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ScienceDirect
International Journal of Project Management xxx (2009) xxx–xxx
International Journal of Project Management
www.elsevier.com/locate/ijproman

Assessing the overall performance of value engineering workshops for construction projects

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Received 4 September 2008; received in revised form 7 August 2009; accepted 11 August 2009

Abstract

Success of a value engineering workshop (VEW) depends on numerous interrelated factors. Unfortunately, some of these factors are overlooked by VEW teams. This study applied factor analysis and the Analytic Hierarchy Process (AHP) to analyze a questionnaire survey distributed to experienced VE practitioners. A VEW performance assessment model was designed based on the data collected. The proposed model was used to assess two VEWs of a construction project to demonstrate its usefulness in performance assessment. Assessment results were analyzed, and suggestions were provided to improve VEW performance. Performance can be enhanced by using the proposed model for self-diagnosis, process improvement, and team motivation.

Keywords: Value engineering workshop; Construction projects; Performance assessment

1. Introduction

Value engineering (VE) is an organized application that uses a combination of common sense and technical knowledge to locate and eliminate unnecessary project costs. Applying sound VE principles can effectively reduce costs and thus enhance project value. Value Engineering, which was introduced to the construction industry during the 1960s, has been employed worldwide for over 50 years. Since its introduction, this technique has been widely applied in construction projects (Palmer et al., 1996; Chen and Chang, 2008; DeEll'Isola, 1997). The VEW process involves several important elements, including teamwork, functional analysis, creation, cost–worth, and the systematic application of a recognized technique. The incorporation of these elements into a VEW job plan distinguishes the VE approach from other cost-cutting exercises. Without these elements, the process is not VE and does not yield the same results (Federal Highway Administration, 2008).

The success of the VEW depends on several factors: (1) VEW job plan execution, (2) VEW team leader's personality, (3) client input, (4) VEW plan and relationships within the design team, and (5) the nature of the project itself (Palmer et al., 1996). Although the overall success of VEW depends heavily on these and other factors, its success is currently judged by the total potential savings accomplished by the VEW team. It is common for value engineers to focus on total potential savings when selling VEW to project owners. Consequently, issues such as team origination, VE methodology implementation, and interactions between the facilitator and the project participants are neglected. Under these game rules, the VEW team somehow suffers reduced ability to identify certain shortages during VEW. Value promotion and the original function of VE are thus impaired. This myopic view of the VEW process then impedes opportunities to enforce the benefits of VEW.

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We sought to fill the gap in appropriate VEW performance assessment models that consider intangible process-related factors (Lin and Shen, 2007). To achieve this, the study surveyed the opinions of VE experts regarding VEW performance assessment. Factor analysis was employed to extract the assessment criteria, which were then further grouped and weighted using the AHP. The assessment criteria were calculated using the Simple Additive Weighting Method (SAWM). The proposed model was then used to analyze two actual VEWs of a construction project to demonstrate its application.

2. Previous studies

Since its introduction in the 1950s in the United States, VE has been employed effectively in numerous countries around the world. The worldwide use of VE has attracted interest from both researchers and practitioners in studying the use of VEWs in construction.

According to Leung and Wong (2002), performance directly influences organizational efficiency and effectiveness. The use of appropriate methods of performance assessment could fulfill the educational requirements of organizations and individuals and boost the cost effectiveness of training. Although a VEW team is a project-based temporary organization, its goals are the same as those of ordinary organizations. Therefore, it is important to assess the performance of the VEW team by examining efficiency, effectiveness, team capabilities, and degree of customer satisfaction. The outcomes of the performance assessment can offer valuable feedback to future VEWs. This study suggests that VEW performance is assessed not solely by traditional financial ratios but also by using input–output value (Sperling, 2002; Acharya et al., 2002; Mohart, 1985).

Male et al. (1998) highlighted 10 critical success factors (CSFs) for Value Management (VM) studies. The CSFs not only address key issues regarding the conduct of VM studies but also differentiate VM from other group decision-making approaches. The main focus of their research was on identifying CSFs and the implementation of VEW job plans. Shen and Liu (2003) identified 15 CSFs. Their research revealed the following variables as significant influences on VMW success: (1) the VM team, (2) the client, (3) the facilitator, and (4) other related departments. Although the 15 CSFs covered the entire VMW, the influence of job plan implementation on VMW, which is the code of VMW, was not examined in detail.

Bethany (2003) described methods used by the US Department of State Overseas Buildings Operations in measuring VE program performance. These methods included the use of two spreadsheet/database files, a listing of VE proposals, and a summary of VE study results. The methods were designed to measure the performance of overall VE programs rather than individual VEWs. An evaluation of four VEWs by Palmer et al. (1996) concluded VEW team members. Martin (1998) proposed three criteria for VEW evaluation: baseline, written report, and comparative proposals. Martin's suggestions provide managers with a simple basis for investigating a VEW. Pucetas (1998) identified five human factors that influence implementation of VEW recommendations, including VE perspectives, incentive consensus building, credibility partnering, teamwork, and cultural issues. Although Pucetas provided some suggestions regarding VEW implementation, his research lacked suggestions regarding the assessment of VE performance.

When establishing a VEW performance assessment model, the aspects and criteria used to measure the performance should be selected, and the interrelationships between aspects and criteria should be identified (Chang and Chen, 2004). The selection of a VEW performance assessment tool depends significantly on the characteristics of VEW. Accordingly, Chen et al. (2003) observed the following factors with regard to the identification of tools for measuring VEW performance: (1) the degree of job plan implementation substantially influences VEW performance; (2) team factors (such as leader experience, leadership and communication ability, and settlement of disagreements), and team dedication to VEW significantly influence VEW performance; (3) criteria for measuring VEW performance are project oriented and related to project attributes.

Although many studies have focused on various individual phases of the VEW job plan, few have examined the overall performance assessment mechanisms and models, and studies of systematic assessment approaches that fully cover the VEW are rare. Additionally, some studies from the construction industry literature have focused only on the key influences on success in VMW (Shen and Liu, 2003). The literature thus lacks research assessing overall VEW performance.

3. Model building

The major objective of this study is to develop a model that can assess the performance of construction VEWs. Our development of the performance assessment model has four major steps: (1) development of a list of nominated performance assessment criteria (NPAC) in relation to VEW; (2) the use of factor analysis (FA) to extract primary performance assessment criteria (PAC) and to identify performance assessment aspects (PAAs); (3) the application of SAWM and AHP to allocate the weights to PACs and PAAs, respectively; and (4) the assessment of two construction VEWs to demonstrate the usefulness of the proposed model. To realize these objectives, we conducted a two-phase questionnaire-based survey to collect related data.

3.1. Phase 1 questionnaire

consolidated through a series of pilot studies. The final version of the questionnaire was reviewed by two experienced Certified Value Specialists (CVSs) and one Certified Associate Value Specialist (AVS) in Taiwan. A total of 32 NPACs were included in the questionnaire. To assist the respondents in understanding the meanings of the NPACs, definitions and explanations regarding these NPACs (Table 1) were attached to the phase 1 questionnaire.

The questionnaire asked respondents to grade the importance of each NPAC in relation to VEW performance assessment using a five-point Likert scale, in which 5 represented "extremely important" for a given NPAC and 1 represented "least important". To ensure consistency in responses, a brief definition of each NPAC was provided. Because the proposed model aims at the performance evaluation of construction VEWs, the professional knowledge contributed to the proposed model is limited to those experienced VE researchers and practitioners who work in the construction industry and are members of the Value Management Institute in Taiwan (VMIT). It should be noted that professional opinions of some experienced VE experts who were not VMIT members but who worked in the construction industry might be left out because of the process of sample population selection. The sample population used for the phase 1 questionnaire survey, therefore, was limited to 212 VE researchers and practitioners in Taiwan's construction industry. All members of the sample population had taken the Module I VE training course certified by SAVE International. Most respondents held AVS certification, and a few were CVS certified by SAVE International.

As shown in Table 2, of 212 distributed questionnaires, 85 were returned (40.10% response rate). The returned questionnaires included eight invalid questionnaires. Therefore, the number of effective questionnaires was 77 (23.19%). Of these, 31 were returned by VE researchers and 46 by VE practitioners. Compared with other similar surveys in the Taiwanese construction industry, this response rate was considered good. Additionally, Student's *t*-tests were performed to clarify whether the researchers' and practitioners' opinions were the same for each of the PAAs. According to Norusis (2001), a *p*-value below 0.05 indicated a high degree of difference of opinion between two sample groups. The Student's *t*-test results showed that the *p*-values ranged from 0.136 to 0.336, which was higher than 0.05, suggesting that there was a consensus of opinion among researchers and practitioners. Therefore, the collected sample was considered valid.

3.2. Interpretation: the important PACs

Based on the consensus of the survey respondents, eight PACs with an average score exceeding 4.00 were identified as important criteria for VEW performance. The eight important PACs (ranked in decreasing order of average tice viewpoints are presented here. For example, *Number of recommendations* should be clarified in terms of size and dimension to assess the criteria on an equal basis. *Attendance stability of VE team members* is important because frequent changes of VEW team members will impede the continuity of value methodology implementation and synergy generation. Experienced team leaders will form a solid multidisciplined team based on their VEW experience and knowledge and their professional problem-solving abilities. Experienced team leaders schedule workshops in a timely and effective manner to minimize resource expenditure in maximizing VEW team performance (*Leading VEW experience of the team leader*).

3.2.1. Constructability of recommendations (4.38)

Although the constructability of construction works is important, the constructability of most construction projects in Taiwan is not identified until the last moment on site. Construction projects lack a feedback mechanism for providing designers with feedback regarding construction experiences. VEW can link the feedback process and enhance the management cycle such as the Plan-Do-Check-Action (PDCA) cycle. Knowledge from site experiences should be taken into account in the recommendations. Constructability of recommendations, representing the recommendations contribution to the constructability of the project, thus is critical in terms of cost, schedule and quality.

3.2.2. Integration and coordination ability of team leader (4.36)

The beauty of VEW is the way it enables simultaneous sharing of member expertise. A VEW team leader must coordinate and integrate both inside and outside the workshop. Externally, the team leader must probe and realize the workshop directions as well as the goals of the client. The team leader must integrate the requirements of the functional departments of the client and coordinate the VEW team to include corresponding integrated solutions in proposals, because innovative proposals cannot create value without customer acceptance. Internally, it is essential for team leaders to coordinate the team technically and to control *team dynamism* during a limited VEW. Care should be taken to convert team friction into creativity. Attention should also be paid to exercising functional analysis and function analysis system technique (FAST) diagrams fluently, because FAST is a powerful core technique for integration and coordination in VEWs.

3.2.3. Team leader's ability to control job plan and schedule (4.18)

The job plan and schedule are also vital contributors to VEW success. Before a VEW, in the preworkshop stage, the team leader should understand the features of the environment, company culture and level of participation of

Table 1
Definitions and explanations of the 32 NPACs.

No.	NPAC	Definitions and explanations
1	Intention of owner conducting VEW	This item represents the level of willingness/intention/desire of the owner executing VEW. Generally, when the results of VEW are linked to the measurement of performance, the intention of the owner is stronger.
2	VEW acceptance level for design unit	A successful VEW is measured by the implemented savings of the recommendations. The designer plays a key role in carrying out the accepted recommendations. When a designer highly recognizes the efforts of the VEW, then the chances of a successful VEW is relatively enhanced.
3	VEW costs	An agent will maximize the benefits of the owner only if the agent is well compensated. Some owners have the misconception that VEW expends no resources. Adequate fee/expenses are required to generate satisfactory results.
4	VEW implementation timing regarding construction project life cycle	The early implementation of VEW is critical to the potential savings. The earlier the VEW is conducted, the bigger the potential savings that can be achieved.
5	Duration constraint of VEW implementation	The study length duration and schedule of VEW is subject to the availability of VE team members, and the urgency of the design schedule. Normally, less impact on the design schedule is preferred. Therefore, design schedule and the length duration constraints of VEW execution must be taken into account.
6	Representing level of designer	There are two interfaces with the designers in a VEW. One is in the information phase, where the designer briefs the VEW team and expresses the original design concepts as well as design details. Another interface is in the recommendation phase, where the VEW team proposes their recommendations after an intensive workshop. The representing level of the designer is important to the VEW.
7	VEW experiences of designer	There are some situations in VEW implementation in regards to the designer. One is that VEW is under the contract of the designer. For example, a VEW is under the contract of the detail design consultant (DDC) and the study objective of VEW team involves the basic design of the previous designer. In this situation, the experience of DDC in conducting VEW is very important.
8	Leading VEW experiences of the team leader	The intrinsic experiences and knowledge of The VEW team leader is vital to the success of the workshop. There is little margin to accommodate errors during the VE workshop. High quality leadership is a good start of a successful VEW.
9	Professional level of VEW team members	The professional level of VEW team members is supposed to be better than or, at least, equivalent to that of the original designer. Because VEW study itself is an improvement process, it is highly recommended that the expertise of the VEW team is to be better than the original designer to improve the existing design.
10	Integration and coordination ability of team leader	A VEW team leader works in a multi-disciplined environment; synergy is well achieved only when the highly professional team is well coordinated and the expertise is integrated.
11	Team leader's ability to control job plan and schedule	VEW itself is a tight project with several constraints on resources. A dynamic control in the workshop is required. VEW team leader's schedule management and job plan controllability is vital to the success of VEW and a challenge to a VEW team leader.
12	Attendance stability of VEW team member	The basic function of a VEW is to focus synergy of the multi-disciplined experts. Stability of team participation is a linchpin to achieve the function. In terms of time and human resources input, team expertise does not only help identifying functions of the study objects, but also generate creative ideas through frictions of expertise discrepancies.
13	Cooperation of VEW team member	It is always a hard task to create a cooperative and mutual supportive environment in a team. Support and cooperation of VEW team members is also a foundation to focus team synergy.
14	Frequency of team member change	In a VEW, some team members might not be the same calibre because of the logistical reasons. Human resource is a fundamental resource in a VEW, and frequent changes of team members might result in poor impact on the VEW performance.
15	Communication, coordination and consensus level during VEW	Theoretically, consensus has to be achieved because the functional, judgment, and recommendation phases all require team consensus to proceed to the next stage because the FAST diagram is completed only when team consensus is reached. Screening, selecting, merging and discarding of the created ideas and recommendations also require team consensus. When the result of a VEW is substantial and being accepted, this factor is supposed to be proportional to NPAC 24 and 25.
16	Interaction among VEW team, owner and designer during VEW	This factor discusses the interactions within VEW and with outside stakeholders. The higher the score of the factor, the higher is the level of *team dynamism* evoked.
17	Completeness of job plan	VEW job *plan* is the roadmap which leads to the success of the workshop. A complete and sound job plan avoids or decreases risks of a VEW.
18	Project scope clarity	Clear definition of the scope and study objective is important for the project scope management. The nature of VEW is always under a tight schedule and under relatively high pressure. Clarity on scope and study objective definition avoids misleading of team's study directions and thus allocates resources at the right spots.
19	Project complexity	A complex project comprises several systems and requires substantial domain knowledge in order to conduct the VEW.

Table 1 (*continued*)

No.	NPAC	Definitions and explanations
20	Appropriate workshop executing progress	The progress of each phase can be estimated based on the Value methodology published by SAVE International and the job plan of VEW. The rate of progress is influenced by project complexity, fluency with value methodology of the team leader and team formation. When the progress is faster or slower than planned, it might imply that some phases are being omitted or skipped.
21	Completeness and implementation of VE six-phase job plan	Some VEW job plan omits the functional phase, which is a cornerstone of value methodology. Some might implement the six-phase VEW job plan incorrectly. The common syndrome is reverse of the functional phase and creativity phase. Some even skip the judgment phase and jeopardize the project. In terms of performance, risk and quality, a systematic approach helps duplicate experiences of success. Omitting phases or cheapening the process will yield disastrous consequences.
22	Completeness of meeting minutes	This item represents the detail level and decision process of VEW records.
23	Number of recommendations	A greater number of recommendations are an indication of more outputs of VEW. This is achieved when the VEW team is properly formed and the adherence to the six-phase job plan is well maintained.
24	Completeness and clarity of recommendations	A recommendation should include descriptions, function definitions, advantages, disadvantages, original cost information and proposals (including savings). In other words, technical and financial packages of the original and proposed recommendations as well as risks should be clearly included. Additionally, a complete recommendation will facilitate greatly the decision making on the recommendations.
25	Proposed savings amount and saving percentage	Taking life cycle costs into account, proposed savings are claimed by VEW. There is a discrepancy between proposed savings and implemented savings which might not be easy to calculate.
26	Return over investment	ROI is a ratio of savings generated versus resources input.
27	Constructability of recommendations	This PAC represents the recommendations contribution to the constructability of the project.
28	Recommendation supports of designer	This PAC represents the level of recognition and acceptance of the designer on the proposed recommendations.
29	Designer's satisfaction with six-phase job plan	This PAC represents the level of satisfaction of the designer with the six-phase job plan. The documentation of a VEW six-phase job plan adhering to acceptable standards is of great value to the designer for the implementation of the accepted recommendations and the development of the follow up design.
30	Team leader's satisfaction with six-phase job plan	Some VEWs might not be led by a CVS. The PAC represents the level of satisfaction of a CVS with the six-phase job plan.
31	Designer's satisfaction with workshop goal	This PAC represents the level of satisfaction of the designer with the degree of achievement of the goals of the VEW. Generally, the goals of a VEW are: savings percentage, profit increasing percentage, increasing customer satisfaction, enhancement of internal process performance and enhancement of staff learning, innovation and ability.
32	Team leader's satisfaction with workshop goal	In terms of the interests of the designer, the goals that might be taken into account are: the percentage of savings if the project has cost overrun, magnitude of design change and schedule constraints.

Table 2
The status of the stage-one and stage-two questionnaires.

	Stage-one		Stage-two	
	Copies	%	Copies	%
Copies delivered	212	100.00	77	100.00
Copies returned	85	40.10	48	62.34
Invalid copies	8	3.77	6	7.79
Total valid copies	77	36.19	42	54.55

initial planning stage, and good planning determines VEW success.

3.2.4. Completeness and clarity of recommendations (4.16)

The project owner requires a corresponding multidiscipline review and approval of every recommendation, both technically and financially. The information requirements are reduced with information completeness and clarity. Completeness of recommendations expedites their tions, discrepancies, advantages, disadvantages, life cycle costs, cost estimation and the technical packages of the original design and the recommendations should be fully elaborated. The VE recommendations should be distinguished from alternatives to meet the rapid pace of the VEW.

3.2.5. Team leader's adherence to the six-phase job plan (4.10)

A good VEW requires smooth data flow between phases. Data flow is influenced by various factors, including the team leader's technical ability and leadership skills, moral hazard, agency problems, and logistical support. The risks of some of these factors are controllable, while others are uncontrollable. Most reasons for team leadership being unsatisfactory involve uncontrollable factors such as agency problems and moral hazard, despite the application of the six-phase job plan. Agents do not maximize client benefit if they are not sufficiently compensated. If the

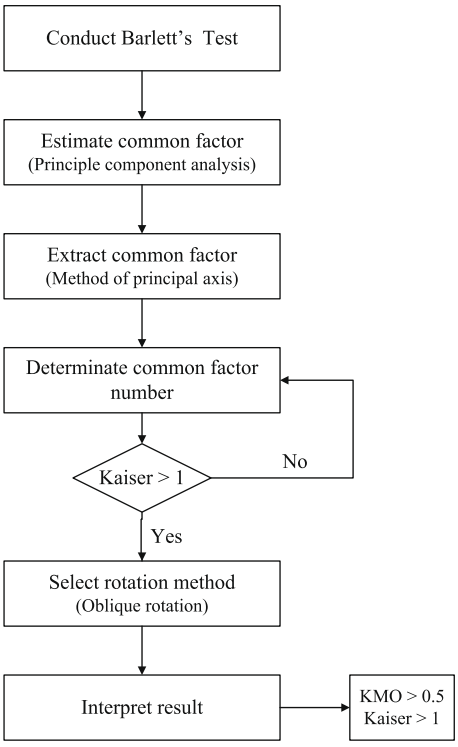

Fig. 1. Factor analysis implementation procedure.

Table 3
KMO value and Bartlett's test.

KMO measure of sampling adequacy		0.723
Bartlett's test of sphericity	Approx. chi-square	1129.9
	df	61
	Sig.	496
		0.000

Table 4
Criteria explanation value of clusters and Cronbach'α value.

Variables	Aspect 1	Aspect 2	Aspect 3	Aspect 4
25	.848			
26	.797			
32	.757			
24	.732			
28	.715			
27	.697			
30	.689			
23	.666			
09		.808		
10		.801		
08		.793		
11		.715		
07		.659		
06		.658		
18			.857	
17			.850	
22			.784	
20			.780	
21			.699	
15				.849
16				.802
13				.774
14				.572
Cumulative (%)	21.267	33.429	45.109	53.820
Cronbach's (α)	0.8697	0.8301	0.8664	0.7668

finally result in the team leader's low satisfaction with the results. Therefore, the satisfaction with the accepted proposals and implemented savings is reduced.

3.2.6. Communication, coordination and consensus level during VEW (4.05)

Team consensus is critical in the functional and judgment phases in order to proceed to the next phase. Special care should be taken when dealing with individuals from Asian cultures; unspoken opinions might be hidden or suppressed if the communication and coordination technique is inappropriate. The FAST technique offers a good communication and coordination tool for use during the functional phase that not only links customer requirements but also integrates technical know-how from the multidisciplined VE team, which normally causes conflicts and disagreement in the work flow outside VEW.

3.2.7. Professional level of VEW team members (4.03)

The professional level of VEW team members is also management process, which can deliberately retrieve, combine and integrate the intrinsic know-how associated with individuals, and can convert most team frictions associated with multidisciplined professional teams into creative recommendations. Synergy is necessary for focusing on a VEW. However, VEW performance and output depend on the professionalism of team members. The more professional the team, the greater the inertia and rigidity of the team members in their professional fields. The challenge to the VEW team leader lies in converting professional discrepancies into creative friction and focusing synergies for purposes of innovation.

3.2.8. Team leader satisfaction with workshop goal (4.03)

Generally, VEW goals provide incentives for the team to pursue good recommendations. Moreover, the goals can help create synergies. To some extent, VEW goals also reflect the qualitative and quantitative expectations of shareholders and stakeholders. In terms of finance, customer satisfaction, operation and learning, and innovation, VEWs can be incorporated with a target costing system, placing a control gate in the judgment phase to generate iterations back to the functional phase until the goals are achieved. It should be noted that "Team leader satisfaction with workshop goal" means "Team leader's satisfaction that the workshop goals were achieved."

3.3. Factor analysis

for 20–50 variables, as the extraction of common factors becomes inaccurate if the number of variables exceeds this range (Hair et al., 1998). In the stage 1 questionnaire, there were 32 NPACs, and the criteria are suitable for FA, which was performed according to the procedure shown in Fig. 1.

From Table 3, the Kaiser–Meyer–Olkin (KMO) value is 0.723, which is larger than 0.5. Bartlett's test has high sampling adequacy, and thus the data collected via the stage-one questionnaire is suitable for the FA. This study selected aspects 1–4 to represent all the criteria used in the VEW performance assessment. Table 4 shows that the Cronbach's α values for all four aspects exceed 0.7, which is the threshold of acceptability. Meanwhile, the cumulative criteria explanation value is 53.82%, meaning that the four aspects can explain 53.82% of the criteria. Table 5 lists the aspects (PAAs) and their associated assessment criteria (PAC) of the VEW performance assessment model. Every PAA is named according to its associated PAC. Of the 23 PACs, eight belong to the aspect of *Satisfaction with VEW results*, six belong to *VEW team composition and capability*, five belong to *VEW job plan*, and four belong to *VEW team participation*.

Table 5
VEW performance assessment names of aspects and their contents.

Aspect	No.	Assessment criteria
Satisfaction with VEW results (aspect 1)	1	Number of recommendations
	2	Completeness and clarity of recommendations
	3	Proposed savings amount and saving percentage
	4	Return over investment
	5	Constructability of recommendations
	6	Recommendation supports of designer
	7	Team leader's satisfaction with six-phase job plan
	8	Team leader's satisfaction with workshop goal
Team composition and capability (aspect 2)	9	Representing level of designer
	10	VEW experiences of designer
	11	Leading VEW experiences of the team leader
	12	Professional level of VEW team members
	13	Integration and coordination ability of team leader
	14	Team leader's ability to control job plan and schedule
VEW job plan (aspect 3)	15	Completeness of job plan
	16	Project scope clarity
	17	Appropriate study executing progress
	18	Completeness and implementation of VEW six-phases job plan
	19	Completeness of meeting minutes
Team member participation (aspect 4)	20	Cooperation of VEW team member
	21	Attendance stability of VEW team member
	22	Communication, coordination and level of consensus during VEW
	23	Interaction among VEW team, owner and designer during VEW

3.4. Phase 2 questionnaire

The phase 2 questionnaire was designed to determine the relative weights of the different PAAs of the assessment model. The paired comparison test was used to measure the importance of PAAs (Table 6). Each of the four PAAs was compared with each of the other PAAs based on the preference identified by the questionnaire respondents. The relative weight of one PAA over another can range from extremely important (5:1) to extremely unimportant (1:5). For example, if *Satisfaction with VEW results* is five times more important than *Team composition and capability*, a "$\surd$" was marked in the column "5:1" in the row for "*Satisfaction with VEW results – Team member participation*". If *Satisfaction with VEW results* was equally as important as *VEW job plan*, a "$\surd$" was marked in the column "1:1" in the row for "*Satisfaction with VEW results – VEW job plan*".

The phase 2 questionnaire was sent to the 77 individuals who responded to the phase 1 questionnaire. Of the 77 phase 2 questionnaires issued in this study, 48 were returned (for a 62.34% response rate). Six of the questionnaires were invalid, meaning there were 42 effective responses (for a 54.55% response rate). A consistency test was used to validate the 42 effective phase 2 questionnaires. The value of the consistency ratio (CR) of each returned questionnaire was calculated: questionnaires with CR values $\leqslant 0.1$ were treated as valid questionnaires (Saaty, 1990).

A total of 24 effective questionnaires passed the consistency test and were therefore considered valid. Based on these, the overall weight of each PAA was further calculated (Table 7). Weights of PAAs were obtained by

Table 6
Paired comparison test of PAAs for phase-two questionnaire.

PAAs	Scale of importance					PAAs
	5:1	3:1	1:1	1:3	1:5	
Satisfaction with VEW results	ˇ	□	□	□	□	*Team composition and capability*
Satisfaction with VEW results	□	□	ˇ	□	□	*VEW job plan*
Satisfaction with VEW results	□	□	□	□	□	*Team member participation*
Team composition and capability	□	□	□	□	□	*VEW job plan*

Table 7
Aspect weights for VEW performance assessment.

Assessment aspect	Related weight
Satisfaction with VEW results (aspect 1)	0.4529
VEW team composition and capability (aspect 2)	0.1990
VEW job plan (aspect 3)	0.1775
VEW team participation (aspect 4)	0.1705

averaging the PAA weights from the 24 valid questionnaires. In addition, the PAC weights were determined based on the percentage of each average value of the phase 1 survey results. Combining the average value of the phase 1 survey and Table 7, the contents and relative weights of the performance assessment model are shown in Table 8, which is further transformed into a VEW performance assessment table (Table 9) for VEW performance measurement.

The proposed approach is designed for VEWs in the design phase of a construction project. It is applicable for any type of project, and the composition of workshop participants, in addition to VE specialist, is pretty much dependent upon the type of project. The major participants should be equipped with professional skills and experience closely related to the project contents.

4. Application of the proposed model

To demonstrate its application, the proposed VEW performance assessment model (Table 9) was used to assess two VEWs of a large transportation project in Taiwan. The following sections address this application.

4.1. Overview of the project

The *Taoyuan International Airport (TIA) Access MRT Construction Project* is designed to improve access traffic for TIA, by linking major transportation hubs such as Taipei Main Station, TIA and the Taoyuan High Speed Rail (HSR) station, and establishing a close link between international airlines and local transportation systems. With a construction budget of $2.84 billion, the project has a total track length of 51.5 km, and 22 stations (Fig. 1).

Currently, the route is divided into two sections. Section one, with a total length of 47.7 km, runs from Sanchung to Jhongli via TIA and Taoyuan HSR station. The work scope primarily includes civil works for section one and electronic and mechanical work for the entire route. Section two (4.1 km) runs from Sanchung to Taipei Main Station, and the associated civil work was commissioned by the Ministry of Transportation and Communication (MOTC) and performed by the Taipei city government.

4.2. VEWs of the project

Fig. 2 shows the scope of projects DE02 and DE03. The DE02 covers four stations, four total service stations (TSSs), one emergency station, a 13,890 m elevated section, and a 193 m ground-level section. The project includes civil and infrastructure work, water supply, HVAC, elevator and escalator engineering and building management systems (BMSs). The VEW of DE02 was performed at the beginning of the detail design phase of the project. Two CVSs were hired by the design consultant, one as the

Table 8
Overall VEW performance assessment model.

PAA (weight)	No.	Performance assessment criteria (PAC)	Avg. score	Criteria weight
Satisfaction with VEW results (0.4529)	1	Number of recommendations	3.79	0.0541
	2	Completeness and clarity of recommendations	4.16	0.0593
	3	Proposed savings amount and saving percentage	3.57	0.0510
	4	Return over investment	3.87	0.0552
	5	Constructability of recommendations	4.38	0.0625
	6	Recommendation supports of designer	3.84	0.0549
	7	Team leader's satisfaction with six-phase job plan	4.10	0.0586
	8	Team leader's satisfaction with workshop goal	4.01	0.0573
VEW team composition and capability (0.1990)	9	Representing level of designer	3.79	0.0318
	10	VEW experiences of designer	3.58	0.0300
	11	Leading VEW experiences of the team leader	3.81	0.0319
	12	Professional level of VEW team members	4.03	0.0337
	13	Integration and coordination ability of team leader	4.36	0.0366
	14	Team leader's ability to control job plan and schedule	4.18	0.0350
VEW job plan (0.1775)	15	Completeness of job plan	3.42	0.0347
	16	Project scope clarity	3.53	0.0359
	17	Appropriate study executing progress	3.35	0.0340
	18	Completeness and implementation of VEW six-phase job plan	3.71	0.0377
	19	Completeness of meeting minutes	3.47	0.0352
VEW team participation (0.1705)	20	Cooperation of VEW team member	3.86	0.0416
	21	Attendance stability of VEW team member	3.94	0.0425

Table 9
VEW performance assessment table.

PAA	No.	Performance assessment criteria (PAC)	Performance assessment				
			VP	P	F	G	VG
Satisfaction with VEW results	1	Number of recommendations	☐	☐	☐	☐	☐
	2	Completeness and clarity of recommendations	☐	☐	☐	☐	☐
	3	Proposed savings amount and saving percentage	☐	☐	☐	☐	☐
	4	Return over investment	☐	☐	☐	☐	☐
	5	Constructability of recommendations	☐	☐	☐	☐	☐
	6	Recommendation supports of designer	☐	☐	☐	☐	☐
	7	Team leader's satisfaction with six-phase job plan	☐	☐	☐	☐	☐
	8	Team leader's satisfaction with workshop goal	☐	☐	☐	☐	☐
VEW team composition and capability	9	Representing level of designer	☐	☐	☐	☐	☐
	10	VEW experiences of designer	☐	☐	☐	☐	☐
	11	Leading VEW experiences of the team leader	☐	☐	☐	☐	☐
	12	Professional level of VEW team members	☐	☐	☐	☐	☐
	13	Integration and coordination ability of team leader	☐	☐	☐	☐	☐
	14	Team leader's ability to control job plan and schedule	☐	☐	☐	☐	☐
VEW job plan	15	Completeness of job plan	☐	☐	☐	☐	☐
	16	Project scope clarity	☐	☐	☐	☐	☐
	17	Appropriate workshop executing progress	☐	☐	☐	☐	☐
	18	Completeness and implementation of VEW six-phase job plan	☐	☐	☐	☐	☐
	19	Completeness of meeting minutes	☐	☐	☐	☐	☐
VEW team participation	20	Cooperation of VEW team member	☐	☐	☐	☐	☐
	21	Attendance stability of VEW team member	☐	☐	☐	☐	☐
	22	Communication, coordination and consensus level during VEW	☐	☐	☐	☐	☐
	23	Interaction among VEW team, owner and designer during VEW	☐	☐	☐	☐	☐

Note: VP – very poor, P – poor, F – fair, G – good, VG – very good.

VEW team leader while the other served as the coordinator/architect. A multidiscipline VEW team with 12 members was formed. Most team members were independent of the design team. Table 10 summarizes the roles and profession of the VEW team members. The company culture is open and supportive. The VEW team generated

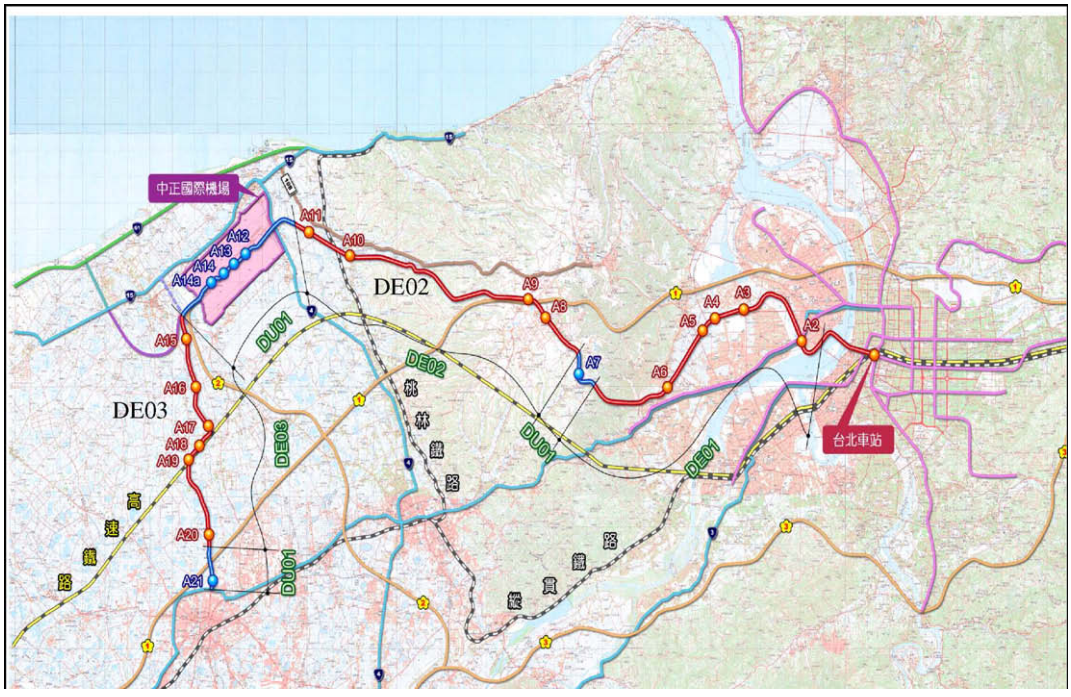

Table 10
Roles and professionals of VEW team members.

Role	DE02 VEW	DE03 VEW
Team leader	CVS, VE company	CVS, VE company
Team coordinator	DDC	DDC
Architect	CVS, VE company	DDC
Landscape engineer	DDC	DDC
Civil engineer	DDC	DDC
Structure engineer	DDC	Same as civil engineer
Geotechnical engineer	DDC	–
Transportation engineer	–	DDC
Electrical engineer	DDC	DDC
HVAC engineer	DDC	DDC
Construction engineer	DDC	AVS, VE company
Cost engineer	DDC	DDC
Secretary	DDC	DDC

11 recommendations and eight design suggestions. Total potential savings of $3,141,406 were proposed based on this VEW, and 30% of the potential savings were accepted by the owner.

The DE03 covers six stations and a 12,000 m elevated section, including the 460 m Chinpu Depot connecting line. The project includes civil and infrastructure work, water supply, HVAC, elevator and escalator engineering and BMS. The VEW of DE03 was conducted at the start of the project design phase. One CVS and two AVSs were hired by the project design consultant. The CVS was the designated team leader (and was the same person as the team leader of DE02 VEW), while one AVS served as the VEW coordinator/transportation engineer and the other served as the construction engineer. The VEW team is multidisciplinary, with 13 members. Most team members were part of the project design team and were closely controlled and strongly influenced by the project manager. The company culture is conservative, with a fairly unsupportive atmosphere, and subcontractor management is not very harmonious. The VEW team generated five recommendations and 28 design suggestions. Total potential savings of $4,777,788 were proposed by this VEW, of which 14% were accepted by the owner.

This study invited the team leader of the two VEWs to assess VEWs performance. The team leader has over 20 years experience in practicing VE and adheres strictly to the value methodology of SAVE International. The team leader has experience of over 200 comprehensive VEWs in the construction, service and manufacturing industries, including 60 huge construction projects, and has presented 126 MOD I courses in Taiwan. The authors explained the use of the performance assessment table (Table 9) to the team leader before the he conducted his assessment of the two VEWs. Table 11 lists the results of the performance assessment for the two VEWs.

4.3. Analyzing the assessment of the VEWs

with scores higher than 90 and another with scores of approximately 75), and a huge gap in aspect score exists between them. Both DE02 and DE03 have two aspects with high scores (larger than 90). Furthermore, the performance of *Satisfaction with VEW results* and *VEW team participation* is particularly poor.

For DE02, there is a significant gap (18.8 points = 93.80 − 75.00) between the best performance (*VEW team composition and capability*) and the worst performance (*VEW team participation*). *VEW team composition and capability* and *VEW job plan* both receive satisfaction scores exceeding 90.00. Furthermore, *VEW team participation* received the lowest score (75.00). For DE03, a significant gap (41.9 points = 92.00 − 50.10) exists between the best performance (*VEW job plan*) and the worst performance (*VEW team participation*). Both *VEW job plan* and *VEW team composition and capability* receive satisfaction scores exceeding 90.00, while *VEW team participation* received a score of just 50.1. The following summarizes other analyses regarding the aspect scores.

1. Achieving the same *VEW job plan* score, together with different *team composition and capability*, and *team participation* will yield different levels of satisfaction with the VEW results.
2. Compared with the other three aspects, *VEW team participation* of DE02 and DE03 are relatively low. There are two main reasons for this phenomenon: (1) the VEWs are embedded in the contract of the detail design consultant, and (2) the VEW team is insufficiently independent of the design team.
3. Although the DE02 VEW team has high independence from the design team, difficulties persist with regard to freedom from the agency and moral hazard problems. That is because the agency will maximize its own benefit rather than that of the owner.
4. The aspect of *VEW team participation* with DE03 has a score of only 50.1% as a result of contract type, low independence of the VEW team, and the poor attendance stability of VEW team members.

Analyzing the scores of assessment criteria may reveal further interesting findings. The scores of *number of recommendations*, *recommendation completeness and clarity*, and *designer support regarding recommendations* for DE03 are lower than those for DE02. Therefore, the effort and resources expended on the recommendation approval of DE03 VEW exceed those of DE02 VEW. The acceptance rate for the recommendations of DE03 is lower than that for those of DE02 and leads to smaller proposed savings and a lower return on investment. In terms of *team dynamism*, *cooperation of VEW team*, and *attendance stability of VEW team member*, the VEW satisfactory level of DE03 is less than that of DE02, and thus in terms of communication, coordination and level of consensus during

Table 11
Summary of VEW performance assessment.

PAA (weight)	No.	Performance assessment criteria (PAC)	PAC weight	DE02 scale	DE02 scores gained	DE03 scale	DE03 scores gained
Satisfaction with VEW results (0.4529)	1	Number of recommendations	0.0541	4	0.2164	3	0.1623
	2	Completeness and clarity of recommendations	0.0593	4	0.2372	3	0.1779
	3	Proposed savings amount and saving percentage	0.0510	3	0.1530	3	0.1530
	4	Return over investment	0.0552	4	0.2208	3	0.1656
	5	Constructability of recommendations	0.0625	4	0.2500	3	0.1875
	6	Recommendation supports of designer	0.0549	2	0.1098	1	0.0549
	7	Team leader's satisfaction with six-phase job plan	0.0586	5	0.2930	5	0.2930
	8	Team leader's satisfaction with workshop goal	0.0573	5	0.2865	4	0.2292
VEW team composition and capability (0.199)	9	Representing level of designer	0.0318	4	0.1272	4	0.1272
	10	VEW experiences of designer	0.03	4	0.1200	4	0.1200
	11	Leading VEW experiences of the team leader	0.0319	5	0.1595	5	0.1595
	12	Professional level of VEW team members	0.0337	5	0.1685	4	0.1348
	13	Integration and coordination ability of team leader	0.0366	5	0.1830	5	0.1830
	14	Team leader's ability to control job plan and schedule	0.035	5	0.1750	5	0.1750
VEW job plan (0.1775)	15	Completeness of job plan	0.0347	5	0.1735	5	0.1735
	16	Project scope clarity	0.0359	4	0.1436	4	0.1436
	17	Appropriate workshop executing progress	0.0340	5	0.1700	5	0.1700
	18	Completeness and implementation of VEW six-phase job plan	0.0377	5	0.1885	5	0.1885
	19	Completeness of meeting minutes	0.0352	4	0.1408	4	0.1408
VEW team participation (0.1705)	20	Cooperation of VEW team member	0.0416	4	0.1664	2	0.0832
	21	Attendance stability of VEW team member	0.0425	4	0.1700	2	0.0850
	22	Communication, coordination and consensus level during VEW	0.0437	4	0.1748	3	0.1311
	23	Interaction among VEW team, owner and designer during VEW	0.0426	3	0.1278	3	0.1278
Total					4.1553		3.6619
% in 100					0.831		0.713

Table 12
Aspect scores of DE02 and DE03.

Aspects/VE workshop	DE02		DE03	
	Raw score	%	Raw score	%
Satisfaction with VEW results (aspect 1)	1.7667	78.0	1.4234	62.9
VEW team composition and capability (aspect 2)	0.9332	93.8	0.8995	90.4
VEW job plan (aspect 3)	0.8164	92.0	0.8164	92.0
VEW team participation (aspect 4)	0.6390	75.0	0.4271	50.1
Overall performance	4.1553	83.1	3.5664	71.3

Some reasons for the DE03 VEW team having a lower score in the above items are summarized below:

1. The team members faced overwhelming pressure on detail designs and tight deliverable schedules, and VEW team members were assigned as detail designers. At the same time, some VEW team members remained attached to ideas generated prior to the VEW and only considered their own expertise, and some team members did not participate actively during the functional, creativity and judgment phases,
2. The VEW team failed to build its FAST diagrams to stimulate and incubate team creativity and closely examine the problem statements on the abstract functional level, while simultaneously considering input synergies from a multidiscipline perspective.
3. Support from cost/construction engineers is vital in VEW. The fickle personality and nonprofessional manner of the cost/construction engineers, and the poor support from the company, hampered the performance of DE03 VEW.
4. The excessive review and approval procedures not only

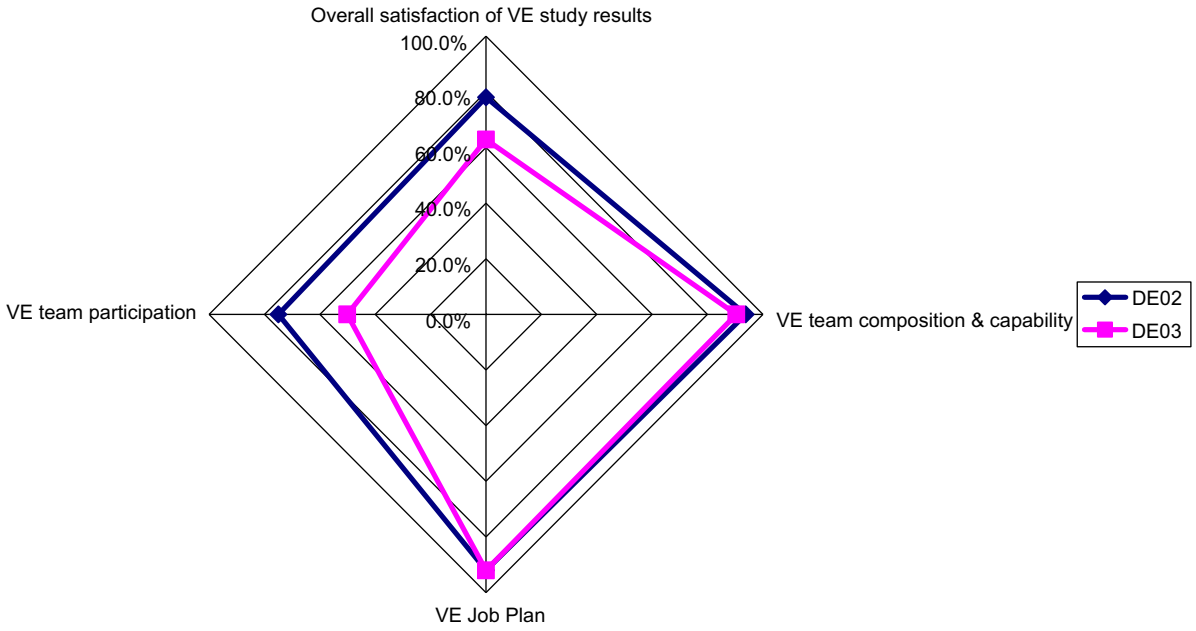

Fig. 3. Comparison between DE02 and DE03 regarding the four PAAs.

regulate the detail of the recommendations to be equivalent to the original design input to the VEW. Clear and distinctive definitions should differentiate VE recommendations and design alternatives.

5. The establishment of a review and approval time limit is urged to gain the benefits from the advantages of VEW while eliminating the disadvantages of VEW.
6. The team did not carefully follow value methodology; in particular, they did not concentrate on creating ideas by functions. Misconceptions were used to explain VE definitions, particularly "What is VE and what is not VE for each contract enacted".

The findings of the performance assessment of the two VEWs indicate that VEW satisfaction increases with *VEW team participation*. Additionally, the personality of the VEW team leader, the information input of the client, the relationship of the VEW and design teams, and the nature of the project contribute significantly to VEW success. The personality of the VEW team leader and the VEW team thus are also important factors in seeking VEW success. Team members should be chosen according to a combination of experience and personality, and should possess credentials comparable with those of the owner and design team members in areas such as education, professional certification, affiliations and experience. Regarding the building of FAST diagrams, this study strongly recommends following the value methodology, particularly concentrating on creating ideas by functions, while simultaneously considering input synergies from a multidiscipline perspective. The main reason for the better performance of DE02 lies in the greater independence of its team than that of DE03 VEW team. The misconceptions of the owner regarding VEW recommendations to participate in the workshops. Finally, the inappropriate definition of VE and miswritten contract clauses should be corrected. Owners of the project must establish a standard review and approval procedure to avoid such defects.

4.4. Validating the results of the VEW assessment

The results generated by the proposed model can be validated in three ways. More details are given as follows.

4.4.1. Comparing the proposed model with the existing evaluation method

The existing evaluation on VEW performance only compares PAC4 (*Return on investment*) with PAC3 (*Proposed savings amount and saving percentage*). From Table 10, the scores of PAC4 and PAC3 of DE02 and DE03 are 4, 3 and 3, 3, respectively. The average scores of PAC3 and PAC4 are 3.57 and 3.87, respectively based on the effective questionnaires. PAC3 and PAC4 are not within the top eight important factors from the survey. The multiplied scores of DE02 and DE03 are the scores from Table 10, and the average scores of PAC3 and PAC4 from the survey are 25.89 and 22.32, respectively. Obviously, the multiplied score of DE02 is better than that of DE03. However, it still leaves several questions to be answered and clarified. Two such questions are "Will the implemented savings be as good as the proposed savings?" and "Will the recommendation be carried out smoothly, because detailed information might not be generated?" The results of the existing evaluation method seem unconvincing.

4.4.2. Validating via the definitions of agency theory and the proposed model results

performance of the workshop, following the methodology and the six-phase job plan prepared according to the methodology is a proven way to generate positive results. The function of the independent inspector, acquiring additional information and reducing the agency problem, is to validate whether the approved six-phase job plan is followed closely. The qualification of the independent inspector requires inclusion of the authorities in charge of the project. In both projects DE02 and DE03, the independent inspectors were representatives of the High-speed Rail Bureau. In reality, only project DE02 was assigned an independent inspector and thus had fewer agency problems. Thus, the DE02 agent (VEW team) yields better performance. This result is consistent with the evaluation results of the proposed model.

4.4.3. Validating from the final implemented savings of the two projects

The implemented savings are also an important factor for validating the results of the VEW. Care should be taken and the benefits of the ideas proposed by the VEW team should be considered as part of VEW's contributions. The implemented savings of DE02 are higher than those of DE03.

5. Conclusions

Performance assessment can examine the efficiency, effectiveness, team capabilities and customer satisfaction of a VEW. The outcomes of the performance assessment can offer valuable feedback to future VEWs. Earlier performance assessment-related research mainly focused on criteria and their interrelationship with performance measurement, key influences on success in VMW and the implementation of VEW job plans, and VEW performance assessment tool selection. Only a few studies considered the performance assessment of VEW. Studies of systematic assessment approaches that fully cover VEWs are rare. This study adds to the body of knowledge by designing a job-plan-based assessment model for VEW performance measurement, and provides a VEW performance assessment model lacking from earlier research.

Performance assessment of a VEW must consider not only final cost cutting but also the interactions among the various factors. We considered the above factors and established a model for measuring the performance of VEWs in construction. The proposed model is based on knowledge obtained from VE experts in Taiwan using a two-phase questionnaire. Analytical techniques, such as FA, AHP and SAWM, were used to group and weight the PAAs and PACs. Two VEWs for a large construction project were used to demonstrate the application of the proposed model.

The proposed VEW performance assessment model consists of four PAAs and 23 PACs. The four PAAs were con-*tion with VEW results* is the most important aspect among the four PAAs when evaluating the VEW performance. Of the 23 PACs, eight belong to the aspect of *Satisfaction with VEW results*, six belong to *VEW team composition and capability*, five belong to *VEW job plan*, and four belong to *VEW team participation*. The eight most important PACs include: *Constructability of recommendations*, *Integration and coordination ability of team leader*, *Team leader's ability to control job plan and schedule*, *Completeness and clarity of recommendations*, *Team leader's conformance to the six-phase job plan, Communication*, *coordination and consensus level during VEW*, *Professional level of VEW team members*, and *Team leader satisfaction with workshop goal.* Based on the performance assessment of the two VEWs, the research suggests that satisfaction with VEW increases with VEW team participation. Team leader and VEW team personality thus are important factors in seeking a successful VEW. VEW success is closely related to VEW team independence. Furthermore, team members should be chosen based on a combination of experience and personality, and should possess credentials comparable with those of the owner and design team members in areas such as education, professional certification, affiliations and experience. For the project owner, the standard review and approval procedure of a VEW must be established to complete a successful VEW.

VEW performance improvement can be achieved by using the proposed model for self-diagnosis, process improvement and team motivation. Moreover, project owners can use the proposed model to assess VEW performance. Besides its use in the construction industry, the procedure for the development of the proposed model can also be employed as a reference for constructing a similar model that is suitable for VEW performance assessment in other industries. The possible practical challenges that the model users may encounter are as follows: (1) the users may find it necessary to verify whether the error of the model is still within the acceptable level; (2) adding and dropping PACs is another challenge the users may encounter; and (3) the numeric data may be too complicated to evaluate and key in, so a graphic model, such as a Radar Map, may be substituted to enhance the human–machine interfaces. To take this research further, two directions can be considered. Several techniques, such as Balanced Score Card, can be further incorporated into the VEW assessment model to link corporate strategy for VEW goal setting and to expand goals from simple cost saving to include financial, customer, internal process, and learning and innovation aspects. Additionally, in accordance with the assessment criteria identified by the study, further research on establishing a VEW procedure specifically suited for Taiwanese construction projects is in progress.

Acknowledgements

Contract No. NSC92-2622-E-224-022-CC3. Special thanks also go to all survey participants for their valuable comments.

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