The effect of using group decision support systems in value management studies: An experimental study in Hong Kong

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Abstract: A group decision support system (GDSS) can be helpful to VM users overcome difficulties in value management (VM) workshops. A web-based GDSS known as interactive value management system (IVMS) is introduced in this paper. A comparative experimental study is undertaken to investigate the extent to which the use of IVMS can improve the performance of VM workshops by using a competing value approach (CVA). This study compares and contrasts the performance of a traditional VM workshop with an IVMS-supported VM workshop in three aspects: (1) process measures, (2) outcome measures, and (3) participants' satisfaction. The process measures indicate that IVMS is helpful in improving the efficiency, information reliability and supportability of decision and participation process, while the outcome measures show groups supported by IVMS perform better in ideas generations. The results also indicate that the use of GDSS results in increasing participant satisfaction.

Keywords: Value management (VM); Group decision support system (GDSS); Competing value approach (CVA)

1. Introduction

Value management (VM) is a structured and analytical process that seeks to achieve value for money by providing all necessary functions at the lowest cost consistent with required levels of quality and performance (AS/NZS, 1994). VM, which has been widely used in many developed countries for several decades, is a useful tool that can help the industry to meet these challenges. However, reluctance to use VM often stems from the time that an expensive team has to be employed to undertake the VM process (Shen and Chung, 2002). It would therefore be helpful to find a way that can make the process more efficient and effective to make the cost of undertaking VM decrease. VM faces more difficulties when employer – employee and superior – subordinate are in the same team, due to member dominance and conformance pressure (Shen et al., 2004), as shown in Table 1.

A group decision support system (GDSS) or group support system (GSS) combines communication, computer and decision support technologies to facilitate the formulation and solution of unstructured problems by a group of people (DeSanctis and Gallupe, 1987). For almost 20 years, researchers have been studying the effectiveness and efficiency of GDSS that support synchronous and asynchronous teams working in both field and laboratory settings. Many research studies have demonstrated that it is successful in improving the efficiency, reliability and quality of the group decision-making process (Dennis et al., 1990; Greenbery, 1991; Nunamaker et al., 1996; Adkins et al., 2002), but on the whole the findings related to the effectiveness of GDSS have been relatively inconsistent (Benbasat and Lim, 1993; Dennis and Gallupe, 1993; Fjermestad and Hiltz, 1999). However, although inconsistent results do indeed relate to variations in the experimental settings and methodology adopted in experimental studies, the common findings of a number of field studies have proved the effectiveness of GDSS in practice. These field studies have consistently shown positive results, and many "real world" users are satisfied with GDSS applications. These findings demonstrate the effectiveness of GDSS in supporting the group decision-making process (e.g., Dennis and Gallupe, 1993; Chun and Park,

1998).

Table 1
Problems of VM implementation in Hong Kong's construction industry (Shen et al., 2004).

Problems	Reasons	Impacts
Lack of information	• Poorly organized project information in the pre-study stage • Difficulty of retrieving project information in meetings	Increases "uncertainty" in the outputs of VM studies
Lack of participation and interaction	• Shy about speaking in public • Pressure to conform • Dominated by a few individuals • Poor team spirit	Member's contributions are reduced
Difficulty in conducting evaluation and analysis	• Insufficient time to compare analysis • Insufficient information to support analysis	Members have difficulty in responding to the "what if" question in meetings

Since the above research findings show that GDSS has the potential to improve the group decision-making process, GDSS was proposed to overcome the above problems in VM workshops. A series of studies have already been conducted to investigate the effectiveness of using GDSS in VM workshops (Fan and Shen, 2004; Shen and Fan, 2005; Shen et al., 2006; Fan et al., 2006, 2007). During the above studies, comparative experimental studies were taken as the main research method. Workshops conducted in traditional ways have been compared with workshops with GDSS support in several aspects (i.e., the decision quality, the quantity of ideas, and the perceived satisfaction). The results of these experimental studies show that GDSS is a useful tool in facilitating information exchange process, encouraging interaction, and promoting active participation in VM workshops. However, these findings were only based on the assessment of outcomes, and process effectiveness was overlooked. Now the question is how to evaluate the performance of GDSS in VM workshops comprehensively. Researchers have different viewpoints on what is or how a performance factor should be measured. Following the approach of Drazin and Van de Ven (1985), Benbasat and Lim (1993), and Dennis and Kinney (1998), Dennis and Wixom (2002) defined performance in terms of three major factors: (1) effectiveness as defined by decision quality or number of ideas generated; (2) efficiency as defined by the time to complete the task, and (3) participants' satisfaction with the process or outcomes. In order to investigate the performance of GDSS supported VM workshops comprehensively, a comparative experimental study is conducted based on the performance framework developed by (Dennis and Wixom, 2002).

According to the framework, this paper compares and contrasts the performance of a traditional and GDSS-supported VM workshop in three aspects: (1) efficiency (process measures), (2) effectiveness (outcome measures), and (3) participants' satisfaction. This paper further revised this framework by integrating with a competing values approach (CVA) which is mainly used to measure the process performance. After the introduction of the framework, this paper turns to describe the design and process of the experimental study. Finally, the results of this experiment are presented and discussed.

2. Evaluating performance

In the three factors (efficiency, effectiveness and participants' satisfaction), efficiency falls into process, and effectiveness falls into outcomes correspondingly. Likewise, Fjermestad and Hiltz (1999) after reviewing approximately 200 published papers on GDSS found that among the outcome factors, group effectiveness and participants' satisfaction were the two factors most studied. Group effectiveness was measured in terms of decision quality and creativity, while participants' satisfaction included process satisfaction, decision satisfaction and general satisfaction (Fjermestad and Hiltz, 1999; Paul et al., 2004). Whereas no one

conception of performance is perfect, the above three factors comprising group effectiveness (outcomes), group efficiency (process) and participants' satisfaction can be considered as a reasonable set of factors to triangulate on the performance construct (Dennis and Wixom, 2002). The outcomes can be measured by the quantity of ideas, the quality of decisions, and the satisfaction is usually measured through a questionnaire survey, while evaluating the effectiveness of the decision process is problematic.

2.1. Evaluating the performance of the group decision process: the competing values approach

Normally, the effectiveness of the decision process will be measured by the outcomes. However, it is quite possible for a most unreasonable method of information integration to be linked over time with coincidence, while in another instance for a most reasonable method of collective choice subsequently to fall far wide of the mark (McCartt and Rohrbaugh, 1989). Also, on many occasions, the decision process of a group, unlike the decision itself (made as a result of such a process), cannot be evaluated readily on the basis of observed outcomes except in most carefully controlled social experiments (Rohrbaugh, 1987). Such research designs must be able to rule out not only the possibility that alternative group interventions at work in the same environment could produce equally satisfactory outcomes, but also the possibility that alternative decisions could do as well or better that the actual choice made by the group (Reagan and Rohrbaugh, 1990).

It is difficult to judge the performance of the decision process by the corresponding outcomes, especially if the intention is to identify a set of interventions that will improve the effectiveness of a variety of managerial groups or executive teams. Our research, which aims to investigate whether the intervention of GDSS in VM workshops can improve the performance, falls in this category. Hence, it is suggested that any assessment of the effectiveness of a group decision process requires directing primary attention to the process itself, not to subsequent outcomes (Reagan and Rohrbaugh, 1990; McCartt and Rohrbaugh, 1989). The competing value approach (CVA), which is a large conceptual framework with criteria, has been suggested by Reagan and Rohrbaugh (1990), McCartt and Rohrbaugh (1989) to judge the effectiveness of group interaction in decision-making process.

The earliest framework of CVA was a multidimensional scaling project that identified three axes strengthening judgments about the similarity of 16 commonly used criteria for assessing collective performance effectiveness (Quinn and Rohrbaugh, 1981). The theory fundamental for the CVA approach is that the criteria commonly used to assess collective performance effectiveness reflect alternative priorities for any group or organization. According to the framework, there are three dimensions:

(1) *Structure:* The need for flexibility competes with the need for operational control;
(2) *Focus:* Attention to internal organizational issues competes with attention to conditions external to the organization;
(3) *Means-ends:* An emphasis on process and procedures (as means) competes with an emphasis on outcomes or objectives (as ends).

Four distinct models are identified based on the first two dimensions of competing values (i.e., focus and structure), (1) the rational goal model, (2) the open system model, (3) the human relations model, and (4) the internal process model. The third value dimension, means and ends, is reflected in each model, since each model is concerned with both process and outcome effectiveness.

When the CVA framework is applied to the process of group decision-making to assess the performance, four similar perspectives are identified based on the above four models. They are:

The rational perspective (corresponding to the rational goal model) favors logic and clear thinking over empiricism, attends primarily to organizational goals and objectives, and tends toward methods that can efficiently assist decision makers with their reasoning;

The political perspective (corresponding to the open systems model) values adaptability and flexibility in a creative decision process, is attuned to shifts in the problem environment, and is concerned about finding solutions that maintain or enhance the standing of the decision makers;

The consensual perspective (corresponding to the human relations model) expects a fully participatory decision process, advocates open expression of individual attitudes and beliefs, and prizes collective agreement on a mutually satisfactory solution;

The empirical perspective (corresponding to the internal process model) emphasizes the importance of information in a decision process, encourages the development of reliable databases to provide decision support, and stresses the need for documentation and full accountability.

Fig. 1 graphically depicts these four perspectives. Moreover, Quinn and Rohrbaugh (1981), and McGrath, (1984) proposed that each of these perspectives might depend on at least two dominant criteria (one oriented toward means, the other toward ends) by which group decision processes are evaluated. The proposed eight criteria were: (1) a goal-centered process; (2) the efficiency of decision; (3) an adaptable process; (4) legitimacy of decision; (5) a participatory process; (6) supportability of decision; (7) a data-based process; and (8) accountability of decision (McCartt and Rohrbaugh, 1989). This study adopts the above eight criteria to assess the effectiveness of VM processes.

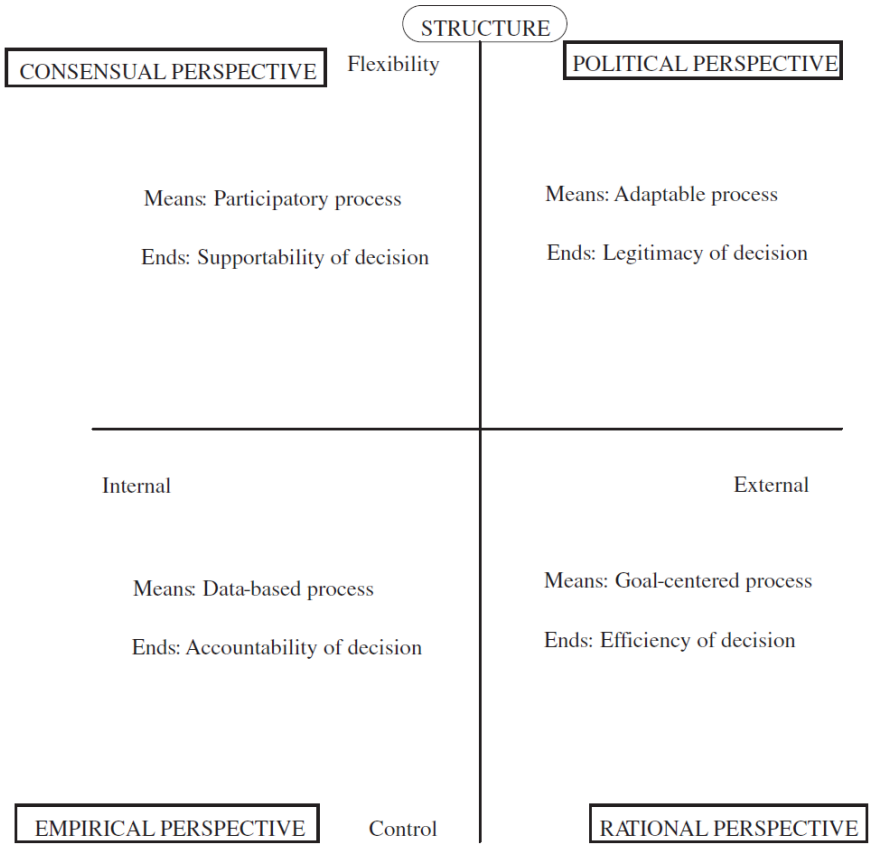


Fig. 1. The CVA framework for group decision processes (adopted from McCartt and Rohrbaugh (1989)).

3. Research method

3.1. Overview of the Study

Hicks (1982) defines an experiment as a 'study in which certain independent variables are manipulated, their effect on one of more dependent variables is determined and the levels of these independent variables are assigned at random to the experimental units in the study'. The experimental style of research suited best to 'bounded' problems or issues in which the variables involved are known, or at least hypothesized with some confidence (Fellows and Liu, 2003). In this research, the variable involved was the application of GDSS. Therefore, it was reasonable for us to use experimental studies to investigate the effect of GDSS use in the processes and outcomes of value management studies.

In order to investigate the effect of using GDSS in VM workshops, a comparative study was undertaken, in which two VM workshops were conducted: one workshop was carried out using the traditional method, and the other one was provided with GDSS support. A real project task in Hong Kong: cycle tracks connecting North West New Territories with North East New Territories was taken as the task. Three main objectives of this study, which are extracted from the real tasks in a real-life VM study, are listed as follows:

- to create a structural forum whereby views from all stakeholders on the construction of new cycle track sections to create a cycle track network;
- to discuss and decide on what supporting facilities should be provided to enhance the tourism value of the existing and new cycle track network;
- to identify and agree on the functions for the education center.

The participants were divided into two groups, and each group was asked to organize, manage and conduct a 1.5 days VM workshop to achieve the above objectives. One workshop was conducted in the traditional way, while the other was conducted with GDSS support. Tests of the differences between the two workshops were conducted to investigate the effectiveness of the GDSS use.

3.2. A Web-based GDSS

A web-based GDSS, named interactive value management system (IVMS) was developed and used in this study. IVMS is built based on the Windows SharePoint Services (WSS) designed by Microsoft, which serves as a platform for application development, typically to facilitate the development of web-based programs for information sharing and document collaboration. Including such IT resources as team workspaces, email, presence awareness, and web-based conferencing, WSS enables users to locate distributed information quickly and efficiently, as well as connect to and work with others more productively. With the help of WSS, IVMS can be integrated with other useful software easily, including Microsoft Visio, Office and Messenger. Based on the functions provided by WSS, IVMS integrates GDSS with the VM methodology to provide useful support to overcome problems in VM workshops. Based on the characteristics of VM workshops and the features of GDSS, the system structure of IVMS is designed, as shown in Fig. 2. Table 2 lists information support, analysis and evaluation support, and communication support provided by the system.

3.2.1. Information support

In a VM workshop, information relating to projects under review needs to be collected together from the

VM team members in the pre-workshop phase, such as costs, quantities, drawings, specifications, manufacturing methods, samples and prototypes. The participants need to give and receive information to understand the project issues and constraints before the workshop. However, one of the main problems in VM workshops is lack of information. This is in line with the work conducted by Park (1993). The findings suggest that many clients have shortened the duration of VM studies from 5 days to 1 or 2 days to save the cost. Hence, this information-gathering process cannot be organized properly without providing any preworkshop activities, such as the pre-workshop meetings and briefings. In order to alleviate the problems, IVMS provides information support to facilitate the information management process through electronic information tools.

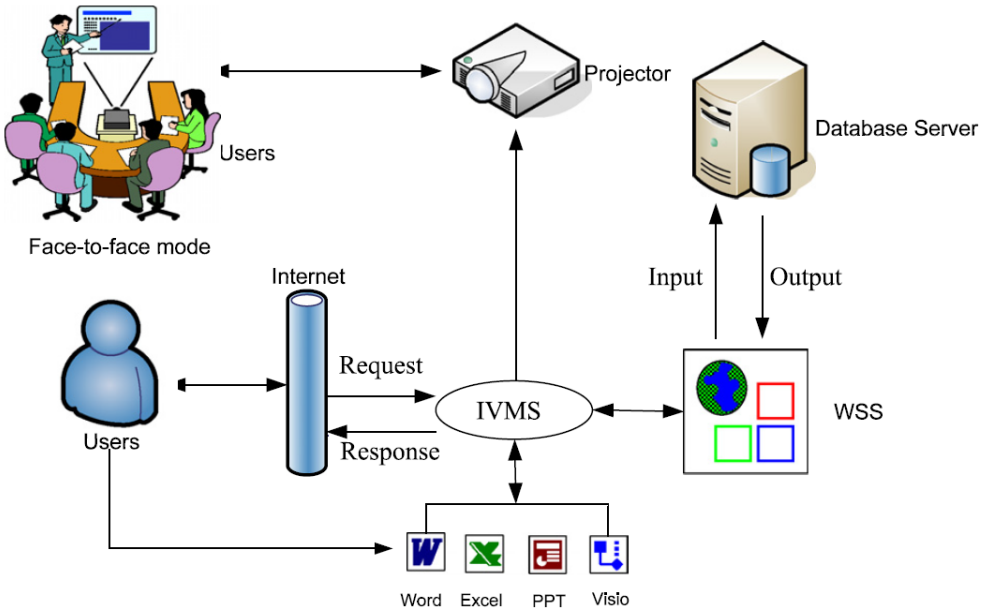


Fig. 2. System architecture.

Table 2
Supports of IVMS.

Supports	Functions	Benefits
Information support	Document library	Upload/download information
	Discussion board	
	Electronic agenda	Disseminate information
	Email notification	Automatic email notification
		Information allocation
Analysis and evaluation support	Electronic analysis tool	Ideas selection
	Electronic voting tool	Function analysis
Communication support	Electronic brainstorming	Anonymous and parallelism in brainstorming
	Discussion board	

A document library is provided for users to store and share the project information needed by the VM workshops. The document library allows users to store and share project information. It enables users in the

group to check documents in and out, thus guaranteeing that there was no chance of two users updating same documents simultaneously. The document library can also track the documents changes and maintain previous versions of documents so that if the team needed to revert to a previous version easily without having to restore a backup. The document library even offers a manageable set of permissions that control whom can read, create, or modify documents. The facilitator can even structure approval routing so that a change to a document will not be posted to the library until it has been approved by a facilitator. A user also can add an alert to a document so that he will automatically receive an email notification when changes are made. This improves the consistency of information and ensures that members can always receive the most up-to-date information throughout the workshops.

Questionnaires are commonly used to collect information before the workshop. IVMS also provides an easy way to conduct a questionnaire survey. The respondent's name can be set up to be visible or hidden in the results, and a graphical summary view will be automatically created to display a compilation of responses. Electronic agenda provides an outline of the workshop so that the team members know what to prepare for the workshop in time.

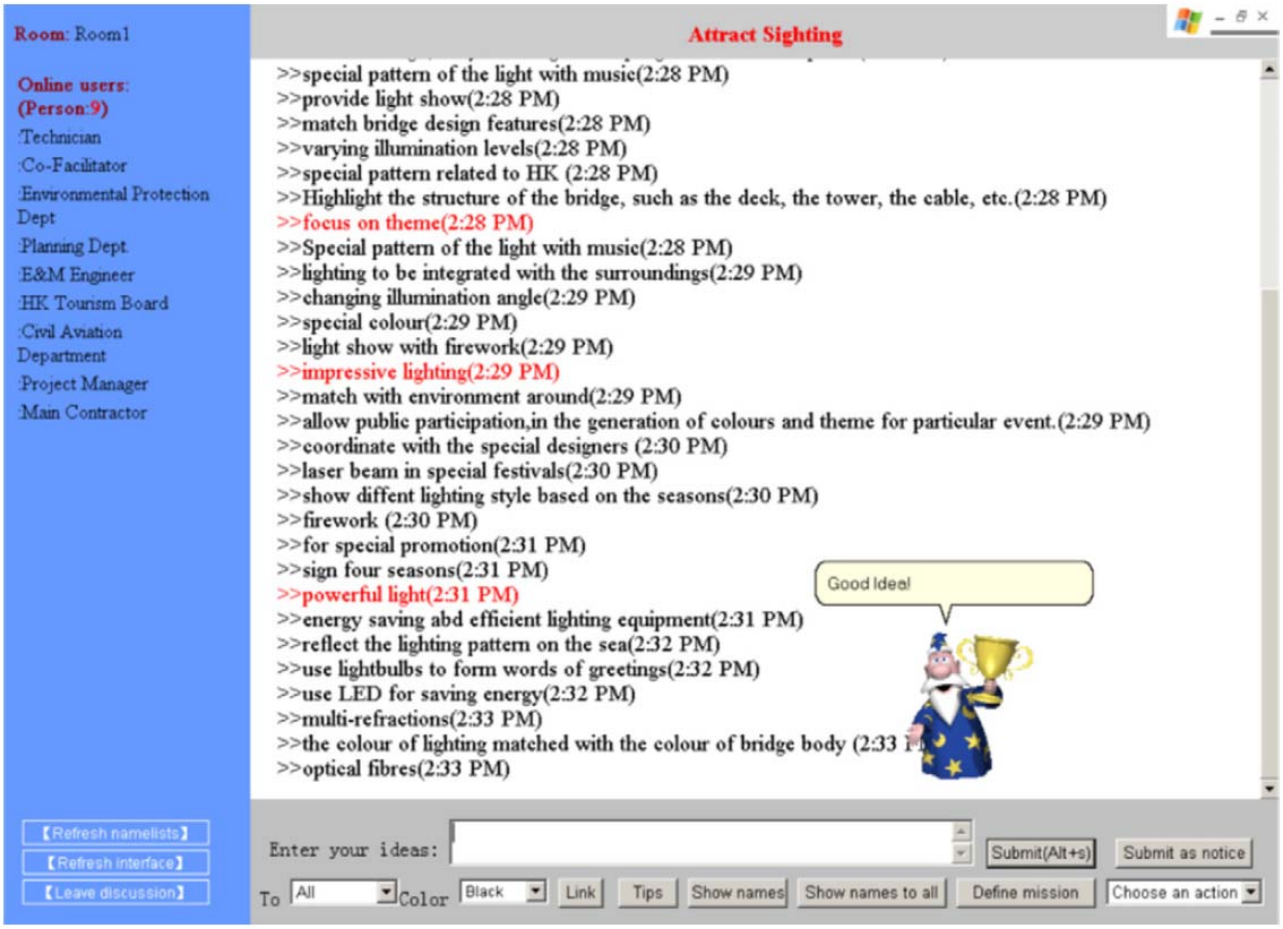
When the workshop durations are driven shorter by the market economics, IVMS will improve the efficiency of information sharing and enhance the information circulation through the above supports, and enable the facilitators easily to computerize and centralize the information gathering, distribution and circulation processes throughout VM workshops.

3.2.2. Communication support

Virtual meeting rooms are provided by the system to improve the quality of the brainstorming phase, which is commonly used to generate different functions or numerous alternatives for accomplishing functions during VM workshops. In order to alleviate the problems of lack of participation and interaction, the main features of the virtual meeting rooms are designed as follows:

- *Optional environment*: *anonymous or nominal mode:* The environment can be set to be totally anonymous or nominal according to the need of workshops. When the environment is anonymous, each user can read on his or her screen the ideas generated by other group members without knowing from whom they originate (as shown in Fig. 3). Users who fear receiving negative evaluations from others in the face-to-face session may not have this fear in the environment of anonymity in IVMS. This form of anonymity can reduce evaluation apprehension losses (Connolly et al., 1990; Gallupe et al., 1992). However, it does not mean that the nominal environment should not be used. While anonymous environment encourages participants to express their ideas freely, it may also lead to laziness. Some may work hard and some may have free ride on the efforts of others. In a nominal environment, the users' names are displayed with the ideas they generated, giving them the stimulus to generate more ideas to prove themselves. Therefore, the system provides an opportunity to choose the environment mode (anonymous or nominal) flexibly to exploit the full benefits.
- *Parallelism:* Parallelism helps to reduce production blocking since users no longer have to wait for others to express their ideas (Gallupe et al., 1991; Jessup et al., 1990). Users can express their ideas as soon as possible and then go onto generate other ideas.
- *Brainstorming agent:* It is found that there is more task-focused communication and less joking and laughing in GDSS-supported groups (Turoff and Hiltz, 1982), and people are more critical of each other's ideas when they communicate electronically (Siegel et al., 1986). DeSanctis and Gallupe (1987) also suggested that features intended to address the social needs of groups should be included in GDSS systems. IVMS provides an agent that can be pop-up with different words and gestures corresponding to the situation. For example, when the atmosphere is not so active, the system can be aware of this and a pop-up agent will

come out automatically to encourage the participants. On the contrary, the agent will also give the participants applause when the participants generate ideas actively (as shown below in Fig. 3).



• *Tips:* This function is designed to inspire the users by providing some constructive suggestions, for example, what if ice cream was hot or what if pigs could fly. The aim is to provide “triggers” to make the participants think in a different way so that fresh ideas may come out.

A discussion board is another tool provided by the system to support communication, which provide a forum for conversing about topics that interest the VM team. For example, the facilitator could create a discussion board to collect team members’ attitude or raise & answer questions.

Integrating with Windows Messenger, users can view the current status of team members and conduct peer-to-peer conversation by sending an instant message. Moreover, with the help of a web camera and microphone, interviews can be conducted through Windows Messenger, when it is not convenient to conduct a face-to-face interview.

3.2.3. Decision and analysis supports

The analysis and decision supports aim to apply electronic tools, including weighted voting, ideas categorization and weighted evaluation tools, to improve the productivity and accuracy of data processing and, therefore, resolve the problems of insufficient time to complete the analysis in the analysis and evaluation phases.

The tools of electronic data analysis of the system simplify the processes of evaluation and analysis. The modelling tools such as the pair-wise comparison and multicriteria evaluation model (Fig. 4) provide

analytical frameworks to standardize the processes of evaluation and analysis. Members can simply input data into the models and results will be generated automatically. With WSS as the platform, IVMS is tightly integrated with Microsoft products such as Microsoft Office, FrontPage, and SharePoint Services, so the individual can work tasks within familiar Microsoft programs in VM workshops. Members can vary the input data and the general pattern or the impact of different solutions can be produced quickly. These tools of analysis improve the productivity of evaluation and data analysis processes.

Fig. 4. Pair-wise comparison and multi-criteria evaluation.

The evaluation and prioritization tools, such as voting, idea categorization and weighting evaluation, can be applied to simplify and shorten the time required in the analysis and evaluation phases.

3.3. Participants in the study

The participants were 34 part-time postgraduate students enrolled in a value management course at the Hong Kong Polytechnic University. An integrated component of the course is a strategic simulation that requires students to organize a VM workshop. All of the students have been working in the construction industry for several years. Their work experience would enable them think in similar ways with the real-life VM participants. They were divided into two groups: one group conducted the VM workshop using the traditional method, while the other conducted the VM workshop with GDSS support.

However, there is often a concern raised regarding the use of students as subjects in GDSS research. Fjermestad and Hiltz (1999) report that 94% of those studies involved students as subjects. The limitation of using students as participants had been recognized long before (Lorge et al., 1958), but there is still much research which uses students due to the difficulty in persuading real managers to participate in GDSS sessions. However, Briggs et al. (1996) found no significant differences between executive business managers and graduate business students in evaluating technology. Also, Remus (1986) found no significant differences between line managers and MBA students with little business experience in production scheduling decisions. The participants in this study are not only students but also experienced parties in the construction industry. Also, an important reason why it is difficult to generalize results from laboratory studies to field studies is that the participants do not care for the outcomes as much as the ones in the field studies. Fifty percent of a student's grade was contingent on their group performance in this VM workshop, which meant that the performance and outcomes of the study was relevant to their scores. Therefore, it is reasonable to assume that the participants would try their best to conduct the workshop. Given these, we felt comfortable with the background of our subjects.

3.4. Experimental equipment and procedures

The task description was given to the participants 3 weeks before the VM workshop in order to help ensure the participants were fully prepared. The workshop was designed as a 1.5 days VM study. During the whole process of the VM workshop, each session was observed unobtrusively by one researcher. The researcher recorded useful information relevant to performance, and also provided technical support to ensure the system worked fluently during the GDSS-supported workshop. Besides, the settings for the two workshops were different. The GDSS-supported VM workshop was conducted in a GDSS room, as shown in the left part of Fig. 5. The right part shows the traditional face-to-face VM workshop. From Fig. 5, it can be found that the GDSS-supported workshop was also set up in a face-to-face environment, as the aim of our study was not to replace the face-to-face environment but to integrate GDSS with it to obtain benefits from both approaches.

Fig. 5. The IVMS-supported and traditional VM workshops.

In order to determine the GDSS effects on the processes and outcomes of both workshops, both workshops were facilitated by the same experienced facilitator to reduce effects of the facilitator variable. Both workshops were also conducted according to the same agenda based on the generic VM process as shown in Fig. 6, including information, creativity, evaluation, development, action planning, and workshop report. Since this study was not a real-life one, the last phase “implementation” was not conducted.

The main difference between the two workshops was that the tasks during the GDSS-supported workshop were conducted through the tools provided by GDSS, as shown in Table 3.

Since all the participants have obtained basic VM knowledge with the process of the VM workshop from the VM course, and IVMS was designed according to the VM process, it is easy for the participants to get familiar with the system with the guide of the facilitator. Hence, no special training was arranged before the workshop for the participants who would use IVMS during the workshop. The process of the workshop also demonstrated that the system was user friendly.

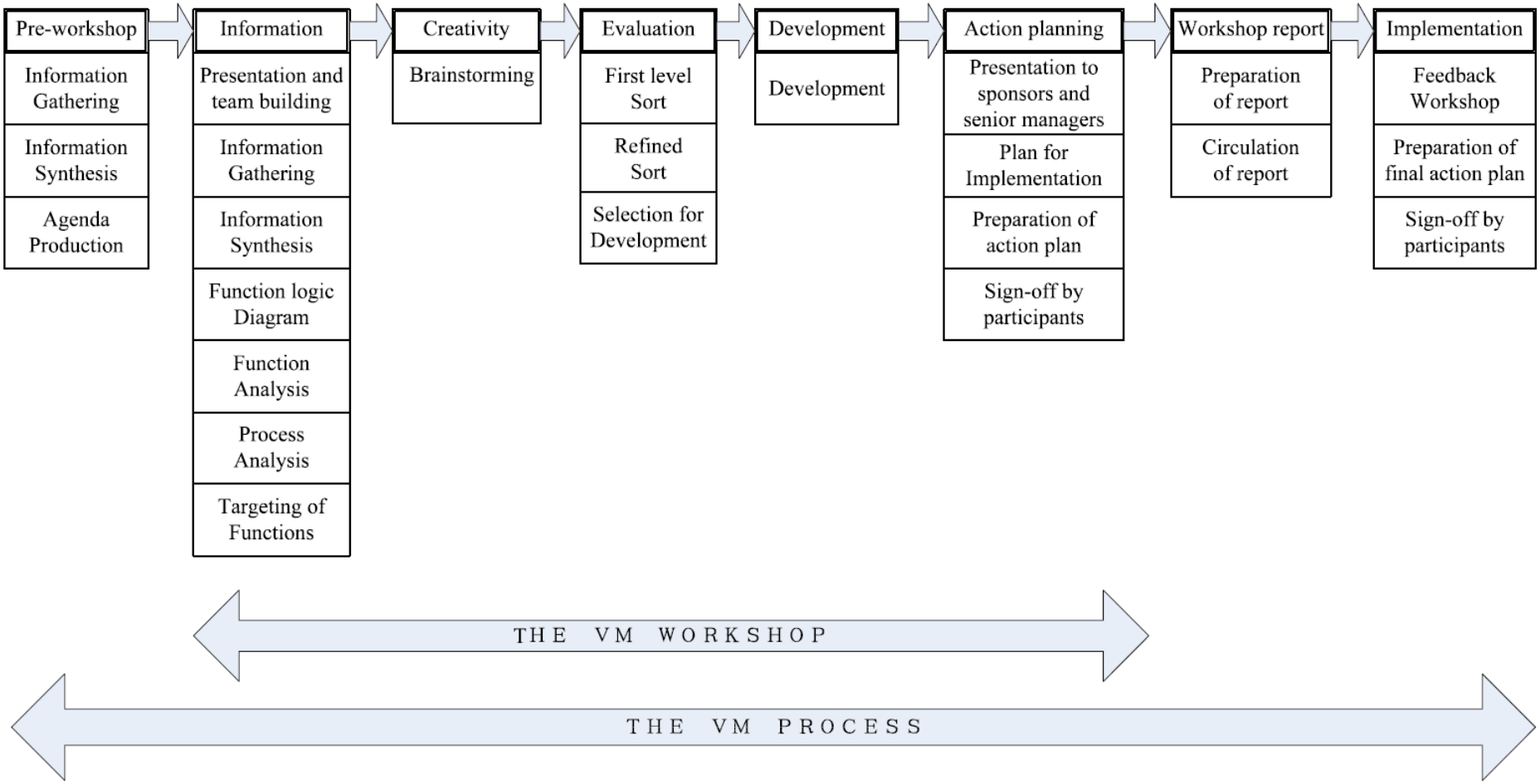


Fig. 6. The generic VM process (Male et al., 1998).

Table 3
Differences between the GDSS-supported workshop and the traditional workshop.

Phase of the workshop	Traditional workshop	GDSS-supported workshop
Pre-workshop	Participants communicated and shared information through email and meetings	Data and files were shared through the information library provided by the system. Automatic email notification notified the participants of the appearance of new information. Questions were proposed and answered through the discussion board
Information	Participants spoke out the functions, and then the functions were written down on small labels to draw the function diagram	Participants typed the functions into the system, and then the system automatically generated standard .doc files with label format
Creativity	Face-to-face brainstorming: users speak the ideas one by one, and the ideas are recorded on paper	Electronic brainstorming: users type the ideas into the system simultaneously and anonymously. Users can also see others' ideas through their own screen
Evaluation	Ideas were typed into Excel before the evaluation. The score was calculated by participants after the evaluation	GDSS automatically collected the ideas generated. Electronic voting and evaluation tools were used to select and score ideas
Workshop report	Since most information was recorded on paper, participants need to type the information into a computer	All the information was stored in the system electronically. It was much easier for the participants to prepare the report

Measures used in the study

Then the two workshops were compared in three aspects to judge the effects of using GDSS:

• *Process measures:* The CVA framework was used to measure the perceived effectiveness of the decision process during the two workshops through a questionnaire. The largest number of items on the questionnaire pertained to the CVA framework, while others related to the outcomes and satisfaction measures. The questionnaire employed a six-point Likert-type response scale (i.e., strongly agree, generally agree, slightly agree, slightly disagree, generally disagree, and strongly disagree). Each of the eight criteria, according to Fig. 1, was determined through the mean of numerically coded participant responses to two or three questionnaire items. Some of the items were reverse-worded to reduce a possible response-set bias. The items comprising the CVA framework in the questionnaire are presented in the Appendix A.

• *Outcome measures:* Unlike intellective tasks, decision making tasks do not have any correct outcome (McGrath, 1984). Yet decision quality as perceived by the participants is an important dependant variable for decision-making work. Perceived decision quality includes group members' confidence in the decision outcome and their perceptions of the usefulness of the decision outcome (George et al., 1990). Also, the quantity of ideas is usually taken as one of the factors to judge the effectiveness of VM workshops. During the workshops, the quantity of ideas can be easily obtained. Then the ideas were evaluated by the workshop participants towards a number of criteria, e.g., safety, time, and cost. The ideas with good quality were categorized as $P1^2$ ideas (the P1 ideas can be taken as quality ideas). Finally, the quantity and quality of ideas generated during the two workshops were compared and analyzed. Another factor to be considered as part of the outcome measures is perceived participation, which has received considerable attention in GDSS research (Fjermestad and Hiltz, 1999). The perceived participation was measured through the questionnaire through asking the participants to what extent they agree that the interaction among the VM team was active in each phase and the workshop has improved the communication and understanding among key stakeholders, etc.

• Participants' satisfaction: Satisfaction is always an important factor. After reviewing approximately 200 published papers on GDSS, Fjermestad and Hiltz (1999) found that among the outcome factors, group effectiveness and participants' satisfaction were the first two most studied. The perceived satisfaction was measured through asking the participants to what extent they are satisfied with the performance of the workshop.

4. Findings and discussion

4.1. Process measures

Fig. 7 presents the differences between the decision process profiles for the two VM workshops. Scale scores for the eight effectiveness measures are plotted on the axes of each profile. When perceptions of an effective decision process are more positive, the profile is extended outward on an axis. Concavities in the profile indicate aspects of decision process effectiveness that may deserve remediation.

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[2] *The ideas were categorized into three categories: P1 = realistically possible; P2 = remotely possible; P3 = fantasy.*

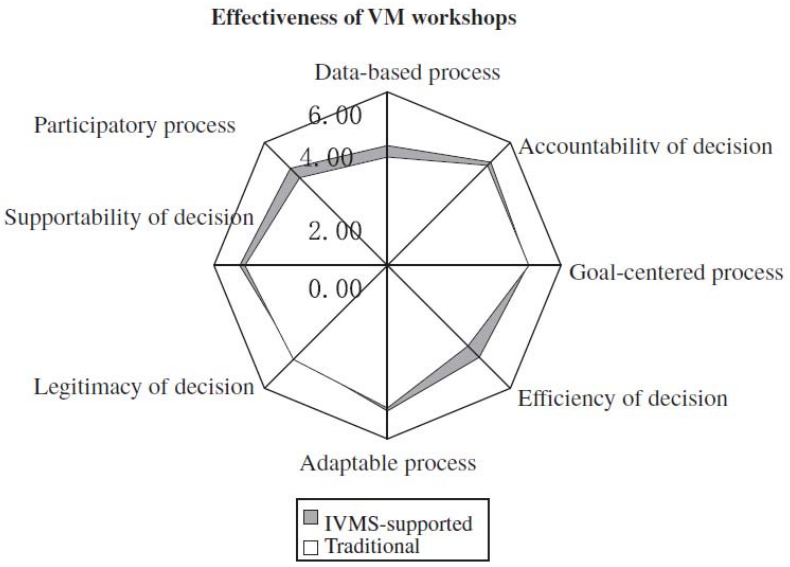

Fig. 7. Profiles of decision-making effectiveness for the two VM workshops.

Since the CVA framework was used to differentiate VM workshops with respect to the methods (IVMS-supported and traditional methods) success. From Fig. 7, several scales discriminate between the IVMS-supported and traditional workshops. The mean and t-test results are shown in Table 4. It can be found that the IVMS-supported VM workshop outperformed the traditional VM workshop in the following aspects: data-based process, accountability of decision, efficiency of decision, adaptable process, participatory process, and supportability of decision. It is also important to note that in other scales both workshops were quite highly scored.

Table 4
Results of variance for process effectiveness.

Criteria of CVA framework	IVMS-supported workshop (mean)	Traditional workshop (mean)	Difference	*t*-test
Empirical				
Data-based process	4.15	3.75	0.40	0.03*
Accountability of decision	5.02	4.90	0.12	0.28
Rational				
Goal-centered process	4.84	4.90	-0.05	0.36
Efficiency of decision	4.49	3.92	0.57	0.005*
Political				
Adaptable process	5.03	4.94	0.09	0.35
Legitimacy of decision	4.49	4.56	−0.07	0.38
Consensual				
Participatory process	4.75	4.29	0.45	0.005*
Supportability of decision	5.10	4.91	0.19	0.24

* Significant at the 0.05 level.

Table 4 shows that there were significant differences between the IVMS-supported and traditional workshops in the following three aspects: data-based process, efficiency of decision and participatory process. In other aspects, there were no significant differences. The reasons were interpreted correspondingly as follows:

• Data-based process and Efficiency of decision: The information support provided by IVMS can collect ideas generated, and store/disseminate information easily among the participants. Therefore, it improved the efficiency of information sharing and enhanced the information circulation, and enabled the facilitators to easily computerize and centralize the information gathering, distribution and circulation processes throughout VM workshops. The above features of IVMS are the possible reasons why the IVMS-supported workshop obtained a higher score in the aspects of data-based process and efficiency of decision.
• Participatory process: The higher score obtained by the IVMS-supported workshop in this scale shows that the communication between participants was better during IVMS-supported VM workshops. The reason could be the communication support provided by IVMS, as shown in Table 1. The anonymous and parallelism in ideas generation encourage the participants to express their personal ideas, which are supported by many previous research studies (Connolly et al., 1990; Gallupe et al., 1991; Gallupe et al., 1992; Jessup et al., 1990).

Referring to other aspects, since there were no significant differences between the two workshops, it indicates that the use of GDSS will not change the VM process in accountability of decision, goal-centered process, adaptable process, legitimacy of decision, and supportability of decision. In this study, the same facilitator was invited to facilitate both workshops, and the participants of both workshops had similar backgrounds. Therefore, the more comprehensive conclusion should be that, with other conditions unchanged, the use of GDSS will not affect the process of VM workshops in the following aspects: accountability of

decision, goal-centered process, adaptable process, legitimacy of decision, participatory process, and supportability of decision.

4.2. Outcome effectiveness

4.2.1. Quantity and quality of ideas

Table 5 shows the number of unique ideas generated by each participant with different brainstorming approaches. Participants using IVMS generated more unique ideas than the ones using the face-to-face method (11.06 > 5.41). Furthermore, there is significant difference between the two sets of data, as the significance is $p = 0.004 < 0.05$, which means that the number of unique ideas generated through IVMS was statistically larger than that through the face-to face approach. In Table 5, the number of unique P1 ideas generated per person through IVMS is also larger than that generated using the nominal method (5.24 < 3.00). There is significant difference between the two sets of data, as the significance is $p = 0.02 < 0.05$, which means that the number of unique P1 ideas generated through IVMS was statistically larger than that using the face-to-face approach.

There are two possible reasons. Firstly, the parallel entry of ideas, i.e., using IVMS users did not need to wait their turn to express their ideas, can be one of the most important reasons, since only one user at a time could express ideas in the traditional workshop. Secondly, the environment of total anonymity of IVMS is another important factor. The results of the observation showed that participants in the workshop with IVMS support were more active than the ones in the traditional workshop. The anonymity made the users more active by removing the participants' fear of receiving negative evaluations from others in the traditional workshop.

Table 5
Unique ideas and P1 ideas from the face-to-face and IVMS approaches.

Brainstorming method (number of participants)	Unique ideas		Unique P1 ideas	
	Traditional (17)	IVMS-supported (17)	Traditional (17)	IVMS-supported (17)
Mean	5.41	11.06	3.00	5.24
Standard deviation	2.06	4.10	1.66	2.47
Significance	$p = 0.004 < 0.05^*$		$p = 0.02 < 0.05^*$	

* Significant at the 0.05 level.

Table 6
Perceived decision quality and participation.

Items	Traditional	IVMS-supported	*t*-test
Interaction among the VM team was active in each phase	4.29	4.65	0.02*
Client's requirements have been identified and clarified	4.06	4.53	0.007*
You are satisfied with the performance of the workshop	4.35	4.59	0.04*

5: strongly agree 4: agree 3: neutral 2: disagree 1: strongly disagree.
* Significant at the 0.05 level.

4.2.2. *Perceived decision quality and participation*

From Table 6, it can be found that the interaction during the IVMS-supported workshop was ranked higher. The participants also thought that client's requirements were better identified and clarified in the IVMS-supported workshop. The corresponding t-test results of the above two items were also significant, which indicated that the perceived decision quality and participation of IVMS-supported VM workshop were better.

4.3. Perceived participants' satisfaction

From Table 6, it is suggested that all of the participants were more satisfied with IVMS than with the

traditional approach (grand mean of 4.59 and 4.35, respectively), and the corresponding t-test result was significant at the 0.05 level. One possible reason could be novelty. Since the users did not use IVMS before the experiment, the feeling of novelty may be the reason that IVMS received a good score. However, since one important aim of the VM workshop is to achieve a consensus among the members of a group and to make people feel satisfied with the decision-making process, if the participants' satisfaction is one important criterion, IVMS should be regarded as a better approach than the traditional one.

4.4. Implications for VM practitioners

In Hong Kong, both the government and the construction industry have called for a wider use of VM. The Construction Industry Review Committee (2001) recommended wider use of VM in local construction, and the newly formed Environment, Transport and Works Bureau (2002) has pushed this further to require VM studies for every major public works project. It is critical to address the urgent needs of VM users and practitioners in Hong Kong, to fully exploit the potential of the technology in improving the effectiveness and efficiency of VM studies, and to overcome the difficulties they have encountered in the use of VM, which prohibit wider use of the methodology. This research investigated the effects of using GDSS in VM studies through the comparison between a GDSS-supported VM workshop with a workshop without GDSS support. This research gives the practitioners direct information on the performance of VM study using GDSS. The practitioners could know the possible outcomes when they apply GDSS in real-life VM studies and then decide whether it is appropriate to apply GDSS in VM studies in which they participate.

4.5. Implications for further research

This research has contributed to the field of knowledge, spanning across different areas: information technology and construction management. GDSS is in the field of information technology, and is applied predominantly in group meetings. Value management belongs to construction management, and its use in construction related projects is focused on during this research. This research has explored the application of GDSS in a new field: value management. The main research outcomes include new knowledge on the impact of using GDSS on the overall outcomes of VM studies, and the generation of quantitative data on the extent to which GDSS can enhance team behavior and group facilitation in VM studies. It indicates that the use of GDSS can be one possible solution to the difficulties frequently encountered by users during VM studies. However, since the findings are concluded from only one study, more similar studies should be conducted to achieve a more comprehensive conclusion. Another limitation is that this research is an experimental study. Although it is difficult, field studies should be conducted to further validate the findings in real-life VM workshops.

5. Conclusions

This paper investigated the performance of using IVMS in a VM workshop in three aspects through a comparative study: process measures, outcome measures, and participants' satisfaction. The results of process measures illustrate that IVMS can improve the process of VM workshops in three aspects: efficiency of process, databased process, and participatory process. The outcome measures show that groups using IVMS can generate more unique ideas and more unique P1 ideas than the groups with face-to-face brainstorming. The participants were also more satisfied with the IVMS-supported VM workshop. All of these findings

indicate that IVMS can be a useful tool in facilitating the information exchange process, encouraging interaction, and promoting active participation in VM workshops.

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Appendix A – Questionnaire: the CVA part

A.1. Data-based process

The process was based too much on subjective judgments rather than factual considerations. (R)
All information relevant to the workshop was available to the group.

A.2. Accountability of outcome

A record was made to document the resolutions of all key issues.
As the result of the process, the group was well prepared to be fully accountable for the decisions made during the workshop.
The process recognized the need for the group to be answerable for the action plan.

A.3. Goal-centered process

The process encouraged you to consider the workshop's goals and objectives.
All the potential effects of all the alternatives were carefully weighed.
The process made the discussions specifically relate to the objectives.

A.4. Efficiency of process

Important resources were wasted in the process of this workshop.
Results were achieved in much less time that it ordinarily would have taken.
It was a productive process involving a lot of hard but worthwhile work.

A.5. Adaptable process

The process was very flexible in dealing with the problem.
The process stimulated innovative ways of looking at the problem.

A.6. Legitimacy of decision

An effort was made to find a solution that would not in any way damage the standing of your organization.
The feasibility of each decision was seriously considered.
An effort was made to find a solution that would not in any way damage how others perceived the group.

A.7. Participatory process

You were always encouraged to express your personal concerns, even when divergent.
A great effort was made to understand the interests and concerns of every party of the workshop.
Conflict was dealt with constructively.

A.8. Supportability of decision

At the end of the workshop, the group displayed a strong team spirit.
During the process the group achieved a common understanding of the problem.
Serious reservations about proposed action make it impossible to get a full consensus. (R)
*R – The items with R are reverse-worded to reduce a possible response-set bias.