introduction screen of this program is illustrated in Fig. 4.

This computerized tool consists of seven primary screens and two supplementary screens. A brief instruction is shown in the

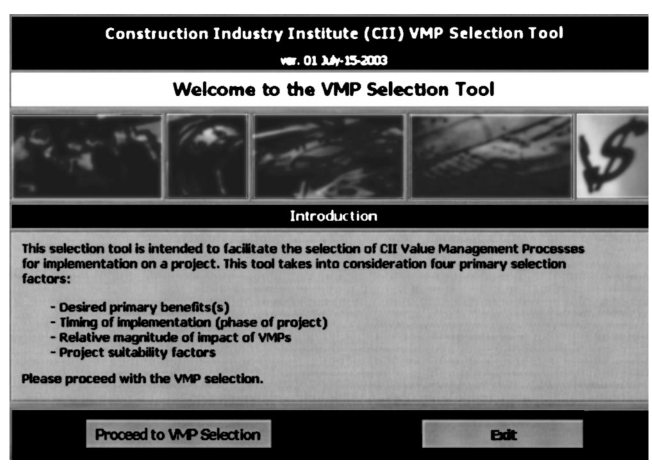

Fig. 4. Value management process selection tool introduction screen

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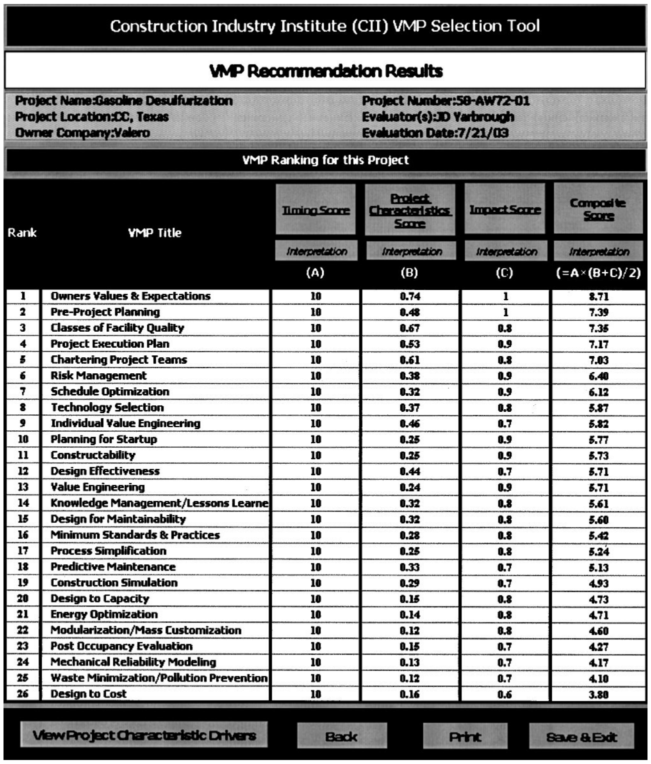
Construction Industry Institute (CII) VMP Selection Tool

VMP Recommendation Results

Project Name:Gasoline Desulfurization
Project Location:CC, Texas
Owner Company:Valero
Project Number:58-AW72-01
Evaluator(s):JD Yarbrough
Evaluation Date:7/21/03

VMP Ranking for this Project

Rank	VMP Title	Timing Score Interpretation (A)	Project Characteristics Score Interpretation (B)	Impact Score Interpretation (C)	Composite Score Interpretation (=A×(B+C)/2)
1	Owners Values & Expectations	10	0.74	1	8.71
2	Pre-Project Planning	10	0.48	1	7.39
3	Classes of Facility Quality	10	0.67	0.8	7.35
4	Project Execution Plan	10	0.53	0.9	7.17
5	Chartering Project Teams	10	0.61	0.8	7.03
6	Risk Management	10	0.38	0.9	6.40
7	Schedule Optimization	10	0.32	0.9	6.12
8	Technology Selection	10	0.37	0.8	5.87
9	Individual Value Engineering	10	0.46	0.7	5.82
10	Planning for Startup	10	0.25	0.9	5.77
11	Constructability	10	0.25	0.9	5.73
12	Design Effectiveness	10	0.44	0.7	5.71
13	Value Engineering	10	0.24	0.9	5.71
14	Knowledge Management/Lessons Learne	10	0.32	0.8	5.61
15	Design for Maintainability	10	0.32	0.8	5.60
16	Minimum Standards & Practices	10	0.28	0.8	5.42
17	Process Simplification	10	0.25	0.8	5.24
18	Predictive Maintenance	10	0.33	0.7	5.13
19	Construction Simulation	10	0.29	0.7	4.93
20	Design to Capacity	10	0.15	0.8	4.73
21	Energy Optimization	10	0.14	0.8	4.71
22	Modularization/Mass Customization	10	0.12	0.8	4.60
23	Post Occupancy Evaluation	10	0.15	0.7	4.27
24	Mechanical Reliability Modeling	10	0.13	0.7	4.17
25	Waste Minimization/Pollution Prevention	10	0.12	0.7	4.10
26	Design to Cost	10	0.16	0.6	3.80

View Project Characteristic Drivers | Back | Print | Save & Exit

Fig. 5. Value management process selection tool results screen

"introduction" screen. The second "project information" screen requires users to input the project information [e.g., project name, project number, project location, owner company, evaluator(s) name, and evaluation date]. The third screen, "VMP screening," enables users to choose an option to limit the candidate set of VMPs. The purpose of VMP screening is to limit the number of VMPs by filtering only high-impact VMPs. The screening process can be achieved by either using the PVO matrix or eliminating specific VMPs.

Under the VMP screening, there are two optional screens. One optional screen is the "project value objectives" that contains the listing of 12 project value objectives with option buttons attached to the respective value objectives so that the candidate VMPs can be elicited based on the users'input. The second optional screen is the "excluding VMPs" that enables the users to eliminate any VMPs listed on the screen by activating the corresponding VMP option buttons. The fourth of the primary screens is the "confirmation of VMPs" and it helps the users to reassure the candidate VMPs and enables them to finalize the set of VMPs to be considered in the selection process. The fifth primary screen, "project characterization," enables the users to characterize the project by answering each project characteristic statement that is generated based on the project characteristics matrix. The sixth screen, "ranking results," shows the rank-order of the candidate VMPs by the "VMP composite score." An example of the ranking results screen is pictured in Fig. 5.

This screen recommends the implementation of the high-scored VMPs with the following interpretation guidance:

- If >7: VMP is highly recommended for implementation.
- If 5 to 7: VMP is recommended for implementation.
- If 3 to 5: VMP may be recommended for implementation but additional analysis is needed.
- If <3: VMP is not recommended for implementation.

The final screen, "top suitability factors," shows the justification of the VMP rank order by listing the high-scored project characteristics of high-ranked VMPs. This screen is helpful to predict the vulnerability of the project in the context of project value improvement.

Selection Tool Validation Strategy

Although the metric scores in the proposed system are based on the expertise of both project practitioners and experienced experts, this system is required to be tested and verified throughout its actual application to real projects. This validation can be achieved by comparing the manual-based-outcome with the system-based outcome. There are two different objectives in the validation process. The first objective is to verify each metric system (e.g., timing score, relative impact score, and project characteristics score). This validation can verify whether the metric systems are convincing in the VMP selection. If there is a big difference between the manual-based and the system-based outcome, this validation provides some hints for modifying each metric system.

Specifically, it verifies whether the impact score basis of "0.6" is appropriate because the impact score of the VMP should not dominate the selection process. The second objective is to verify the composite score algorithm. Throughout the validation, the composite score equation is verified in terms of whether it is correctly applicable in the VMP selection. If there is a remarkable difference between the manual-basis and the system-driven outcome, that difference provides guidance for modifying the proposed equation.

A strategic validation process consists of five steps. First, a project with a core project team is selected. Second, the limited set of applicable VMPs is identified by the core team. In the third step, the manual-based selection method is applied based on both a completely intuitive approach and a step-by-step approach. In the step-by-step approach, the core team is required to rank-order VMPs based on the five criteria (e.g., project value objectives, relative impact, timing of initiation, project characteristics, and the combination of these four selection principles). In the fourth step, the systemized selection tool is applied in the same project. Finally, the results of the rank-order of VMPs are compared and discussed with the core team in the fifth step.

This validation strategy is advantageous in many ways. It is easy to recognize any defects of the system by a pair-wise comparison that makes it possible to modify the proposed VMP metric scores, specifically the relative impact scores. It also provides guidance in how to interpret the composite scores. Although the VMP composite scores are previously interpreted, it would be more constructive if these score ranges are verified with the help of this validation process. At the time of this writing, eight real projects have been volunteered for the validation process. The detailed validation results will be presented in full in a subsequent paper.

Conclusions and Recommendations

The construction industry environment has become "megachallenging" because of both internal and external factors. Internally, construction projects are more integrated and complicated. Moreover, technology-driven projects with limited resource availability have become most common. From the external perspective, the

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business climate is highly competitive and involves numerous project stakeholders within a single project. To surmount these difficulties, the innovative VMPs are introduced and proven effective in the construction industry. Overwhelmed by the number of these VMPs, the selection process is dependent on a nonsystemized or hit-and-miss approach that results in the failure to select the best-fit VMPs.

To solve these problematic situations, this paper proposes an unprecedented selection mechanism for the purpose of systematically pointing out the most suitable VMPs for capital facility projects. This newly developed selection method is based on the identification and quantification of the selection principles (e.g., PVO, timing of initiation, relative impact, and project characteristics). Furthermore, a computerized application tool has been developed to facilitate this selection process. The preliminary pilot tests of this tool effectively rank ordered the selected 44 VMPs in terms of suitability for a particular project, although rigorous validation tests have yet to be completed.

Additionally, the present study identified 149 leveraged project characteristics that can trigger one or more VMPs, and these characteristics are categorized into 12 classes. Based on the knowledgeable expert input, the significant project characteristics in need of VMPs are presented in this paper (see Table 5). In addition, the degrees of interrelationship between these project characteristic factors and the VMPs are measured to fit in the systemized selection process. Indeed, the leveraged project characteristics can be useful in deciding the application of the VMPs to a project to maximize its value.

As a first-ever research on this subject, this paper contributes to a growing area of research not only by providing comprehensive and structured knowledge of VMPs, but also by developing a selection method to pinpoint the most beneficial VMPs. From the industry perspective, the results of this study, especially the computerized selection tool, facilitate the implementation of the VMPs on the construction industry and maximize the potential benefits to a particular project.

However, an in-depth tool validation should be conducted by expanding the number of projects and modifying the proposed selection methodology. Although the project characteristics are identified and quantified in this study, a more rigorous investigation can be made by expanding the respondent VMP expert pool. Further research can also pursue the synergetic effect on VMPs by determining the benefit of combining VMPs, because the magnitude of benefit can vary according to the collaboration of two or more VMPs.

Acknowledgments

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Appendix. Example of Value Management Process Descriptive Profile

VM Process:	**Function Analysis Concept Development ("FAC-D")**

Purpose & Objectives:

- To efficiently and quickly "rough-out" an agreed-upon conceptual design for the facility and resolve all significant design and budget issues through an intense 2-week workshop involving all key stakeholders and design personnel
- A scaled-down 3 to 5 day version (called a "charette") is another option for smaller, less complicated projects

Primary Benefit(s):

- Buy-in of conceptual design by customer authority and facility users
- Early documentation and resolution or tasking of all significant design and budget issues/conflicts
- Early Value Engineering analysis where appropriate, thereby enhancing capital cost value and operating cost value
- Partnering-like team-building effects, including alignment of all key stakeholders on approval of the conceptual design
- Project review at 35% design complete that has few surprises and is more easily accomplished
- Reduced need for subsequent redesign, change orders, etc.; may experience some acceleration in the overall design phase
- Identification of key contacts needed for the detailed design phase

Key Output or Deliverable(s):

- "Best value" agreed-upon conceptual design for facility that is within budget
- Clear understanding of remaining issues needing attention/resolution

Circumstances for Leveraged Application:

- For projects with multiple unaligned customers or customers with conflicts
- For the most challenging projects, which may be technically complex or unique
- For projects with tight budgets and TIC over $5 Million
- For foreign projects involving diverse stakeholders

Optimal Timing of Implementation:

- Two-week workshop should be scheduled to begin two to three months after the start of conceptual design; This will allow adequate time for site survey, customer interviews, and development of first conceptual design for critique/feedback during the workshop

Lead Organization(s) for Implementing:

- Owner project management
- Planning/design contractor
- Independent experienced facilitator that leads the process and helps ensure quality of output

Other Participants:

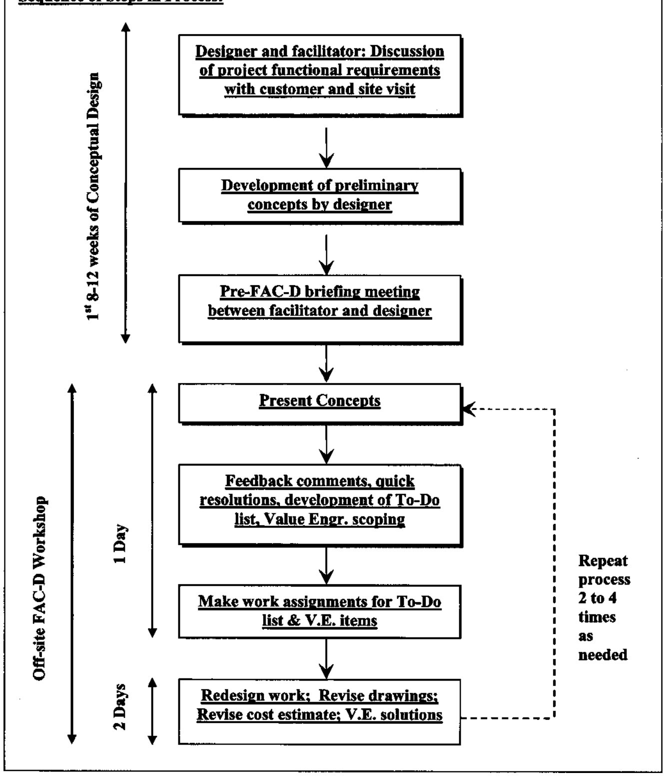
- Authoritative, knowledgeable facility customer representatives committed to the process
- Adequate senior experienced design specialists (e.g., mechanical, electrical, architectural, etc.)
- Experienced qualified cost estimator equipped with all needed data resources

References for More Information:

Value Engineering specialists from the Naval Facilities Engineering Command
Pena, William, Parshall, Steven, and Kelly, Kevin, *Problem Seeking: An Architectural Programming Primer*, AIA Press, Washington, 1987

VM Process:	**Function Analysis Concept Development ("FAC-D")**

Sequence of Steps in Process:



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