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THE EFFECT OF USING GROUP DECISION SUPPORT SYSTEM (GDSS) ON VIRTUAL VALUE MANAGEMENT WORKSHOPS FOR MAJOR CONSTRUCTION PROJECTS

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Ph.D

The Hong Kong Polytechnic University

2015

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Department of Building and Real Estate

The Effect of Using Group Decision Support System (GDSS) on Virtual Value Management Workshops for Major Construction Projects

YUAN Zhao

A thesis submitted in partial fulfillment of the requirements for the Degree of Doctor of Philosophy

August 2014

Certificate of Originality

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YUAN, ZHAO

Abstract

The construction industry is struggling to meet its customers' demands for value for money for their projects, especially for major projects because there are so many stakeholders such as the client, government agencies, specialist consultants, contractors and subcontractors. As suggested by the HKSAR Construction Industry Review Committee, many of these problems could be avoided through more thorough consideration at the planning and design stages. This problem has been rectified to some extent by the practice of Value Management (VM), in which stakeholders of major construction projects work together in a workshop, to systematically and proactively improve value for money for the projects by providing the required functions and specifications at the lowest life cycle cost, and eliminating potential sources of wastage and inefficiencies. For a number of practical reasons such as time and cost savings, there is an increasing need to conduct VM workshops virtually, with participants of the workshops dispersed geographically. The lack of understanding of the effects of this special setting on the processes and outcomes of the VM workshops, however, poses a serious problem to the use of VM for major construction projects.

This research aims at improving the performance of virtual VM workshops through the use of remote Group Decision Support Systems (GDSS) to facilitate workshop participants in their search for value for money; and investigating to what extent the use of remote GDSS affect the processes and outcomes of virtual VM workshops

where participants are geographically dispersed and rely on mediated (rather than face-to-face) communication to produce outcomes?

The research objectives of this investigation are: (1) To identify the essential features and functions to be possessed by a purposely-designed GDSS in order to support virtual VM workshops for major construction projects; (2) To validate and verity the extent to which a purposely-designed GDSS can support the completion of various tasks in a virtual workshop environment; and (3) To investigate and evaluate the extent to which the use of a purposely-designed GDSS affects the processes and outcomes of virtual VM workshops. These objectives have been achieved by adopting a group of rigorous research methods involving literature review, system development, system validation, experimental studies, interviews and questionnaire survey. A conceptual framework of virtual VM workshop was proposed based on the features of virtual team and virtual collaboration, in order to guide the implementation of virtual VM studies. A specific remote GDSS named as virtual value management system (VVMS) has been developed for realising virtual VM workshops in practice. Two experimental virtual VM workshops were conducted to achieve the research objectives mainly through a systematic approach using purpose-designed experimental studies conducted in Hong Kong. The results of the experimental studies have been analysed and discussed as well as of a questionnaire survey specifically conducted for the purposes of this research. The results have shown that GDSS is a useful technology to support the implementation of virtual VM studies with

satisfactory effectiveness and efficiency. In particular, the creativity of virtual VM workshop participants could be significantly stimulated in virtual context. Finally, a number of issues which have major potential impact on the performance of virtual VM workshop were identified and discussed in details.

This project leads to new knowledge and improved understanding of the actions, processes and changes in virtual VM workshops for major construction projects. The findings of this investigation are likely to enhance the effectiveness and efficiency of collaborative working of multiple stakeholders in a virtual workshop, and to have a significant impact on the way these workshops are managed and conducted to ensure best value for these projects.

Publications

Refereed Journal Papers:

1. Mohamad Ramily, Z., Shen, Q.P., Yu, A.T.W., Yuan Z. & Chung, J. K.H. 2013. Learning by doing: A hands-on value management workshop for postgraduate students. *Value World*, 36(1), 4 -11.
2. Peng, Y., Shen, Q. P., Shen, L. Y., Lu, C. & Yuan, Z. 2014. A generic decision model for developing concentrated rural settlement in post-disaster reconstruction: a China study. *Natural Hazards*, 71(1), 611-637.

Journal Papers Under Review:

3. Yuan, Z., Shen, Q.P., Chung, K.H., Mohamad Ramly, Z. & Yu, T.W. 2013. Using group decision support system (GDSS) to support virtual value management workshop: An experimental study. *ASCE Journal of Management in Engineering.* (under review)
4. Yuan, Z., Shen, Q.P., Chung, K.H., Mohamad Ramly, Z. & Yu, T.W. 2013. A comparative study of GDSS-supported and VVMS-enabled value management workshops. *Construction Innovation: Information, Process, Management.* (under review)
5. Mohamad Ramly, Z., Shen, G.Q.P, Yu, A.T.W., Yuan, Z. & Chung, J.K.H. 2013. Group Decision Support Systems for Value Management Workshops: A Case Study in Hong Kong. *ASCE Journal of Professional Issues in Engineering Education and Practices.* (under review)
6. 原钊，沈岐平，钟建雄. 2014. 虚拟价值管理工作坊在大型工程项目管理中的

应用研究. *土木工程学报*. (under review)

Conference Papers:

7. Yuan, Z., Shen, Q.P., Chung, K.H. & Mohamad Ramly, Z. 2013. A study of virtual value management workshop: identifying risks of its implementation. *Proceeding of International Conference on Construction and Real Estate Management, 2013*, 10-11 October, Karlsruhe, Germany, 712-724.
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11. Peng Y., Shen Q.P., Shen L.Y., Yuan Z. & Lu C. 2013. A comparison of two common approaches in developing concentrated rural settlement after Sichuan earthquake. *2013 International Conference on Public Policy,* 5-7 June, Beijing, China, 345-355.

Acknowledgement

I would like to express my deepest gratitude to Prof. Geoffrey Q.P. Shen for his supervision, direction and encouragement throughout this research. His noble character and moral, profound knowledge and research experience guided me to complete this research. Also, sincere appreciate must be expressed to my co-supervisor Dr. Jacky K.H. Chung for his valuable suggestions and comments.

My thanks go to The Hong Kong Polytechnic University for the excellent research support and facilities. I also thank both academic and non-academic staffs in the Department of Building and Real Estate for their kind help during these years.

Thanks are also due to all my friends and the colleagues in our research group whose help and encouragement supported me during my study. Although I will not list their names here for probably never being able to complete the list, my gratitude to them is no less sincere.

This thesis is dedicated to my wife, my son and my parents for their constant love and support over the years that this journey has taken.

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List of Abbreviations

CSCW	Computer Supported Cooperative Work
CSF	Critical Success Factor
DSS	Decision Support System
EMS	Electronic Meeting Systems
F2F	Face-to-Face
FAST	Function Analysis System Technique
FPS	Functional Performance Specification
GDSS	Group Decision Support System
ICT	Information and Communication Technologies
IVMS	Interactive Value Management System
KPI	Key Performance Indicator
VA	Value Analysis
VE	Value Engineering
VM	Value Management
VT	Virtual Team
VVM	Virtual Value Management
VVMS	Virtual Value Management System
WET	Weighting Evaluation Technique

Chapter 1: Introduction

1.1 Background

This chapter provides the overview of this study, describes the significance of using value management (VM) in construction industry, and proposes the need for a virtual VM (VVM) workshop when participants are geographically dispersed. The research process and significance of the research are introduced, and thesis structure is presented to help readers to understand better this research.

1.2 Research context

Major construction projects involve stakeholders coming from different occupational and professional backgrounds who are often geographically dispersed in the national and international contexts. In Hong Kong, this idea refers to projects with estimated costs exceeding HK$200 M, but this cost may vary in other places. The complex nature of these projects requires appropriate recognition and management of multiple stakeholders to achieve the best value outcomes and to accommodate individual stakeholder values.

As a structured and analytical group process, VM seeks to improve value and value for money in products, processes, services, organizations, and systems. The VM process focuses on a participatory workshop that involves a multi-disciplinary and representative group of people working together to seek the best value outcomes for a particular situation (AS/NZS 4183, 1994). An essential feature of the VM

methodology is that it enables major stakeholders to make better understanding of their needs in briefing stage of a construction project, and to establish consensus between the stakeholders during the workshops (Kelly and Duerk, 2002). The process encourages the VM stakeholders to work collaboratively in identifying potential improvement and problems at the beginning of the project (Gray et al., 1994; Lawson, 2006). One of the major characteristics of VM workshop is the formation of a formal but temporary team of the participants during the process, which includes pre-workshop preparation, the workshop, and post-workshop implementation (Shen et al., 2004b). While the entire VM study may last for a few months, the actual workshop normally lasts for only a few days (Male, 1998). The different locations of participants of the workshops further complicate this issue. Therefore, conducting VM workshops virtually faces an increasing demand among geographically dispersed participants.

However, the lack of appropriate tools to support VVM workshops (in which the participants are located in different locations and rely on mediated, rather than face-to-face, communication to produce outcomes) is a major obstacle to the successful use of VM methodology in these projects. As one of the effective methodologies, VM ensures value for money for these projects. Previous research has proven the effectiveness of Group Decision Support Systems (GDSS), which combine computing, communication, and decision support technologies to facilitate participants of the workshops in their search for value for money, to be effective in supporting VM

workshops among participants within the same location (Fan, 2009; Luo et al., 2011). However, the efficient and effective management of multiple stakeholders who are geographically dispersed in a virtual workshop environment is challenging and critical. Thus, a systematic and comprehensive experimental study on the effects of using GDSS on VVM workshops is essential.

However, existing GDSSs are designed to support VM workshops where participants are in the same location and to supplement face-to-face (F2F) discussions during the workshops. Until now, only a few tools provide useful support to VVM workshops for geographically dispersed participants. Moreover, the effects of using such tools on the group dynamics of participants in VVM workshops have yet to be investigated. This study aims to address this gap in current research on VM.

1.3 Research propositions and objectives

Lack of a theoretical foundation and appropriate tools to support multiple stakeholders in a VVM workshop hinders the implementation of VM in major construction projects. The primary research question focuses on the extent of the use of GDSS and is effects on the processes and outcomes of VVM workshops where participants are geographically dispersed. This study addresses several key issues in-depth: How does a large group of stakeholders interact in a workshop environment? What are the strengths and weaknesses of the existing tools for such a purpose? What will constitute the essential functions of GDSS to support effectively and efficiently

the VVM workshops? How can GDSS be used to assist geographically dispersed stakeholders in a virtual workshop environment? What benefits would stakeholders obtain from using the proposed system?

This research aims to improve the effectiveness and efficiency of VVM workshops through the GDSS. The GDSS combines computation, communication, and decision support technologies to facilitate workshop participants in their search for value for money. The research objectives for this investigation are as follows:

1 To identify the essential features and functions required by a purposely-designed GDSS to support VVM workshops for major construction projects

2 To validate and verify the extent to which a purposely-designed GDSS can support the completion of various tasks in a virtual workshop environment; and

3 To investigate and evaluate the extent to which the use of a purposely-designed GDSS affects the processes and outcomes of VVM workshops

1.4 Research process

Several research methods will be adopted to achieve the research objectives. First, literature review will be used to reveal important findings, and historical research will support the need for VVM workshops. System development is used to create an

effective and efficient tool to support the implementation of VVM workshops with user-friendly interface and powerful functions that provide process and communication applications at each phase of the workshop. Experimental studies will generate empirical data on the actual influence of GDSS on VVM workshops and the usefulness of the proposed system in facilitating collaborative working. System validation will be used to develop and to test the validity of the proposed system in real world situations. The involvement of researchers as part of the situation under investigation is necessary to examine the real effect of using the proposed system in VVM workshops. In addition, a questionnaire survey was conducted the feedback of participants in the experimental workshops and the system used in the VVM workshops.

Five specific tasks will be conducted during the PhD study to achieve the research objectives using the research methodologies. These tasks include the (1) establishment of a theoretical foundation for the investigation, (2) identification of essential functions of GDSS for VVM workshops, (3) development of a prototype GDSS to supportVVM workshops, (4) validation and verification of the proposed GDSS in VVM workshops, and (5) evaluation of the effect of using GDSS on VVM workshops for major construction projects.

1.5 Significance of the research

The novelty of this research lies in the following aspects. First, the study broadens the

understanding of the effects of using GDSS on the dynamics of multiple stakeholders in facilitated and participatory VVM workshops with participants dispersed in different locations. Second, the study improves the means to obtain information and decision-making through virtual synchronous and asynchronous VM workshops. Further, this research paves the way towards new knowledge and improves understanding of group dynamics (i.e., actions, processes, and changes that occur in social groups) of VVM workshops for major construction projects. The findings could enhance the effectiveness and efficiency of collaborative effort of multiple stakeholders in a virtual workshop environment. Examples of these efforts include building consensus and making collective decisions to create ownership and commitment throughout the projects.

The virtual value management system (VVMS) will improve the processes and outcomes of VVM workshops, the effectiveness of communication, and the quality of decisions made by multiple stakeholders in different geographical locations.

The findings of this research will be valuable and timely particularly for the local construction industry and generally for the international community. The outcomes of the research will improve the likelihood of the successful delivery of major construction projects by involving several stakeholders through GDSS-supported VVM workshops. Such efforts will help to improve that the completion of the projects on time, within the budget, compliance with specifications, and following

safety and environment friendly standards.

1.6 Thesis structure

The structure of this PhD thesis reflects the research process.

Chapter 1 briefly introduces this study by describing the context, specific aim and objectives, method, and significance.

Chapter 2 comprehensively reviews literature on VM and its implementation in the construction industry, as well as the development of ICTs application in VM. VVM workshops will be introduced briefly in this chapter.

Chapter 3 presents how GDSS supports VVM workshops and improves the group decision process. This chapter discusses the concepts of the virtual collaborative environment, which is significant in understanding the significance of VVM workshop and its implementation.

Chapter 4 proposes a conceptual framework for VVM studies. The procedure of the workshop is described as a structured job plan. The main activities for each workshop phase are introduced in detail in this chapter.

Chapter 5 introduces the VVMS, which is a web-based GDSS developed for the

implementation of VVM workshops.This chapter discusses the implementation of the VVMS in VVM workshops, the preparations prior to the workshop, and data collection and management.

Chapter 6 introduces the validation of system with two rounds of experimental VVM workshops. The two workshops were conducted with actual projects and involved part-time students who were engaged in a VM course. The results of the workshops were collected quantitatively and qualitatively through outcomes, observation, and questionnaire surveys.

Chapter 7 presents the research findings, which include the quantitative and the qualitative data from the two VVM workshops. The impact of the use of GDSS in traditional F2F VM workshops and in VVM workshops is discussed as well. Moreover, several key issues that affect the performance of VVM workshops are identified and addressed in this chapter.

Chapter 8 summarizes the research and highlights the research conclusions. The contributions of the research to knowledge and practice, and the research limitations are explained. Recommendations for further studies on VVM are also forwarded.

1.7 Summary

The overview of this research is presented in this chapter, in which the research

context, propositions and objectives, process, significance, and structure are presented. The next two chapters discuss the literature review on VM, GDSS, and the virtual collaboration environment. These discussions will establish the theoretical foundation for the research.

Chapter 2: Review of VM in Construction

2.1 Introduction

This chapter reviews VM, its development in the construction industry as well as in the VM workshop. First, the background explains the rationale of proposing a VM system to engineering and construction. Second, definitions and benefits of VM in construction are introduced. Third, the implementation of VM in terms of its setting, systematic process, and performance measurement are discussed. Finally, the ICT application and the limitation of VM are proposed based on current research.

2.2 Background of VM

VM is a structured and analytical process that aims to achieve value for money and necessary functions at the lowest cost while delivering the required levels of quality and performance (AS/NZS 4183, 1994). In December 1947, Lawrence D. Miles, who was a purchasing manager at the General Electrical Company (GEC), introduced VM. To avert the shortage of materials caused by World War II, he developed a systematic approach called the Value Analysis Functional Approach (VA) to achieve the better performance at lower cost for the procurement process. The VA approach is an original model of the value methodology. Miles published a book in 1961, named "Techniques of Value Analysis and Engineering," which is a popular handbook of value methodology (Miles, 1972).

From 1954 up to the 1970s, the functional value approach entered into a rapid

development stage. The United States Navy's Bureau of Ships first adopted a formal program of VA in 1954. The navy set up this program to maximize the costs incurred during the designing phase, and used the term "Value Engineering" (VE) to emphasize performance in engineering and the systematic functional approach. The promotion of VE of government organizations made VE common in the USA. In 1959, the Society of American Value Engineers (SAVE) was established. Currently, SAVE is one of the most authoritative organizations in VM and the organization has published a series of VM standards and has changed its name to SAVE International.

In 1963, Dell'Isola first introduced VE to the construction sector of the Navy's Facilities Engineering Command of the US Department of Defense. The objective was to improve the designs by encouraging contractors to suggest alternatives for their contract (Dell'Isola, 1966). The term, value management (VM), was first adopted by a UK organization, which changed its name from the UK Value Engineering Association to the Institute of Value Management following the suggestion of Kelly and Male (1988). Currently, several terms synonymously describe value methodology, such as VM, VE, and VA. However, in this research VM was adopted instead of VE or VA to emphasize its feature in management and application in the full process of a project.

In the 1990s, VM was introduced to Hong Kong, and the Hong Kong Institute of Value Management (HKIVM) was established in 1995. In 1998, the Works Bureau

Technical Circular 16/98 and the Planning, Environment and Lands Bureau jointly released Technical Circular 9/98, “Implementation of Value Management,” that called for VM studies in all major projects in the public works program (Luo, 2010).

2.3 Definition of VM

After decades of development, VM expanded, from a program intended for obtaining alternatives to a systematic functional approach for achieving best value for money. In this process, many researchers or organizations defined VM in several ways, such as the following:

“Value management is concerned with defining what ‘value’ means to a client within a particular project context by bring the project stakeholders together and producing a clear statement of the project's objectives” (Green, 1992).

“Value management is a structured and analytical process, which seeks to achieve value for money by providing all the necessary functions at the lowest cost consistent with required levels of quality and performance” (AS/NZS 4183, 1994).

“Value management (synonymous with value engineering and value analysis) is a function-oriented, systematic team approach to providing value in a product, system, or service” (SAVE International, 1998).

“Value management is a structured organized team approach to identify the functions of a project, product, or service with recognized techniques and providing the necessary functions to meet the required performance at the lowest overall cost” (SAVE International, 2001).

“Value management is a service that maximizes the functional value of a project by managing its development from concept to use through the audit of all decisions against a value system determined by the client” (Kelly et al., 2008).

Despite these definitions being widely used in the academe, Woodhead and Downs (2001) emphasized that each definition of VM cannot completely describe its features. However, from these definitions, some common key features of VM could be identified. The first similar key feature is the multi-disciplinary team comprising key stakeholders. Lin and Shen (2007) suggested that a successful VM study should bring all necessary stakeholders to form a team in multi-disciplines. The team should review the project’s objectives and develop alternatives. Benefits of involving multi-discipline professionals from parallel perspectives to examine the same issue was noticed by researchers, such as Luo (2010) and Norton and McElligott (1995). The second feature is the systematic functional approach. The systematic functional approach is an essential element of VM that distinguishes value methodology from traditional cost reduction activities and cost planning efforts (Norton and McElligott, 1995; Gregory, 1984). The function in VM refers to the description of requested

characteristics, which reflect the intrinsic client needs for a particular project or a product (Miles, 1972). In VM practice, an expression of VM function normally consists of a verb and a noun to describe project behaviors (Shen and Liu, 2004). This approach leads to a systematic identification and clear definition of client requirements, such as the improved understanding of the design (Yu et al., 2006b). The third feature is the value improvement method. Here, VM emphasizes performance to improve value. The term "value" in project management could be expressed in the formula:

(1) $Value = \frac{\text{Function}}{Cost}$ (SAVE International, 1998)

(2) $Value = \frac{\text{Satification of needs}}{use\ of\ resources}$ (Kelly et al., 2003)

Value in a project is a comprehensive concept in terms of worth, performance, quality, overall cost, and completion time. Therefore, to achieve the improved value of a project means to enhance the performance of each identified function (Jensen, 2010).

The objective of VM is to achieve the required functions that clients have specified at the lowest possible overall cost and are consistent with requirements for performance (Shen, 1993). VM is most effective when applied to a project that has specific start and completion dates (Yu et al., 2006b).

2.4 Benefit of VM in construction

In the construction industry, information, communication, and coordination are the

three main factors that could cause completed projects to exceed their budgets (Shen et al., 2004a). Norton and McElligott (1995) highlighted that these unnecessary costs contribute to poor value, and therefore, should be identified and removed by VM methods. Since VM was first introduced into the construction industry in 1963 (Dell'Isola, 1982), the practice has been implemented in construction projects to achieve the best value for money and to meet stakeholder expectations in these projects (Thiry, 2001).

From the perspective of project management, VM studies maximize the project value by satisfying client requirements at the lowest lifecycle cost and achieving the required functions at the lowest consumption of resources (Lin and Shen, 2007; Yu, 2006). VM is a team-based systematic approach that aims to achieve the effectiveness and efficiency of a project with reasonable allocation of project resources. Implementing VM in construction projects is beneficial in cost reduction, profit increase, performance improvement, and quality enhancement. Hence, SAVE International has emphasized the application of VM in the construction industry as early as 1972 during their 12th annual conference.

Yu et al. (2006a) developed a briefing manual for VM that serves as a guide to the application of VM in Hong Kong's construction industry. They summarized five potential elements for achieving the expected performance of VM studies (Figure 2.1). These five elements form an environment for generating alternatives creatively.

Therefore, besides reducing costs, VM studies clarify project objectives, improve communication among different parts, and enhance the function of projects among others (Lin and Shen, 2007).

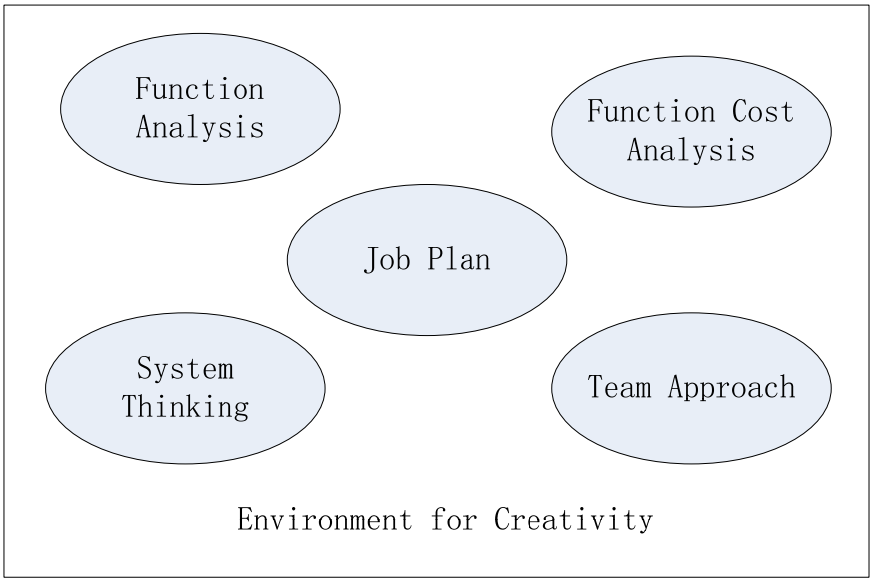

Figure 2.1 Elements of VM Methodology

(Yu et al., 2006a)

The effect of applying VM to the construction industry is significant. The U.S. Department of Defense (2012) states that VM activities contribute a combined actual savings and cost avoidance of $4.7 billion USD to construction projects during fiscal year 2011. Other organizations have identified their efforts on applying VM. The Virginia Department of Transportation, for instance, achieved a total cost avoidance of $214 million USD by applying VM studies from 2005 to 2012 (Virginia Department of Transportation, 2013).

Table 2.1 shows the survey result of VM in the U.S. San Diego area. Data indicate the percentage of the reduced project cost of the 98 projects from 6 governmental agencies, which accounted for 2.8% up to 26.9% (SAVE International, 2010). Evidence of VM effect was published by the US Army Corps of Engineers (USACE). The USACE analysed 286 studies that were conducted between 2002 and 2009. The average construction cost savings they calculated per VM study was $12,116,600 USD (USACE, 2012). Their analytical results indicated that the practice of VM should be conducted promptly. Some researchers devoted to the promotion of VM have also identified the optimum opportunity to implement VM studies. To achieve optimum performance, this opportunity has to be implemented during the briefing stage of a project (Shen, 1993; Kelly et al., 2003; Dell'Isola, 1997). Figure 2.2 shows a time/cost/achievement curve, which explains the relationship between time and cost of implementing VM to different stages of a construction project.

Table 2.1 Results of VE in San Diego Area

(SAVE International, 2010)

Agency	A	B($000)	C($000)	D(%)	E($000)	F($000)	G(ROI)
City Of San Diego (MWWD)	22	1,402,843	183,327	13.1	1,909	86	96/1
International Border Water Commission	2	320,000	86,000	26.9	148	74	582/1
County Of San Diego	20	306,000	8,427	2.8	552	26	21/1
Metropolitan Transit Dev.	3	359,000	10,945	3.0	364	121	30/1

Board (MTDB)							
U.S. Navy Southwest	40	807,930	74,655	9.2	1,261	31	59/1
Caltrans	11	1,179,980	38,114	3.2	816	74	47/1
Totals	98	4,375,753	401,469	9.2	5,051	51	79/1

A NUMBER OF STUDIES PERFORMED

B TOTAL COST OF PROJECTS BEFORE STUDIES

C TOTAL SAVINGS

D PERCENT PROJECT COST REDUCTION = C/B

E TOTAL COST OF STUDIES

F COST PER STUDY = E/A

G AVERAGE RETURN ON INVESTMENT (ROI) = C/E

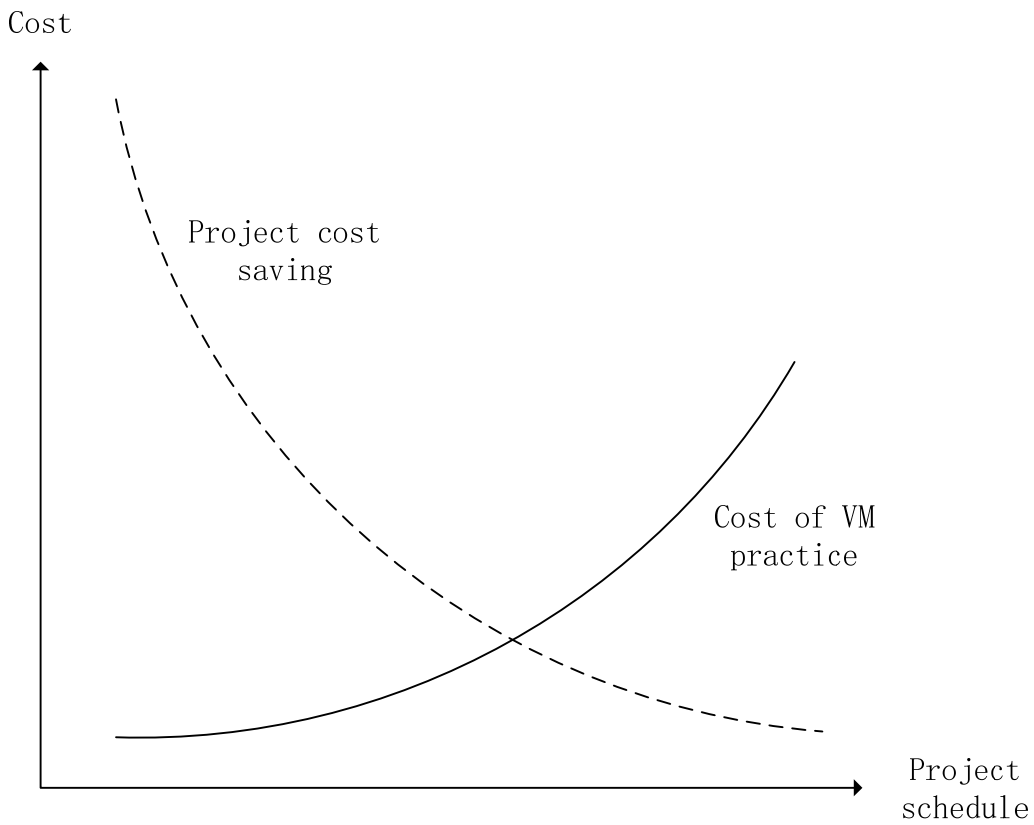

Figure 2.2 Time/Cost/Achievement Curve of VM study

(Adapted from: Kelly et al., 2003)

The performance of VM studies depends on the size and complexity of projects (Shen and Liu, 2003). Large-scale constructions, especially major infrastructure projects, can achieve better cost reduction rate with VM, as compared to small-scale projects. Therefore, VM studies become mandatory to major construction projects in some countries or local governments. For instance, the Hong Kong government requires all construction projects with estimated costs exceeding 200 million HKD to conduct VM studies (LEUNG, 2009).

2.5 Implementation of VM

In practice, VM is implemented in the form of workshops conducted by trained facilitators, and participated in by major stakeholders of a project through a structured job plan (Yuan et al., 2013; Fan et al., 2008; Lin and Shen, 2007; Luo et al., 2011). A VM workshop is an organized creative activity supported by the entire VM team, which comprises key stakeholders of a particular project. Existing frameworks for VM reveal the essential factors for the guidance and VM implementation, such as Male (1998) and SAVE International (2001). Yu (2007) and Lin (2009) deemed these essential factors should respond to the fundamental questions of VM implementation, namely:

What are the objectives of the workshop?

When should the workshop be conducted?

Where should the workshop be carried out?

Who will be the participants?

How should the workshop be processed?

In line with the fundamental questions, Lin (2009) identified 13 essential factors that should guide the implementation of VM practices according to literature:

- Clients
- Facilitators
- Participants
- Team and team dynamics
- Time and venue of VM studies
- Processes of VM studies
- Techniques used in VM studies
- Types of VM studies
- Project
- Post project evaluation (PPE)
- Post occupancy evaluation (POE)
- Critical success factors (CSFs)
- Key performance indicators (KPIs)

These factors are related to the overall performance of a VM study, and respectively describe the VM study from the settings, process, and performance measurement perspectives. Thereupon, the review on the implementation of VM study will be

expanded from these three perspectives.

2.5.1 Settings of VM study

The settings in VM study refer to the manner of conducting VM workshops, which include several elements, such as workshop mode, time and venue, communication, group size, participants' composition, and agenda. According to Shen and Liu (2003), these elements are closely related to the critical success factors (CSFs) of VM workshops. Therefore, changing these elements will lead to changing the approach and affecting the performance of VM workshops.

2.5.1.1 Workshop mode

Among these elements, the workshop mode of VM is the most important in directly affecting how other elements are implemented. The workshop mode is generally based on the techniques used in VM studies especially in the decision making process of the VM workshops (Fan et al., 2007; Fan et al., 2008; Luo et al., 2011; Male, 1998). From literature review, the three modes of VM workshops are the traditional, nominal, and GDSS-supported workshops.

Traditional VM workshop

A traditional workshop in VM is described as an F2F workshop with traditional brainstorming approaches (Fan, 2009). Traditional brainstorming was first devised by Alex F. Osborn to encourage creative thinking in solving group problems (Furnham

and Yazdanpanahi, 1995). This method requires two or more participants to generate several ideas for a specific question. Before the brainstorming process, sufficient background information is provided to all participants to ensure performance and clear tasks are identified for brainstorming (Parnes, 1961). Osborn (1953) proposes four fundamental principles for brainstorming:

- The quantity of ideas is important.
- Criticism is ruled out.
- Wilder ideas are better.
- Combination and improvement of ideas are the goals.

Nominal VM workshop

Nominal group technique (NGT) is an individual idea generation process that follows distinct steps to develop information (Gallupe et al., 1991). NGT was originally developed by Delbecq and Van de Ven (1971). The major difference between the NGT and the traditional approaches in VM study is the interaction of participants (Fan et al., 2007). In the nominal VM workshop, idea generation is an independent process for each participant, and any form of interaction, such as discussion, is forbidden during this process. Participants express their views on the tasks, and the team eliminates duplication and ranks the remaining solutions (Delbecq et al., 1975). NGT provides a solution to a common problem in group interaction, in which people shy away from suggesting ideas, by its anonymous policy in idea generation (Chapple and Murphy, 1996). Therefore, in empirical research, NGT groups have consistently performed

better than F2F traditional groups (Fan et al., 2007; Delbecq and Van de Ven, 1971; Diehl and Stroebe, 1987; Mullen et al., 1991; Sutton and Hargadon, 1996).

GDSS-supported VM workshop

The GDSS is one of the most popular technologies in group decision making. Shen and Chung (2002) introduced the system for its potential to enhance communication and decision making process in VM workshops. The GDSS is a computer-based system that supports information exchange, computer-aided analysis, and electronic brainstorming in the VM process. The application of GDSS alters the pattern of implementation of VM studies, which could affect facilitation and other conventional VM procedures. After more than a decade of development, the GDSS-supported VM workshop has become the main setting for VM studies used in Hong Kong and has demonstrated its improved performance in VM practices compared with the traditional and nominal settings (Shen et al., 2004b; Fan et al., 2007; Fan, 2009; Luo et al., 2011).

2.5.1.2 Time and venue

VM workshops normally need a specified time and place to meet the satisfaction of participants. From an experimental research, Lin (2009) found that participants rated the arrangement of time and venue with high scores. He emphasized that organizers should ensure “all participants could be free and to allow them to concentrate on the workshop” (Lin, 2009). Meanwhile, the workshop venue should be quiet, comfortable,

and spacious. The venue was identified as one of the CSFs to the implementation of VM workshops (Shen and Liu, 2003; Lin, 2009).

2.5.1.3 Duration and agenda

The duration and the agenda of a specific VM workshop refer to the adopted job plan (Dell'Isola, 1966). Among the several famous settings of workshop duration are the 40-hour job plan used in the U.S. and the one- or two-day job plan practiced in Hong Kong (Fong and Shen, 2000). Duration and agenda highly depend on the settings of the VM workshop. In this study, a typical one day (8 hours) duration is adopted to evaluate the proposed framework of the VVM workshop and to assess the effects of two experimental VVM workshops supported by a prototype VVM system. The details of the job plan are reviewed in Section 2.5.2.

2.5.1.4 Communication

Views differ on the issue of whether communication should be engaged in the full process of VM (Delbecq et al., 1975; Shen and Liu, 2003; Kelly et al., 2003; Chapple and Murphy, 1996). The effect of allowing communication during the creativity of VM workshops remains controversial. Encouraging communication among VM team members is beneficial in establishing team spirit and accelerating the arrival of consensus among stakeholders (Shen and Liu, 2003). Fjermestad (2004) defined communication mode as the medium or media of communication adopted by a group. VM studies adopt several typical modes of communication. First, the direct F2F

communication exists in traditional F2F workshops. Second, prohibited communication, which is a basis of nominal VM workshop, disallows interaction among participants. Third, the Delphi method is an anonymously indirect, and structured communication method based on two or more rounds of questionnaires conducted among a panel of experts (Linstone and Turoff, 1979). Fourth, text-based communication is a typical computer-mediated communication (CMC) and widely used in GDSS-supported workshops. Hence, this mode allows remote communication among participants. Fifth, video/audio conferencing is an advanced CMC that had gained popularity over the years. The main difference between video/audio conferencing and text-based communication depends on whether the synchronous video/audio features are supported (Johnson, 2006). Table 2.2 shows the main differences and applicable scope of these communication modes in VM studies.

Table 2.2 Communication modes in VM workshops

	Face-to-face	Remote
Text-only	Text-based communication	Text-based communication
Intuitive interaction	Directly f2f communication	Video/Audio conferencing
No directly interaction	Prohibited communication	Delphi method

This research primarily reviews the CMC due to its features that support GDSS and remote communication. Chapter 3 presents the detailed review and discussion.

2.5.1.5 Group size

The influence of group size on the performance of group works has been verified by many researchers (Mullen et al., 1989; Dennis, 1991; Gallupe et al., 1992; Valacich et al., 1992). However, whether the size of a group should be considered in the generation of creative ideas remains debatable. Hunt (1992) suggested that a group with 6 to 10 members is an effective setting in organizations. Valacich et al. (1992) conducted an experimental research by following a comprehensive literature review. They selected a three-and a nine-member group to test the difference in performance in generating ideas and found that the larger group formulated more unique ideas than the smaller group. A similar result was found in a GDSS environment.

In VM studies, group size tends to be larger especially for mega projects. Kelly et al. (2003) emphasized that the group size of VM team is generally between 18 and 20 as practiced in Hong Kong. Therefore, to enhance the performance of VM workshops, recent studies divided VM teams into several smaller groups with four to six members, with these small groups separately working on assigned tasks (Fan et al., 2007; Shen et al., 2007; Fan et al., 2008; Luo et al., 2011).

2.5.1.6 Team composition

The participants of VM studies comprise those who make the decisions about and add value to the target project through the systematic approach of VM studies. Professional experience, knowledge, and personalities of participants are CSFs

according to Shen and Liu (2003). Essentially, participants should include all relevant disciplines and stakeholders to encompass completely the issues in the study.

Only a few specific standards regulate the team composition of VM studies. Initially, VM was proposed as a bridge between investors and engineers (Dell'Isola, 1966). Zimmerman and Hart (1982) further identified VM as an approach for owners, designers, and contractors. They highlighted that a VM study should involve experts in different professions to maximize performance. The development of VM methodology has indicated the benefit of having multi-discipline participants, and this multi-discipline rule has been widely employed in VM studies. Meanwhile, the team composition of VM studies transformed from an "original team with several external experts who are familiar with the project" into "relevant stakeholders of the project" (Shen and Liu, 2004). Stakeholders in a construction project comprise any individual or group with the power to be a threat or a benefit to the project (Yang et al., 2009b).

The group size of a VM study is normally no more than 20 in current VM practice, which makes involving all stakeholders into a VM workshop impossible. Therefore, only the representatives of key stakeholders are the potential participants for a VM workshop. Often, such representatives include the client's managerial team, design and project management team, contractor's team, and end users (Yu et al., 2006a; Shen and Liu, 2004; Yang et al., 2009b; Fan and Shen, 2011).

2.5.2 Systematic process

The systematic process in VM methodology is referred to as the job plan, which is often used as a standard in the implementation of VM workshops (Norton and McElligott, 1995). According to Luo et al. (2011), VM studies are conducted in the form of workshops where a facilitator with VM expertise leads team members who represent major stakeholders through a structured job plan. Hence, adopting a job plan is important, as it determines the process and duration for a VM study. A well-designed job plan is a structural process that clearly defines the VM process for each workshop at different stages of a project, and it also defines the beginning and the end of VM workshops (Yu et al., 2006a). Shen et al. (2004b) suggested that functional representation of job plan should bridge the client and the designer.

Historically, scholars have proposed a variety of VM job plans. The Charette job plan and SAVE 40-hour plan are the two most-widely used and frequently mentioned job plans in recent VM studies (Kelly and Male, 1993; Luo, 2010; Yu et al., 2006a). The Charette method rationalized the client's briefing by identifying the function of key elements and the spaces. This task is achieved by involving the representatives from the client and the design team in a meeting early in the project. This creation of the job plan usually takes less than two days and concentrates on the client's requirements and the functions identified by the participants (Kelly and Male, 1993). The Charette job plan was crucial in historical VM studies as it provided a basis to succeeding practices.

In construction industry, the SAVE 40-hour job plan is the most acceptable formal approach (Lin, 2009). The 2007 edition of the VM Standard, which was published by SAVE International, illustrated that a standard VM process flow should define three main stages, namely, pre-workshop, workshop, and post-workshop (Figure 2.3).

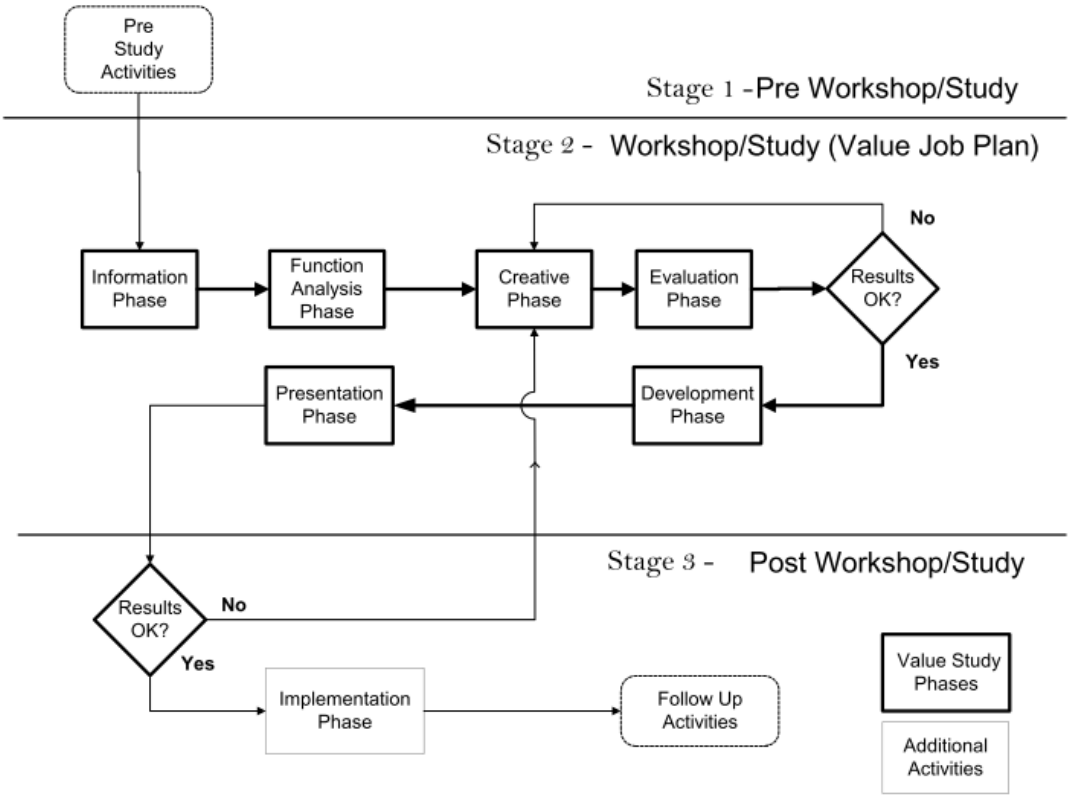

Figure 2.3 A standard VM process flow

(Adapted from: SAVE International, 2007)

The pre-workshop is a planning stage for the VM study. A series of activities is included in this stage to determine the participants, to provide sufficient background information, and to organize the following VM workshop. Normally, the

pre-workshop is organized by VM facilitators and organizers, and supported by the clients and other stakeholders. Necessary information is provided by indirect contact methods, such as emails and phone calls. The workshop stage is the core part to implement the VM methodology. The SAVE 40-hour job plan defines six phases in this stage, such as information, function analysis, creativity, evaluation, development, and presentation. The key functions in a particular project are identified during this process, and the possible alternatives for each key function are generated in the creativity phase. After evaluating these generated alternatives, best solutions will be identified and the detailed action plan will be further developed. The post-workshop stage is a review activity for the VM study. This stage ensures the accepted value alternatives are implemented, and the benefits projected by the value study are realized (SAVE International, 2007).

The SAVE 40-hour job plan is widely accepted in VM studies. However, the plan was confronted with serious drawbacks in construction projects. First, a five-day VM workshop is normally too long for most participants. Maintaining focus on tasks throughout the 40 hours could be difficult. Second, appointing the time and venue for the assembly of stakeholders could be difficult for such an extended workshop period. These problems are more prominent in Hong Kong because of the area's special case in the construction industry. The cost of consultancy is very high in Hong Kong. For instance, a five-day VM workshop means that the client needs to pay a relatively large amount of money. Therefore, most VM studies conducted in Hong Kong complete the

VM workshops in one or two days.

Other job plans for particular studies are effective and arouse attention. For instance, Male (1998) developed a VM job plan for a pioneering research on VM frameworks. Luo et al. (2010) suggested a non-generic VM process by using functional performance specifications in a construction project briefing. These job plans suggested a targeted well-designed job plan is necessary and more effective on responding to specific research questions.

2.5.3 Performance measurement

Determining the performance of a VM workshop is a serious issue in VM studies. Most VM studies focus on improving the VM process and enhancing thecollaboration among project stakeholders. However, few studies delve on measuring the performance of VM studies. In previous decades, the performance measurement of VM studies focuses on cost saving and function improvement (Lin, 2009). Shen and Liu (2003) emphasized that considerate economic achievement is insufficient in evaluating the performance of VM activities. They suggested that objective-oriented and process-related performance should be considered in measuring VM studies. Therefore, performance measurement in the context of VM studies concerns quantifying the efficiency and the effectiveness of VM workshops (Lin and Shen, 2007).

Identifying CSFs is an effective method to ensure the successful implementation of a project. Male (1998) identified 10 CSFs for VM study in a benchmarking research. The identification of CSFs that describe how an objective of VM studies can be measured and achieved is important in performance measurement (Lin, 2009). Shen and Liu (2003) further developed 15 CSFs based on their literature review and VM practices in Hong Kong. They divided these factors into four clusters, namely, value management team requirements, clients' influence, facilitator competence, and relevant department's impact (Table 2.3).

Table 2.3 Critical success factors for VM studies

(Adapted from: Shen and Liu, 2003)

Factors	**Clusters**
• Preparation and understanding of related information • Multidisciplinary composition of VM team • Professional experience and knowledge of participants in their own disciplines • VM knowledge and experience of participants • Personalities of participants	Value management team requirements
• Client's support and active participation • Clear objective of VM study • Timing of study	Clients' influence

• Adequate time for VM study	
• Control of workshop • Qualified VM facilitator • Function analysis • Interaction among participants	Facilitator Competence
• Cooperation from related departments • Plan for implementation	Relevant Departments' Impact

In addition to CSF, the KPI is another main method used to assess VM studies. The first KPI framework for construction, which was published by the Construction Best Practice Program (CBPP) in the late 1990s, provided a tool to assess construction activities at strategic and operational levels (Beatham et al., 2004). Lin et al. (2011) identified 18 KPIs out of 47 selected potential indicators through a survey administered to groups of VM experts in Hong Kong. These KPIs are divided into three groups according to their characteristics, namely, predicting, process performance, and outcome performance (Table 2.4).

Table 2.4 KPIs for measure the performance of VM studies

(Adapted from: Lin et al., 2011)

Key Performance Indicators
Predicting indicators
Clear objectives of workshop

Client's participation
Client's support
Disciplines of participants
Qualification of facilitator
Relevant stakeholders' support
Process-related performance indicators
Background information collected
Client's objectives clarified
Interaction among participants in each phase
Primary functions/processes identified
Project givens/assumptions clarified
Outcome-related performance indicators
Percentage of action plan without uncertainty carried out
Quality of the report
Accelerating the decision-making
Client's satisfaction
Identifying and clarifying the client's requirements
Improving communication and understanding among stakeholders
Improving the project quality

Shen and Lin conducted immense research in measuring the performance of VM studies. Based on the CSF and KPI, they developed a performance measurement

framework, which is suitable in evaluating the performance of VM studies in the construction industry (Lin and Shen, 2010).

2.6 Application of information and communication technologies (ICT) in VM

Computers have extensively supported group decisions (DeSanctis and Gallupe, 1984; Chung et al., 2002). Er and Ng (1995) defined the GDSS as a computer-based information system using decision-making techniques to identify, analyse, evaluate, and solve problems encountered by computer-supported groups. Since Shen et al. (2004b) first introduced GDSS with specific VM functions into Hong Kong in 2004, its use for supporting VM workshops has developed rapidly.

Luo et al. (2011) created a GDSS named GDSS CBRFPS for supporting group dynamic and decision processes in VM studies. The proposed system contains functions to support each phase of VM workshops in the F2F setting. It is not a web-based service, but client/server structure software that was developed based on Visual C.NET. Moreover, GDSS CBRFPS provides a graphical method for conducting the function analysis phase of the VM method and an intelligent evaluation system with a graphical interface for evaluating ideas. The system was designed by following the process of VM practice in Hong Kong and providing a series of support for VM methods. The effectiveness and efficiency of the system in supporting VM workshops were validated by a set of experimental studies (Luo et al.,

2010; Luo et al., 2011).

2.7 Limitation of current VM studies

A study by Shen and Chung (2000) investigated the encountered difficulties in VM studies in both of Hong Kong and overseas. They identified most of the common difficulties encountered in VM workshops are time-related in nature, such as not enough time to complete tasks and insufficient time to prepare information or data. One of major limitation of VM studies is that there was lack of effective tools to support VM studies. Therefore, they suggested the use of IT tools to overcome these difficulties.

As one of the powerful IT tools in supporting decision making, GDSS has strong potential to enhance the effectiveness and efficiency of VM studies. The effect of using GDSS in VM has been investigated and justified by some benchmarking researches, such as Shen and Chung (2002), Shen et al. (2004b), Fan and Shen (2004) and Luo et al. (2011). They developed various GDSSs with different highlighted features to support VM studies and to overcome these difficulties (the GDSS will be detailed reviewed in the next chapter).

In particular, Shen and Chung (2000) suggested to introduce virtual workshop to conduct VM studies with team members in different locations, which saved travelling time and reduced study cost. This finding was in line with the current needs of

conducting VM studies with geographically dispersed stakeholders, especially for major construction projects. The existing systems of GDSS for VM studies had been successfully validated to support the traditional VM workshop. However, these systems can only run in local network environment without web-conferencing and online collaboration features. Therefore, to realize a VVM workshop and support its entire process in the construction industry, a GDSS for VVM studies should be studied to enable a totally VVM workshop to be conducted for an experiment as part of this research. Participants were invited to join the VVM workshop without having to leave their own physical location.

2.8 Summary

In construction management, VM defines what value means to a client within a particular context by bringing the project stakeholders together and producing a clear statement of the project's objectives (Yuan et al., 2013; Kelly and Male, 1993). The adoption of VM will significantly benefit a construction project, especially, large-scale construction. Major infrastructure projects can achieve better cost reduction rate by practicing VM, as compared to small-scale projects. The review of VM could establish an overall understanding to VM methodology and the implementation of VM studies, thereby establishing a framework for VVM studies in major construction projects.

Chapter 3: Review of GDSS and Virtual Collaborative Environment

3.1 Introduction

The implementation of VVM workshop highly depends on the GDSS and virtual setting. This chapter reviews the GDSS and the features of the virtual collaborative environment. First, the development of GDSS and its application in VM are introduced. Second, the features of virtual setting and virtual collaborative environment are reviewed. Thereafter, some key issues are identified and discussed in detail, such as virtual team, information exchange, and virtual communication.

This chapter discusses how GDSS can be used to support VVM workshops and to improve the group decision process. Understanding the virtual collaborative environment is significant in establishing an overview of the VVM workshop and its implementation.

3.2 GDSS and its application in VM

Currently one of the most widely used groupware techniques, the GDSS is an interactive computer-based information system that supports enhanced group communication, database technologies, collaboration in the identification, analysis, formulation, evaluation, and solutions for a group-based decision-making environment (Er and Ng, 1995). Different researchers used various terminologies to describe GDSS, such as group support system (GSS), computer-supported collaborative work (CSCW), and electric meeting system (EMS). These terminologies

are synonymous to GDSS in this study (Chung et al., 2002).

3.2.1 Development of GDSS

Since the first computer in the world was invented in 1947, machines have accepted the task of complex calculations for humans (Paul, 1981). The application of computers rapidly expanded from single to many areas given its extremely rapid information processing capability compared to traditional methods. As a result, a computer-aided decision support process became possible during that time.

The first incident of using computers in decision support was conceived in 1965 at the CASE Institute of Technology (Dennis et al., 1988). As computer and information technologies developed, this topic became more popular and has attracted worldwide interest during the next decades. The first theoretical models of decision support system (DSS) were provided by Gerrity (1971). He coined the term of "DSS" and defined the system as "an effective blend of human intelligence, information technology, and software, which interact closely to solve complex problems." This DSS is designed to benefit individuals in their decision making processes. However, most decisions are made by groups of people in industries and require an accelerated decision-making process by DSS. Hence, the concept of the GDSS in which a DSS for a group of people requires a decision making environment was proposed in the early of 1980s. The first paper on GDSS was published in 1984 by Huber, who also gave the earliest definition of GDSS. The GDSS is "a set of software, hardware and

language components, and procedures that support a group of people engaged in a decision related meeting" (Huber, 1984).

In addition to Huber (1984), the early pioneering studies of GDSS include the works of Desanctis and Gallupe (1987), Gray (1987), and Er and Ng (1995). Their research established the theoretical foundation to GDSS and provided guidance to system development (Chung et al., 2002). For instance, Desanctis and Gallupe gave the most acceptable definition of GDSS, which states "a computer technology that combines computing, communication, and decision support technologies to facilitate the formulation and solution of unstructured problems by a group of people." They introduced the classifications and configurations of GDSS in their benchmarking studies, which significantly affect the development of GDSS (DeSanctis and Gallupe, 1984; 1987). They also proposed the five characteristics of GDSS, which are summarized by Chung et al. (2002) below:

(1) "GDSS should be a specially designed system, not merely a configuration of already existing system components.

(2) GDSS should be designed with the goal of supporting groups of decision-makers in their work. As such, GDSS should improve the decision-making process and/or decision outcomes of groups over that which would occur if the GDSS were not present.

(3) GDSS should be easy to learn and easy to use. It

accommodates users with varying levels of knowledge regarding computing and decision support.

(4) GDSS may be specifically designed for on type, or class, of problems or generally designed for a variety of group-level organization decisions.

(5) GDSS should contain built-in mechanisms, which discourage the development of negative group behaviors (such as destructive conflict, miscommunication, or group thinking) in the group decision-making process."

Owing to the development of technologies, the GDSS research experienced a turning point in the 1980s. The reduced cost of hardware and software provided the opportunity for GDSS researchers to shift their research focus from theory to practice. Investigations focused on the effect of GDSS by comparing the GDSS-supported decision-making process and conventional ways (e.g., Lewis, 1982; Liang, 1985; Gallupe et al., 1988; Zigurs et al., 1988; Dennis et al., 1989; Nunamaker et al., 1989; Benbasat and Lim, 1993). However, these studies showed the different trends of the actual effectiveness of using GDSS in experiments or in field studies. In the issue of the quality of decision during the process, some researchers reported that GDSS performed better (i.e., Lewis, 1982; Gallupe et al., 1988), whereas others believed the system bore no significance (Zigurs et al., 1988). The same situations existed in the results of participation and satisfaction outcomes.

After in-depth review, the main reasons behind this problem concern the choice of group members and the setting of group dynamics. Nunamaker et al. (1989) emphasized that many factors may negatively influence group decision-making process (Figure 3.1).

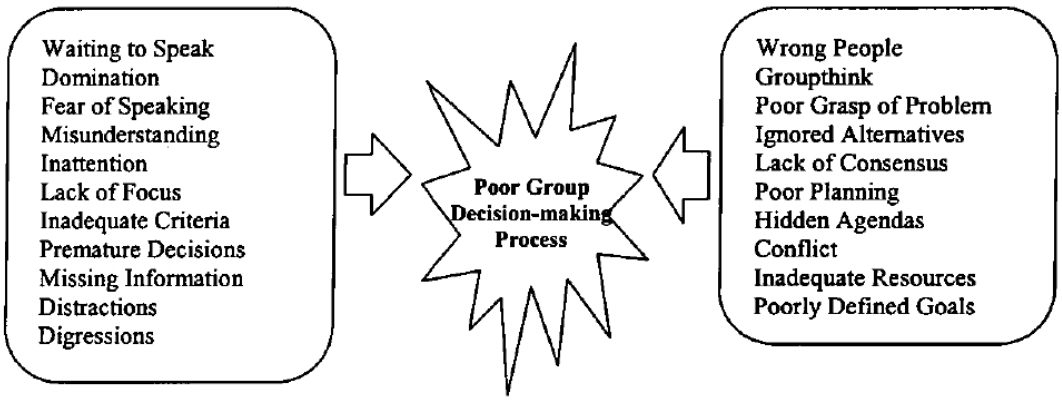

Figure 3.1 Problems of group in decision-making process

(Nunamaker et al., 1989)

With the development of GDSS technology, these problems were overcome gradually. Dennis (1991) claimed settings of parallelism, anonymity, group size, and meeting structure will significantly influence the performance of GDSS. He believed that "the use of GDSS provides technological efficiencies and interaction advantages that can overcome some of the difficulties frequently encountered among large teams." Benbasat and Lim (1993) formed a similar conclusion and suggested that the trend of using GDSS could improve the effectiveness and efficiency of the decision-making process.

After 2000, a new trend of web technology and electronic communication was

introduced such that people could work together through the internet. The GDSS can possibly address problems among remote groups by adopting new technologies. Pioneer research in this field started in the late 1990s and early 2000. Tung and Turban (1998) first proposed a framework for distributed GDSS, Shen and Chung (2002) focused on interactive GDSS for construction, and Palaneeswaran and Kumaraswamy (2005) developed a web-based GDSS for design-builder pre-qualification.

3.2.2 Taxonomy of GDSS

During decades of development, several GDSS emerged. Classifying the GDSS is an effective means to investigate GDSS features and the trend of future development. The earliest classification of GDSS was done by DeSanctis and Gallupe (1984), who abstracted GDSS characteristics from comprehensive literature review and integrated these studies in different types (Figure 3.2).

MEMBER PROXIMITY	DURATION: Limited	DURATION: On-going
Close proximity	Decision Room	Local Decision Network
Dispersed	Teleconferencing	Remote Decision Making

Figure 3.2 A taxonomy based on duration of session and proximity of group members

(Adapted from: DeSanctis and Gallupe, 1984)

This taxonomy of GDSS is proposed from the perspective of decision making types, and is established based on the proximity of group members and the duration of decision. However, with in-depth research in the GDSS, group size is a key factor that dramatically influences the performance of group and decision quality (Desanctis and Gallupe, 1987).

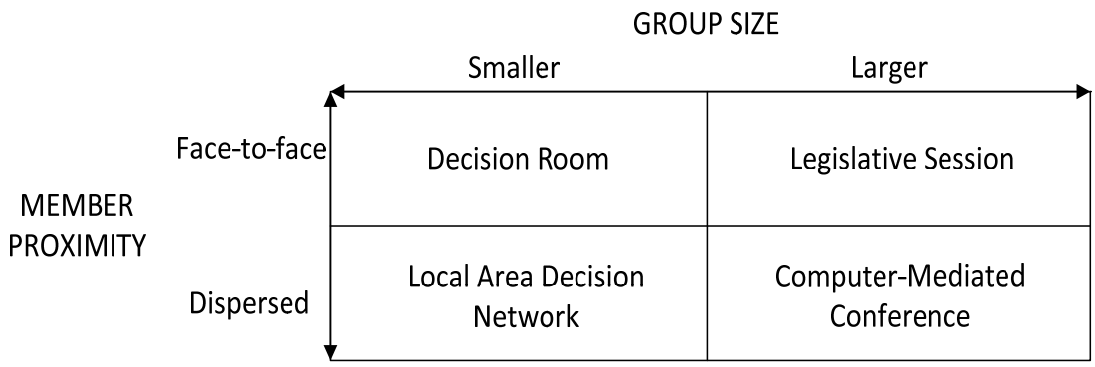

Figure 3.3 A taxonomy based on group size and proximity of group members

(Adapted from: Desanctis and Gallupe, 1987)

Figure 3.3 shows the taxonomy matrix based on group size, which reflects that communication mode in the group decision environment was emphasized in GDSS studies during this period. Four basic communication types exist among groups of people (Table 3.1) (Dix and Beale, 1996). Restricted by technological development, only text- or audio-based media can support communication between different places. Therefore, the early works on GDSS communication focused on F2F conversation.

Table 3.1 Basic matrix of communication

(Adapted from: Dix and Beale, 1996)

	Same place	Different place
Same time	Face-to-face conversation	Telephone
Different time	Post-in note	Letter

A virtual workshop is based on remote GDSS, which is a large group GDSS supported by same-time-different-place communication. Telephone meetings cannot support the group decision making process. However, video conferencing, which appeared in the late 1990s, enables the conduct of virtual meetings within a remote collaborative environment. Meanwhile, asynchronous communication and group dynamic techniques developed rapidly as well. Baecker (1993) summarized GDSS studies and applications, and classified GDSS types in his book (termed as “CSCW”) (Table 3.2). He highlighted that video conferencing and conferencing system with desktop sharing and multi-media functions are the most featured GDSS applications for remote interactive environments.

Table 3.2 A GDSS matrix

(Adapted from: Baecker, 1993)

	One meeting site (same places)	**Multiple meeting sites (different places)**
Synchronous communication (same time)	**Face to Face Interaction** • Public computer displays • Electronic meeting rooms • Group decision support systems	**Remote Interactions** • Shared view desktop conferencing systems • Video conferencing • Media spaces
Asynchronous communication (different time)	**Ongoing Tasks** • Team rooms • Group displays • Shift work groupware • Project management	**Communication and Coordination** • Vanilla email • Asynchronous conferencing bulletin boards • Structured messaging systems • Workflow management • Version control • Meeting schedulers • Cooperative hypertext & organisational memory

In addition to time and space matrix, another famous taxonomy based on the development of GDSS comprises the three level model of GDSS, which was proposed by Desanctis and Gallupe (1987). They described GDSS from an information-exchange perspective:

Level 1 GDSSs provide technical features to removecommon communication barriers, such as large screens for instantaneous display of ideas, voting solicitation and compilation, anonymous input of ideas and preferences, and electronic message

exchange between members. Level 1 GDSSs improve information exchange among participants. Most systems during the early stage of development of GDSS belong to this category, such as electronic boardrooms and computer-mediated conferencing.

Level 2 GDSSs provide decision modeling and group decision techniques to reduce uncertainty and noise in the group's decision making process. Groupware is emphasized in this level of GDSSs. Level 2 GDSS provide basic functions to support individual decision making process for group members to work and to review simultaneously, against a large common screen. These functions include, but are not limited to, computer-mediated creativity, risk analysis, anonymous rating, electronic voting, and multi-criteria evaluation. The Delphi method and NGT are also incorporated in this level (Luo, 2010).

Level 3 GDSSs are characterized by machine-induced group communication patterns and can include expert advice in the selection and arrangement of rules to apply during a meeting. The system should contain a rule-based discussion and automatically arrange the communication and speaking order to avoid group conflicts among virtual team members.

These two typical taxonomies are widely accepted in the GDSS research. To meet the requirements of VVM workshop, the system used for this research should be conducted at the same time, in different places, and in compliance with level 3 GDSS

requirements.

3.2.3 Components of GDSS

Er and Ng (1995) defined the GDSS as an interactive computer-based information system that supports enhanced group communication, database technologies, collaboration in the identification, analysis, formulation, evaluation, and solution for group-based decision-making environment. Therefore, the components of GDSS should include hardware, software, process, and people (Bidgoli, 1998; Desanctis and Gallupe, 1987; Gallupe et al., 1988):

(1) **Hardware**: The common requirements of a GDSS include a terminal device (a computer or mobile device), a stable GDSS server, and network devices to provide local or internet network environment. For remote GDSS, webcam and audio devices are necessary to ensure communication between participants.

(2) **Software**: The software environment of different GDSSs is also slightly different, and needs special requirements. Generally, a GDSS consists of client and server programs. The client is the operation side for GDSS participants, and comprises a user-friendly interface and applications to access each function of GDSS applications. The server side of a GDSS is an information terminal of the system, which includes an interface to allow and to manage multi-users access, and a database to restore user information and the data produced in the meeting. A network environment is an additional requirement to the remote GDSS.

(3) **Process**: The GDSS process includes process control and other "procedures." Facilitators conduct process control, coordinate GDSS functions with meeting phases, and ensure participation of GDSS users. The procedures either apply to the operations of the hardware and software or extend to include rules regarding verbal discussion among members and the flow of events during a group meeting (Chung et al., 2002; Fan, 2009).

(4) **People**: A GDSS supported activity should include both facilitators and participants. Facilitators guide the implementation of the activity, maintain the smooth operation of GDSS technology, and help participants solve problems. The participants are users who use client software to participate in the GDSS-supported activity.

Except the basic ones, remote GDSS contains special features and components. Luo (2010) highlighted that a remote GDSS should include communication features. The same idea was suggested by Bidgoli (1998), that is, communication and networking technologies were added for group participation. According to the three-level GDSS model, communication between remote GDSSs should include communication technologies to support group communication, or a communication control technique. Meanwhile, communication among virtual groups is conducted based on networking technologies via the internet, which is among the fundamental elements of virtual meetings or VVM workshops. Therefore, a remote GDSS for a VVM workshop

should include hardware, software, process, people, communication, and internet access (Figure 3.4).

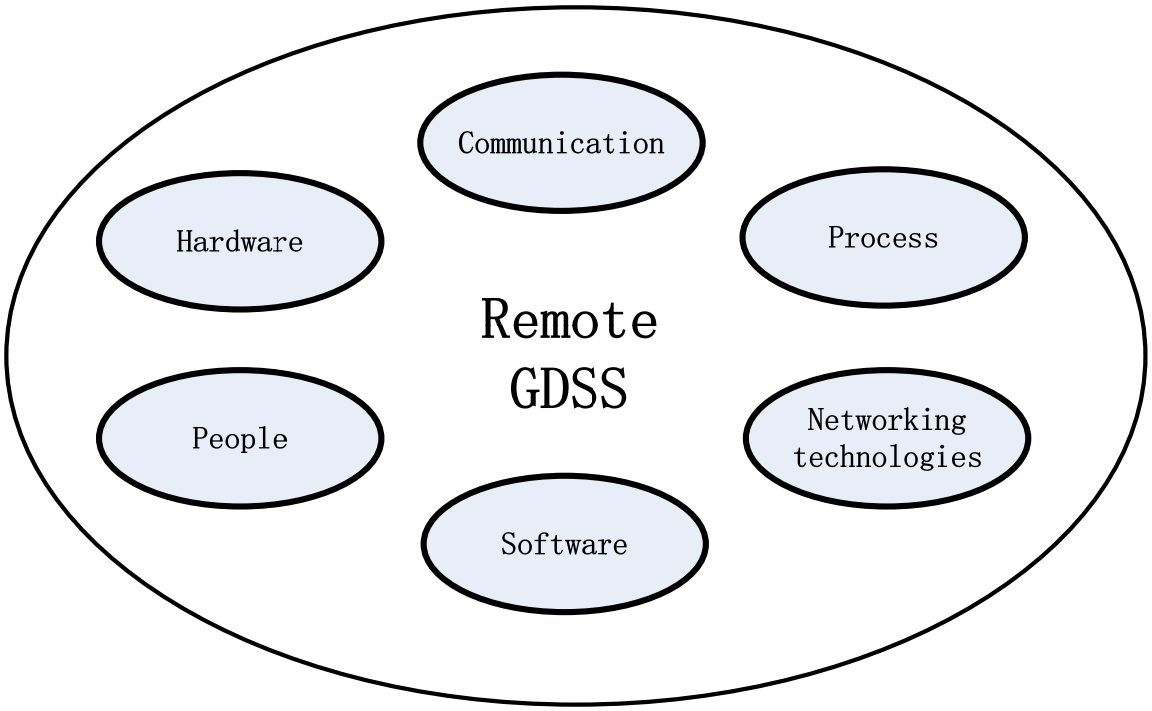

Figure 3.4 Components of remote GDSS

3.2.4 Application of GDSS in VM

From the 1990s, researchers investigated the possibility of adopting IT to help in VM studies (Shen and Brandon, 1992). After 2000, information technology advanced and catered to many research fields. Shen and Chung (2000) identified key problems in conducting VM and discussed the use of IT to resolve these problems. GDSS has been recognized as one of the most effective IT tools. Hence, Shen and his team investigated the feasibility of using GDSS to improve VM studies (Chung et al., 2002).

The first GDSS module for VM was developed by Shen and Chung (2002). They proposed a theoretical framework of the VM-specific GDSS and named it as "interactive value management system (IVMS)." They developed a specific IVMS prototype to illustrate how the system can support the discussion, information, collaboration, and analysis of decisions to resolve problems in VM studies (Shen et al., 2004b). The prototype system was simple and constructed based on Microsoft Office Suite. Although the prototype IVMS encountered several problems, results showed the GDSS advantages in VM and began the trend of "a major step forward in using information technology to improve VM studies."

Fan et al. (2008) further developed the IVMS based on web technology and investigated the depth of using GDSS to improve the process of idea generation in VM. The comparative study of a GDSS-supported team and traditional VM team was initiated (Fan et al., 2007). The GDSS-supported team created more ideas and performed better than the team in the tradition method of idea generation. They enhanced the idea generation tool and developed a full version of IVMS based on Microsoft SharePoint. This version supported information exchange, analysis, evaluation, and communication in the VM process, and allowed the implementation of VM studies in a local network environment (Fan and Shen, 2011; Fan et al., 2012).

However, the functions of the adopted commercial suite limited the performance of IVMS. Desanctis and Gallupe (1987) indicated that a GDSS should be a designed as

system-specific for solving particular problems. Therefore, Luo et al. (2010) developed a specific GDSS. A case-based reasoning feature for functional performance specification into the system was added. This feature was termed "CBRFPS GDSS," and was programmed by using the C++ programming language. The GDSS allowed a client to "define and represent his or her requirements with functions and functional performance, to bring forward ideas to achieve the functions, and finally to evaluate and highlight the ideas against the functional performance for further development in design" (Luo et al., 2011).

The above GDSSs for VM can support a VM workshop and improve its performance, especially during the function and idea generation phases. However, these systems are usually limited as they can only run in a local network environment for F2F VM workshops. None of the remote communication and collaboration features is supported by existing GDSS for VM studies.

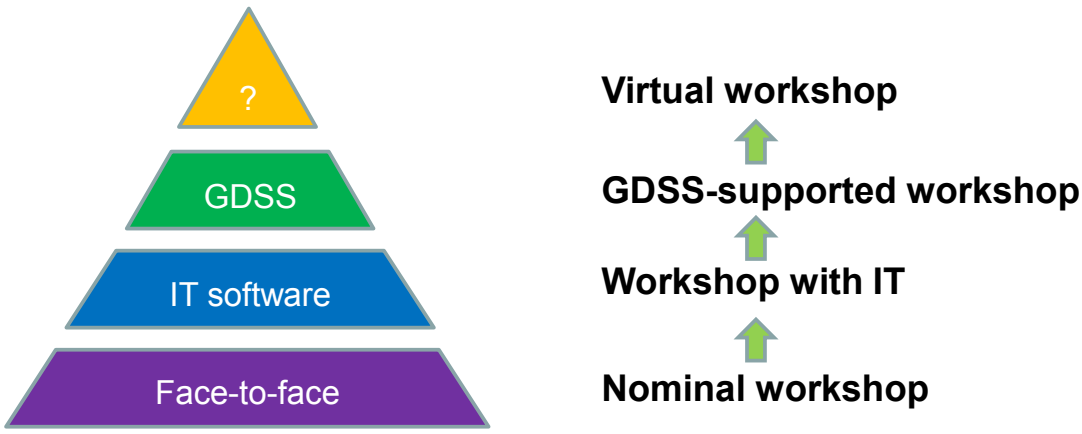

Figure 3.5 Development of VM workshop

Figure 3.5 illustrates the development of a VM workshop. From the traditional VM workshop without IT support up to the current GDSS-supported workshop, the VM workshop indicated the flexible quality of the workshop mode. IT has a crucial role in the decision making process. Conducting a VM workshop in different places or periods is the next step of VM development. To meet the requirements of applying VM in major construction projects, this research investigates the effects of using remote GDSS in VVM workshops comprising of respondents gathering at the same time but in different places.

3.3 Virtual setting and virtual collaboration

The emergence of the Internet changed the lifestyle and work habits of people. As a new meeting mode, internet-based virtual meetings break the hindrance of distance of participants. The National Aeronautics and Space Administration (NASA) is a pioneer in the use of collaborative tools for virtual workshops with its establishment of a virtual institute and publication of a guidance in virtual meeting practices (Dolci et al., 2011).

Virtual workshops rapidly developed after 2000s. Many organizations and research institutes adopted virtual workshops to realize virtual collaboration and designed systems for its implementation. One famous example is the CAIRO system that was developed by Pena-Mora et al. (2000).The CAIRO system allows designers and engineers to work together in virtual teams by supporting multi-media interactions

over computer networks. Compared with pure text-based virtual meetings, CAIRO provided a user-friendly interface that constructed a relaxed atmosphere, and simulated a “table meeting environment” in the form of background pictures with actual ones as the avatars for participants. The situation was improved by the emergence of video conferencing software, which allowed people to see each other via the internet by a floating window of dynamic images instead of simple avatars. This brings new opportunity to VM studies that key stakeholders of a construction project can meet virtually. However, the virtual setting of meetings brings new features that have positive as well as negative effects.

What are the differences between a virtual workshop and a traditional one? According to Veen et al. (1998), a virtual workshop is a web-based discussion that uses groupware facilities and focuses on the enhancement of future collaboration plans. The main differences include network environment and techniques used in the workshop, such as virtual team and indirect interaction. New circumstances usually occur in a virtual environment. For example, interaction in a virtual environment eliminates strangeness among participants and diminishes the seriousness of barriers in information exchange (Veen et al., 1998; Lipnack and Stamps, 2000; Axtell et al., 2004; Anderson et al., 2007).

From the positive perspective, the most valuable contribution of adopting virtual settings in a workshop is overcoming geographical and time boundaries. Schweitzer

and Duxbury (2010) noted that virtual meetings can effectively reduce venue costs and travel expenses. Other benefits include improved productivity, timing effectiveness, higher response speed, and enhanced quality of work.

Renninger et al. (2011) indicated these benefits are results of the techniques employed in the virtual meetings or workshops. Further, Renninger et al. (2011) stated, "*The potential of hypermedia lies in its designers' abilities to support participant stake by providing for multiple representations or ways into thinking and working with the disciplinary content of the given online learning—design that both accommodates and supports those with differing strengths and needs.*" Similar views were proposed by Enjalbert et al. (2011), who proved that efficiency can be enhanced with the coordination between multi-sites by a distributed simulation of virtual workshop. However, literature showed both strengths and weaknesses to the technique-supported virtual workshops (Han et al., 2011).

Virtual workshops are confronted with certain problems. Rezgui (2007) summarized the problems in the implementation of virtual workshops in the construction sector. He suggested that the culture of participants, flat structure, effective communication, and participation and involvement in decision making enhance the sharing of information and facilitate team cohesion. Nonetheless, trust establishment is a major problem that needs to be solved in virtual workshop studies.

This section reviewed the major differences between traditional F2F workshop and virtual workshops, including virtual team, interaction, and communication among virtual teams, virtual facilitation anonymity policy, and the performance of virtual workshop.

3.3.1 Virtual teams

3.3.1.1 Definition and team construction

A virtual team (VT) is "a group of people striving toward a common goal, dispersed in many locations, and communicating with each other predominantly via ICT" (Axtell et al., 2004). VT is a core component of GDSS-supported virtual workshop. This term originated from the term that was proposed by Valacich et al. (1992). "Interacting team" refers to two or more individuals who communicate and influence each other/one another through any medium. This term emphasized the importance of communication medium adopted in group activities. Therefore, the use of ICT in communication is an important characteristic to VT.

Moreover, VT is task orientated. Powell et al. (2004) defined VT as a group of geographically, organizationally, and/or time-dispersed workers brought together by information and telecommunication technologies to accomplish one or more organizational tasks. The members of VT should collaborate towards a common goal based on cooperation and effective communication (Rezgui, 2007).

However, the essential characteristic of VT that distinguishes it from other types of teams is its virtuality, which reflects that the VT members are geographically, organizationally, and/or time-dispersed collection of individuals who rely primarily on ICTs to accomplish one or more organizational tasks (Rezgui, 2007). Hence, VT can be involved in any remote collaboration behavior, such as virtual meetings and remote decision making activities.

3.3.1.2 Group size and group design

Several studies have cited the effect of group size on team performance. One typical study that received more than 700 citations is the paper of Martins et al. (2004). The study identified group size as one of the input variables that affect the performance of VT. Indeed, this problem arises from VTs and traditional F2F teams. Several studies on traditional team behaviors proved that group size is inversely proportional to team satisfaction (Mullen et al., 1989; Mullen et al., 1991; Diener, 1980). Olaniran (1996) suggested that the maximum effective group size for traditional groups is five participants. However, when the GDSS was used, the effect of team members generated debates. Gallupe et al. (1992) recognized the positive effect of group size as it increased the satisfaction level from a number of studies. Fjermestad and Hiltz (1998) concluded that larger groups performed better than smaller groups through various factors in GDSS. The disparate opinion was regulated by Valacich et al. (1992), who found larger groups to be no more satisfied than smaller groups.

Several variables can affect team performance, such as different GDSS used in the studies and various workshop settings. Thus, no determined evidence can be adopted to make a definitive conclusion. Larger group size will lead to negative results, but the CMC minimized the effect, and thereby, the process losses that a larger group might ordinarily experience can also be reduced through CMC (Lowry et al., 2006; Furst et al., 1999).

In VM workshops, the VM team always involves 18 to 20 participants, and the number is rarely below 10 (Kelly et al., 2003). To enhance team performance, Fan et al. (2008) divided the VM team into several small sub-groups to avoid the problems associated with a large number of participants and the short duration of VM workshops in Hong Kong. This setting combined the advantages of both large and small groups in team activities, and can be applied to VVM studies.

3.3.1.3 Trust establishment

Paul and McDaniel Jr (2004) proved the positive association between integrated interpersonal trust and virtual collaborative relationship performance. However, trust establishment performed poorly in the virtual environment (Wilson et al., 2006; Moore, 2010).

People in the same team can work together because they trust one another (Lipnack and Stamps, 2000). This rule exists in both F2F teams and VTs, but trust started lower

in VTs at the beginning stage after team building. Wilson et al. (2006) suggested that the problem was led by computer-mediated communication because people cannot see each other unlike in traditional F2F conversation. While the use of ICT helps participants in a VT across space, trust may be challenged over the distance.

The essence of trust is identification among team members (Scott and Fontenot, 1999). In a conventional workshop, identification is established on direct F2F interaction, such as verbal interaction, and paired communication will simulate this process. By contrast, team identification has been raised in VT as well as the challenge posed by distance to team cohesion (Scott and Fontenot, 1999; Connaughton and Daly, 2004). Identification is crucial for the success of VT as it provides a sense of belonging despite the relatively lack of F2F interaction in the virtual context (Hakonen and Lipponen, 2008). Hence, successful VT should focus on establishing such an identification throughout its lifecycle (Lipnack and Stamps, 2000).

Fortunately, this circumstance is not that difficult to improve. Time positively affects trust establishment (Wilson et al., 2006), "the trust started lower in VT but increased to levels comparable to those in F2F teams over time." The application of new technology, such as video-conferencing, could simulate F2F communication in virtual context, thereby improving the establishment of trust.

3.3.2 Interaction and communication among VTs

3.3.2.1 Communication among VT

Effective communication is important for team effectiveness for both conventional teams and VTs. Despite people having recognized its importance, the effect of communication of VT in practice does not appear as perfect as people imagined (Warkentin and Beranek, 1999; Gibson and Cohen, 2003). A reason for this imperfection is that the communication among virtual team members is influenced by the way technology is implemented (Anderson et al., 2007). For example, technologies used to support VT-related research are inconsistent. Therefore, the high technology used by team facilitated smooth communication. For example, the use of video-conferencing technology significantly improved communication effectiveness in VTs (Townsend et al., 1998).

However, the major problem is the indirect interaction between participants. Hambley et al. (2007) classified team communication into three ways, namely, F2F, videoconference, and text-based chat. They found that team communication and interaction were higher in F2F than in videoconference and chats. Similar results were reported by Warkentin and Beranek (1999) and Gibson and Cohen (2003). To encourage effective communication, Anderson et al. (2007) suggested the introduction of trained facilitators to guide and the inclusion of communication patterns across distributed locations.

Psychological barriers, such as “shyness in speaking in public” and “identification barrier,” negatively affect VT’s communication (Powell et al., 2004; Fan et al., 2008). To some extent, the use of technology can solve these problems. For example, Fan et al. (2008) designed text-based communication by using an electronic chatroom between participants to promote communication through overcoming the fear of public speaking.

3.3.2.2 Information sharing in workshops

Stasser et al. (2000) emphasized the difficulty of ensuring the good sharing of information among team members, especially unique information known to only specific individuals. For an extended period, this problem had plagued people in practice and affected team effectiveness. When VT came out, the particular problem became more serious in virtual context, where direct communication is lacking.

To enhance information sharing, GDSS was introduced in the particular research area. Desanctis and Gallupe (1987) constructed a taxonomy of GDSS from the perspective of information exchange. They defined basic GDSS as focusing to improve information exchange between participants. The GDSS helps people share their information through various forms by its management tools and database storage. In the 1990s, Gallupe and McKeen (1990) started bringing the benefits of GDSS from F2F to remote meetings, which is the rudiment of virtual meeting. With the rapid development of technology, information sharing was enhanced by newly developed

remote GDSS system. Fan et al. (2008) developed a remote GDSS system based on Microsoft SharePoint Service to support VM studies. The system can achieve convenient online document sharing and provide user-friendly interface that users can easily access without specific training. In addition to the GDSS, the current effective tools for improving information sharing among VTs include a chat room, cloud storage, and online collaboration tools (Anderson et al., 2007). These technologies allow virtual workshops a flexible creative environment and an efficient information sharing channel.

3.3.2.3 Sharing facilities in discussion

The issue on sharing facilities emerged with the implementation of VTs. A benchmarking research by Anderson et al. (2007) emphasized that when the VT expands beyond a certain size, IT facilities have to be shared to meet the needs of communication. In the implementation of virtual workshops, participants used an LCD projector to broadcast the GDSS display, and utilized a central microphone to collect audio data from the participants. However, when individual audio and video devices became affordable in recent years, small groups opted to use these individual devices to support their virtual meeting or virtual workshops.

However, limited studies are focused on the effect of sharing facilities in virtual workshop. A few are limited to the sharing of facilities in communication (Anderson et al., 2007; Rafaeli and Ravid, 2003). Studies noted that despite sharing IT facilities,

more discussions are possible in VT. However, to encourage free communication across distributed VT, each participant was suggested to have his/her own communication facility regardless of whether the technology is less advanced, as compared with the shared technology support (Anderson et al., 2007).

3.3.3 Virtual facilitation

3.3.3.1 VM facilitation and process

To implement VM studies, facilitation is a CSF that significantly affects the success of a VM workshop (Shen and Liu, 2003). One or more skilled VM facilitator conducts the workshop. A VM facilitator is someone familiar with the VM process and technologies used in the workshop. The facilitator helps a VM team to understand workshop objectives and to assist them to plan to achieve these objectives. When the role of VM facilitator is transferred from conventional F2F team to VT, new challenges emerge as virtual settings are introduced. Evidence proves that approximately 50% of unsuccessful projects with VTs result from incompetent facilitation of virtual teams (Schweitzer and Duxbury, 2010). Therefore, the understanding of VT facilitation and the tasks of VT facilitator is important.

Fisher and Fisher (2000) suggested that facilitating a VT not only involves communication complexities, but also requires a certain shift in project leadership approach. The major objective of a VT facilitator for VM workshop includes two specific tasks, which are facilitating the technologies used in the VM workshop and

facilitating the VM process. Lantz (2001) recommended that participants should first be familiar with the technology before they can participate in the study. Hence, the facilitator should provide specific guidance to the technologies used in each workshop phase and provide technical support to participants in the virtual participation. For the second aspect, a specific and well-designed process is crucial for the success of virtual workshop (Arkesteijn et al., 2004). Facilitators should control the VVM workshop to ensure its constant success, which affects workshop performance. The success of the implementation of VT is more about processes and people than about technology (Bal and Teo, 2001).

3.3.3.2 Facilitation skill changed in virtual

To date, VT research has not probed into the application of traditional team process views to the virtual environment. Formalisation of working procedures and managerial structures remain limited (Rezgui, 2007). From a pilot study, Kear et al. (2012) indicated that the VT facilitators experienced challenges in the virtual settings. Creating social presence and managing cognitive load when dealing with multiple tasks online are examples of challenges.

First, facilitation should be changed to adjust the effect of indirect contact among VTs. The network effect will reduce the efficiency of communication, and affect how facilitators obtain timely feedback from participants. However, the positive perspective of the effect occurs when participants slip into an avatar, which leads to

more freedom and abundant exchange of ideas than what is currently possible at physical meetings (Moore, 2010). Second, facilitation style will be changed in virtual context. Veen et al. (1998) suggested that specific pedagogical actions must be considered in conducting a virtual workshop. Some specific settings could be adopted to enhance virtual facilitation. Examples are using separate online meeting rooms for the divided sub-VT groups to avoid large group effect on VT performance (Han et al., 2011), and extending workshop duration to several days to accommodate participants who are in different time zones (Dolci et al., 2011). These examples are effective measures for facilitating a VVM workshop.

3.3.4 Anonymity policy

Fan et al. (2007) used anonymous electronic brainstorming in the creativity phase of an experimental VM workshop. However, contrary to such an idea, Luo et al. (2011) adopted and forwarded an idea generation process in the same phase of GDSS-supported workshops. These two studies were conducted under the same VM job plan, but were applied in different settings. The use of anonymity policy depends on workshop settings, instead of a fixed anonymous process, to achieve optimum performance in the VM workshops.

The anonymity in the VVM workshop is evident in two sides. An anonymous policy is adopted in traditional F2F VM workshops to ease the concern of receiving negative assessments from others during the creativity phase (Er and Ng, 1995; Fan et al.,

2008). However, in this case, anonymous electronic input is often supplemented by less anonymous verbal explanation or discussion (Arkesteijn et al., 2004). Thus, no such concern is necessary in VVM workshops because of the virtual settings. Hence, non-anonymous and an actual name policy can be adopted to stimulate the participation of stakeholders. Anonymous evaluation and voting processes are necessary for avoiding negative comments among participants (Dennis, 1991). Therefore, a synthesized "dual anonymity policy" could be adopted in the VVM workshops.

3.4 VVM workshops

Veen et al. (1998) defined virtual workshops as web-based discussions using groupware facilities that mainly focus on the enhancement of future collaboration plans. Thus, a VVM workshop can be regarded as a VM workshop with virtual participation of stakeholders via web-based discussions and decision making process using ICTs.

One of the major limitations of VM studies is the difficulty in choosing the time and place to conduct them with the full attendance of invited participants (Shen and Chung, 2000; Lin and Shen, 2007). When the number of those invited exceeds 15, the problem becomes more complex, and the process of arranging workshops requires more time and resources (Benbasat and Lim, 1993; Chung et al., 2002). SAVE International defined the typical 40-hour job plan for the implementation of VM

workshops (SAVE International, 1998). However, in most cases especially in the major construction projects, stakeholders are often located in different places far from each other. As a result, the coordination of stakeholders' schedule for a 5-day VM workshop is a difficult task, and travel and accommodation costs are high as well. Therefore, VVM workshops have a growing demand because stakeholders who are geographically dispersed can join.

For traditional workshops, with or without GDSS support, facilitators have to arrange a meeting room with enough space to accommodate participants and to provide a comfortable environment to encourage creative thinking and to minimize negative influences on brainstorming (Yuan et al., 2013; Shen and Chung, 2002). Lin et al. (2011) found that the environment of VM workshops is one of the CSFs of VM practice in Hong Kong. They found that assessing the environment is always a challenge when conducting a VM workshop as high financial cost is incurred. Therefore, conflict arises between having a fixed and environmentally friendly venue and having geographically dispersed participants. Currently, the development of information technology, web conferencing, and virtual collaboration technology has benefited many fields and has improved research and development (R&D) in these fields (Sonnenwald et al., 2001). Therefore, conducting a VVM workshop via these information technologies is possible, although some challenges still exist in managing a large group.

3.5 Summary

This chapter reviewed studies on various GDSS, application of GDSS in VM, and the virtual collaborative environment.

The first part is the GDSS review. First, the background and the development of GDSS were introduced. Then, the taxonomy of GDSS was reviewed to identify the current GDS research direction and to clarify of the concept of the GDSS. Included were two widely accepted taxonomy based on duration of session and proximity of group members, and the taxonomy on group size and proximity of members. The relationship among three factors (duration, group size, and proximity of group members) was discussed. Another famous three-level GDSS model was introduced, and GDSS was defined from an information-exchange perspective. Following that, the components of GDSS were presented. Finally, the review of application of GDSS in VM provided an understanding of the current situation of GDSS-supported VM studies.

The second part reviewed the virtual collaborative environment. Initially, the concepts of virtual setting and virtual workshop were introduced. Several key characteristics in the virtual collaborative environment were mentioned in four sections. The first section is the comprehensive review of VT. This part started with a detailed introduction about VTs, its definitions, and team construction. Group size and design of VT are important factors that significantly influence the performance of VT. The

difficulty of establishing trust among VT members is discussed in detail. The second section presented the interaction and communication among VTs from the perspectives of communication, information sharing, and facilities sharing. The last two sections tackled virtual facilitation and anonymity policy in workshops. The review of the virtual collaborative environment helped in understanding the differences between traditional F2F workshops and the virtual workshops, and provided a basis for the development of the framework of the VVM workshop.

Chapter 4: Conceptual Framework of VVM Workshops

4.1 Introduction

A conceptual framework is defined as "the way ideas are organized to achieve a research project's purpose" (Shields and Rangarajan, 2013). The conceptual framework is an analytical tool to describe elements and procedures in approaching the research target. A strong conceptual framework is an abstract representation and guide for the implementation of research content. The demand is currently high for implementing VM studies to encourage participation of stakeholders who are geographically far from the workshop venue. However, there is lack of existing knowledge on VVM and no existing framework for VVM studies.

To achieve the research objectives, this chapter illustrates the proposed conceptual framework for VVM studies. The procedure of the workshop is described as a structured job plan and the main activities for each workshop phase are introduced in detail in the current chapter.

4.2 Linkage of VM, GDSS and virtual settings

4.2.1 Development from VM to VVM

In terms of project management, the objective of VM studies is to maximize the value of a project by satisfying the client requirements at the lowest life-cycle cost and meeting the required functions with the lowest consumption of resources (Lin and Shen, 2007; Yu, 2007). VM is a systematic team-based approach that seeks various

means of achieving effectiveness and efficiency of a project with the reasonable allocation of project resources.

According to Kelly et al. (2003), the briefing stage is the optimal time to implement VM in a construction project, to avoid waste of resources, and to achieve the best value for money. The project briefing stage refers to the information gathering and exchange stage for decision-making and implementation, which includes identifying and clarifying project objectives and requirements (Yu et al., 2007; Kelly and Duerk, 2002). This term is widely adopted in the UK and Hong Kong as the same meaning of "architectural programming" in the U.S.

Shen and Chung (2000) identified three common problems faced by VM studies in construction briefing in Hong Kong, namely, lack of information, low participation and interaction, and difficulty in conducting evaluation and analysis. To overcome these problems, they introduced GDSS into VM and proposed a GDSS-supported VM methodology. GDSS provides enhanced information exchange and encourages a collaborative environment and computer-based evaluation for the VM process. Furthermore, the effectiveness and efficiency of the GDSS-based VM workshop in supporting VM studies with expected outcomes has been proven by a benchmarking research on the implementation of GDSS in VM workshops (Shen and Chung, 2003; Shen et al., 2004b; Fan et al., 2007; Fan and Shen, 2011; Luo et al., 2011). GDSS is distinguished from other information systems for its excellence in team-based

creativity and collaboration.

A VM team is normally comprised of representatives from each project stakeholder. According to Yu (2007), more than a half of thirteen identified variables of VM can be classified as team-oriented behaviors and activities. These variables are listed below:

1. Projects
2. Stakeholder management
3. Teams and team dynamics
4. Client representation
5. Change management
6. Knowledge management
7. Risk and conflict management
8. Post-occupancy evaluation and post-project evaluation
9. Critical success factors (CSFs) and key performance indicators
10. Types of business and organizational theory
11. Decision making
12. Communication
13. Culture and ethics

A VM study addresses each variable by providing appropriate techniques and functional tools, such as function analysis, the Function Analysis System Technology

(FAST), and team-based brainstorming. Therefore, individual participation and team collaboration are important to the whole process of a VM study, as these factors can affect the quality and value of the project.

The main difference between a VM team in a traditional workshop and one in a virtual workshop is the virtual context. Although the members of a virtual team are from different places, time zones, and organizational boundaries, they work together toward common goals as a structural team through virtual collaboration. Hence, for its indispensable role in the composition of VTs, GDSS is proposed to provide all necessary functions for overcoming the time and space barriers and difficulties in communication and collaboration in a virtual environment.

After the literature review, the inter-relationship between elements of a VT for a construction project was identified (Figure 4.1). VT brings potential benefits to VM, such as saving time and costs, improving efficiency, and enhancing workshop performance. However, VT also introduces new problems. For example, trust between VT members is difficult to establish in a virtual context. Therefore, when virtual VM is adopted, achieving its effectiveness while enhancing project performance is an interesting topic to study.

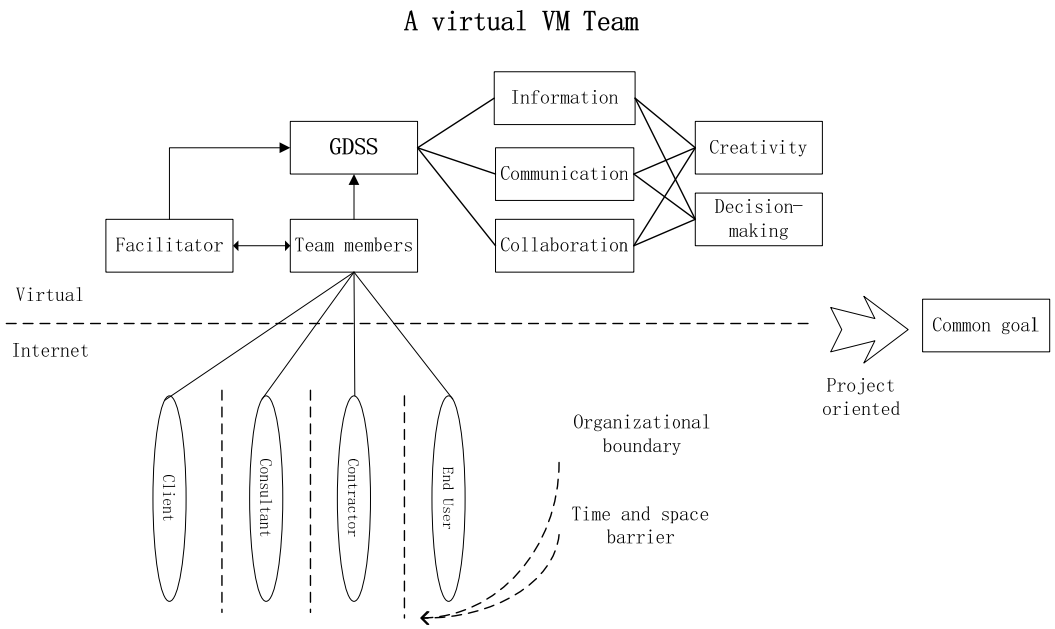

Figure 4.1 A typical virtual VM team for construction project

4.2.2 Characteristics of VVM workshops

Virtual workshops possess special characteristics that differ in many aspects from traditional F2F workshops due to virtual settings and environments. Previous studies have identified some unique issues, and have recognized the importance of such issues in the implementation, process, and performance of virtual workshops.

4.2.2.1 Virtual Teams

Veen et al. (1998) defined virtual workshops as web-based discussions that use groupware facilities and mainly focus on the enhancement of future collaboration plans. These web-based discussions normally occur among groups of people who are geographically dispersed, and thus, form virtual teams (VTs). A VT is often described as a group of people striving toward a common goal, dispersed across space, and

characterized by non-physical communication with one other through ICT (Axtell et al., 2004; Lurey and Raisinghani, 2001; Powell et al., 2004; Rezgui, 2007)

VTs play a very important role in virtual workshops and online meetings. Therefore, the construction of VTs affects the quality of workshop outcomes directly. After a review of VT benefits based on existing literature, Schweitzer and Duxbury (2010) concluded that VTs have the ability to resolve geographical and time boundaries, incur lower costs, improve productivity and timing effectiveness, obtain higher response speed, and enhance the quality of the tasks.

In VVM studies, VTs are expected to exhibit these advantages. However, a VT in a VVM workshop is often a temporary task-oriented team that relies on coordination among dispersed project stakeholders working toward a common goal. Studies suggested that cultural differences, effectiveness in communication, difficulty in information sharing, and the involvement of participants in decision making are major problems faced by VTs (Rezgui, 2007).

4.2.2.2 Identification in virtual team

People work together in a team because they trust one another (Lipnack and Stamps, 2000). In traditional teams, members can easily eliminate their unfamiliarity with one other and establish identification through F2F interaction and icebreakers, but these tasks are difficult among VT members. Identification within the team is crucial for the

success of both F2F teams and VTs because identification provides a sense of satisfaction and belonging (Hakonen and Lipponen, 2008). Scott and Fontenot (1999) indicated that the issue of team identification has been raised in evaluation work. Moreover, despite the establishment of a simple link among members, the distance challenges the ties that bind VT members. Therefore, VTs should pay more attention to building and maintaining trust during the team's lifecycle (Lipnack and Stamps, 2000).

To build trust within teams, icebreakers were introduced to VM practices in traditional VM workshops. Normally, these icebreakers are led by facilitators and included a series of physical interactions and verbal communication activities among team members, such as paired introductions, cipher text passing games, and indoor-outward bound (Shen et al., 2004a). Nevertheless, such traditional icebreakers cannot be conducted in VTs due to the considerable lack of F2F interaction in the virtual context. Therefore, specially designed virtual icebreakers should be introduced in VVM workshops to improve the identification and participation of VT members.

4.2.2.3 Virtual facilitation

A VM study facilitator is a trained professional who facilitates a VM workshop with support from a multidisciplinary team of stakeholders, follows an established set of procedures to review the project, and makes sure that the team understands customer needs and comes up with cost-effective solutions (Lin and Shen, 2007). Facilitation is

a very important element of VM studies. Facilitation skills are among the CSFs of VM workshops that significantly influence the performance of VM teams and the outcomes of VM studies (Lin and Shen, 2006).

In traditional VM workshops, facilitators communicate with the participants, encourage participation, answer questions, and solve technical problems. This facilitation style requires professional skills in encouraging attraction and leading a series of interactions among participants, which include oral presentations, expressions, gestures, and eye contact. Unfortunately, these skills cannot be applied in VVM workshops because of indirect communication in the virtual context. Evidence shows that the current facilitation style has been challenged in such virtual environments. Schweitzer and Duxbury (2010) reported that around 50% of unsuccessful VT projects resulted from incompetent management working with the VTs. Therefore, effectively facilitating a VT requires a certain shift in the facilitation approach, and should include the skilled use of technical tools, flexible process control, attractive virtual icebreakers, and improved virtual communication skills (Fisher and Fisher, 2000; Yuan et al., 2013).

4.2.2.4 Virtual communication

In F2F meetings, people can easily recognize the person speaking through visual observation and tracking sound direction. However, in the virtual environment, people can only communicate through ICT with indirect methods, such as text, audio, or

video chat. Therefore, technical tools significantly affect the quality of communication among VTs. Anderson et al. (2007) and Schweitzer and Duxbury (2010) have indicated this point in their studies.

A positive aspect is that VTs tend to lead to more talking in the virtual environment than in F2F communication. People worry about making mistakes in F2F communication because mistakes can easily be recognized and may leave a bad impression to others. "A failure in communication could result in a defensive or even a roadblock response" (Shen and Liu, 2003). The problem in a virtual context is diluted because of the non-physical interaction and indirect communication. Therefore, one way to stimulate effective communication among VT members may be the encouragement of open and inclusive patterns of communication across the different locations (Anderson et al., 2007). Hence, a *counter-anonymity approach* is needed.

4.2.2.5 Countering anonymity in a virtual collaborative environment

Anonymity in VVM workshops is usually evident in two aspects. To counter this anonymity, two measures can be carried out.

First, a non-anonymous policy should be encouraged. In traditional F2F VM workshops, an anonymous policy is adopted to ease the concern of receiving negative assessments from others during the creativity phase (Er and Ng, 1995; Fan et al., 2008). However, in the case of VVM workshops, anonymous electronic input is often

supplemented by a less anonymous verbal explanation or discussion (Arkesteijn et al., 2004). Therefore, no such concern exists in VVM workshops because of the virtual setting. Hence, a non-anonymous and real-name policy can be adopted to stimulate the participation of stakeholders. Second, anonymous evaluation and voting processes are necessary to reduce effectively negative comments among participants. The dual anonymity policy is an important feature of VVM workshops.

4.3 Job plan for VVM workshops

In practice, VM is implemented in the form of workshops led by trained facilitators and participated by major project stakeholders through a structured job plan (Yuan et al., 2013; Fan and Shen, 2011; Lin and Shen, 2007). The job plan is often used in VM methodology as a standard to guide the implementation of VM workshops (Norton and McElligott, 1995). A well designed job plan is a structural process that clearly defines the VM process for each workshop at different stages of a project and defines the beginning and end of VM workshops (Yu, 2007). Shen et al. (2004a) suggested that the functional representation of the job plan should act as a bridge between client and designer. Male (1998) developed a VM job plan for a pioneering research on VM frameworks, while Luo et al. (2010) suggested a non-generic VM process for using functional performance specifications in a construction project briefing.

To conduct VM in virtual environments and maintain the benefits of the systematic process of VM methodology, a new job plan for the implementation of VVM

workshops in major construction projects is proposed. Among the characteristics of stakeholders in major construction projects, real-time communication and information exchange are preferred to improve decision-making efficiency and quality (Yang et al., 2009a). Therefore, for major construction projects, the job plan is designed as a VVM workshop in a single time but held in different places.

This job plan includes typical VM processes and creative items in the balance of technology, environment, and management. As a result of the employment of virtual features, the information exchange process and the operational procedure are emphasized dramatically in this new job plan. Therefore, the job plan acknowledges the fundamental implication of GDSS in VVM processes and arranges a specific phase. The preparation phase, which comes before the information phase, aims to eliminate technical problems early on and to help the participants prepare for the VVM workshop. Meanwhile, the function of the pre-workshop stage is emphasized through more than one round of pre-workshop meetings in the new job plan. In addition, an agenda for experimental studies is established in this research based on the job plan.

The job plan consists of three stages, namely, pre-workshop, workshop, and post-workshop. The workshop stage is further divided into six phases, namely, preparation, information, function analysis, creativity, evaluation, and development.

4.3.1 Pre-workshop stage

According to SAVE International (2007), the main purpose of the pre-workshop stage is to plan and to organize the VM study. To achieve this purpose, the project objectives, resources, and constraints should be understood by all workshop participants from the different parties. The requirements of the VVM workshop are delivered to these participants and their devices will be tested before the VM workshop.

4.3.1.1 Pre-workshop activities

Workshop organizers and facilitators, representatives from clients, and other stakeholders usually lead pre-workshop activities. The series of activities conducted in this stage, includes, but not limited, to the following agenda:

- Obtain background information and data on the project
- Develop the scope and objectives
- Identify VT members
- Establish workshop agenda
- Select appropriate GDSS for the virtual workshop
- Distribute information to VT members for review
- Distribute GDSS guidelines to VT members
- Define the successful objectives of the VM study

4.3.1.2 Pre-workshop meeting

Unlike in traditional VM job plans, a pre-workshop meeting is a compulsory element in the new job plan. The participants of the VVM workshop are assumed as first-time participants in a VM workshop supported by online GDSS. In this case, preliminary knowledge about virtual workshops, and the functions and operation method of the GDSS should be provided to the participants to ensure their successful participation. A VVM workshop not only imposes demands on the workshop facilities of the organizers, but also proposes requirements on the equipment used by participants. A pre-workshop meeting is conducted in this stage to test the compatibility and stability of these devices. The meeting can also contribute to the elimination of unfamiliarity and the establishment of trust among virtual participants.

4.3.2 Workshop stage

The workshop stage is the core element of a VM study, and is composed of six phases, namely, preparation, information, function analysis, creativity, evaluation, and development.

4.3.2.1 Preparation phase

Two objectives are expected to be achieved in the preparation phase, which are to build identity and trust among participants and to solve potential technical problems during the workshop. Trust establishment is one of the CSFs of VM studies (Shen and Liu, 2003). In traditional workshops, identity is easy to build through ID labels,

figures and appearance, voice, behavior, and spatial location. However, the nature of virtual settings makes the same task difficult under a virtual context. Only a video avatar and no voice direction or soft-pointer can be used to identify one other in a virtual workshop. Hence, an impressive self-introduction of participants following a particular sequence is a main task in this phase. Furthermore, some online icebreakers are adopted to eliminate unfamiliarity among VT members and to build trust that could motivate the team to meet the workshop objectives.

In addition, unpredictable technical problems caused by the uncontrollable user environment threaten the success of VVM workshops. In some cases, a participant can lose access to the virtual workshop if there is a change in devices or location. Therefore, troubleshooting technical problems is an important task in the preparation phase.

4.3.2.2 Information phase

The aim of the information phase is to deliver and to facilitate the exchange of information among all VT members to ensure that everyone fully understands the project background, limitations, and workshop objectives (Shen et al., 2004a). In this phase, the facilitator introduces all participants to the procedure and methodology of the workshop. This introduction will be followed by a presentation given by each representative of the stakeholder parties about the description of their respective requirements and understanding of the target project. These presentations are given

virtually through an online GDSS platform that broadcasts to all VT members. After this phase, the participants are expected to have a thorough understanding of client needs, project costs, and objectives of the study.

4.3.2.3 Function analysis phase

Function definition and analysis are the most essential elements in the VM methodology. In this phase, participants identify the main functions of the project in line with the client's requirements. A function may be a task that reflects a project objective or an area that has potential for further development. A function is normally expressed as a verb plus a noun, such as "*Improve economics*" or "*Reduce waste.*"

After identifying key functions, the Function Analysis System Technology (FAST) is employed to address the difficulty of arriving at an agreement on function analysis (Luo et al., 2011). FAST, which was developed by Charles W. Bytheway, is an effective approach to enable participants from different stakeholders to communicate effectively and to resolve issues that require multi-disciplinary considerations (Luo, 2010; Luo et al., 2011). The FAST diagram arranges all identified functions for a project in a how-why logic, which reflects a clearly hierarchical relationship between functions. Therefore, project stakeholders can easily understand issues on how to achieve a high-level function and reasons on why a low-level function should proceed could through this logic. Moreover, the redundant functions and missing functions can be identified in this process.

Other tools, such as SWOT analysis, can be employed at this phase to assist the identification of key functions. Luo et al. (2011) proposed a special technique named "Performance Specification" to give each function a detailed level at which the client's requirements are clearly understood by team members from all professional disciplines in a particular GDSS. The purpose of these techniques is to recognize the priority and negotiability of the functions, and to clarify how a function should be measured in the next phase or how the function should be revised to express the requirement more accurately.

4.3.2.4 Creativity phase

The objective of this phase is to develop ideas for each of the functions selected in the *Function Analysis Phase*. A brainstorming technique is implemented to facilitate the idea generation process, and the VM members are requested to finish this process in small groups with four to six participants.

During the idea generation process, all sub-groups work together on the same task. However, communication among participants is regulated through technical means, which is controlled by the facilitator. Generated ideas can be reviewed by participants within the same sub-group, but not across different sub-groups. Hence, ideas generated by different sub-groups can be diversified and the creativity rate can be kept at a high level. To gain high-quality alternatives, the participants are encouraged to generate ideas in multiple disciplines and aspects. Therefore, discussions and

judgments are not allowed during the idea generation process to avoid affecting the participants' innovative thinking. When all sub-groups have finished their tasks, ideas from each of the sub-groups will be merged by the facilitator for further development.

After the idea generation stage, all generated ideas will be reviewed and organized in two steps. First, duplicates are identified and eliminated by the whole VT. Then, the ideas are sorted into "P categories," where P1 refers to "Realistically possible," P2 refers to "Remotely possible," and P3 refers to "Fantasy"(Shen and Chung, 2003). Only P1 ideas are legitimate and are carried over for evaluation in next phase. Meanwhile, spelling and grammar errors in these ideas will be corrected during this process.

4.3.2.5 Evaluation phase

The purpose of the evaluation phase is to identify the best alternatives for a specific task through a comprehensive evaluation process with several criteria. The candidate alternatives are the P1 ideas in the previous phase. To evaluate these ideas, four to six key criteria are proposed by all participants (too much criteria will lead to severe overtime of this phase). Participants finish the evaluation process individually on the GDSS adopted for the particular study. First, the criteria are compared in pairs with given scores to show the weightings. The importance of the criteria for the task is reflected in the idea evaluation process. The ideas are then evaluated in a matrix with the criteria, and each idea will be given a score to show its level of satisfaction in a

particular criterion. The total score of each idea is the sum of the scores of each line in the evaluation matrix. After this process, the ideas that receive the highest scores are selected as the best alternatives for the task.

4.3.2.6 Development phase

The objective of this phase is to develop the selected "best" alternatives to improve the project's value and to make the action plan. The investigation of these ideas considered the multi-disciplines of the participants, issues of cost, performance, and schedule for implementation. Yu (2007) recommended that a VM workshop should be concluded with an action plan created by the members of the project team. The action plan should indicate the specific tasks, the person/s responsible for performing the task, and the target completion date of the action.

4.3.3 Post-workshop stage

The objective of the post-workshop stage is to ensure that the approved action plan is properly implemented. A person monitors the progress of the implementation of recommendations and collects feedback to refine the study. Therefore, the post-workshop stage involves revision when a design is under way.

4.4 Overview of the conceptual framework

In this section, a conceptual framework is developed to guide the implementation of VVM workshops (Figure 4.2). The framework consists of four levels, namely, process,

implementation, communication, and collaboration. This framework describes the VVM workshop from management and technical aspects. Each level has several sub-components that reflect the requirements or key functions of VVM workshops.

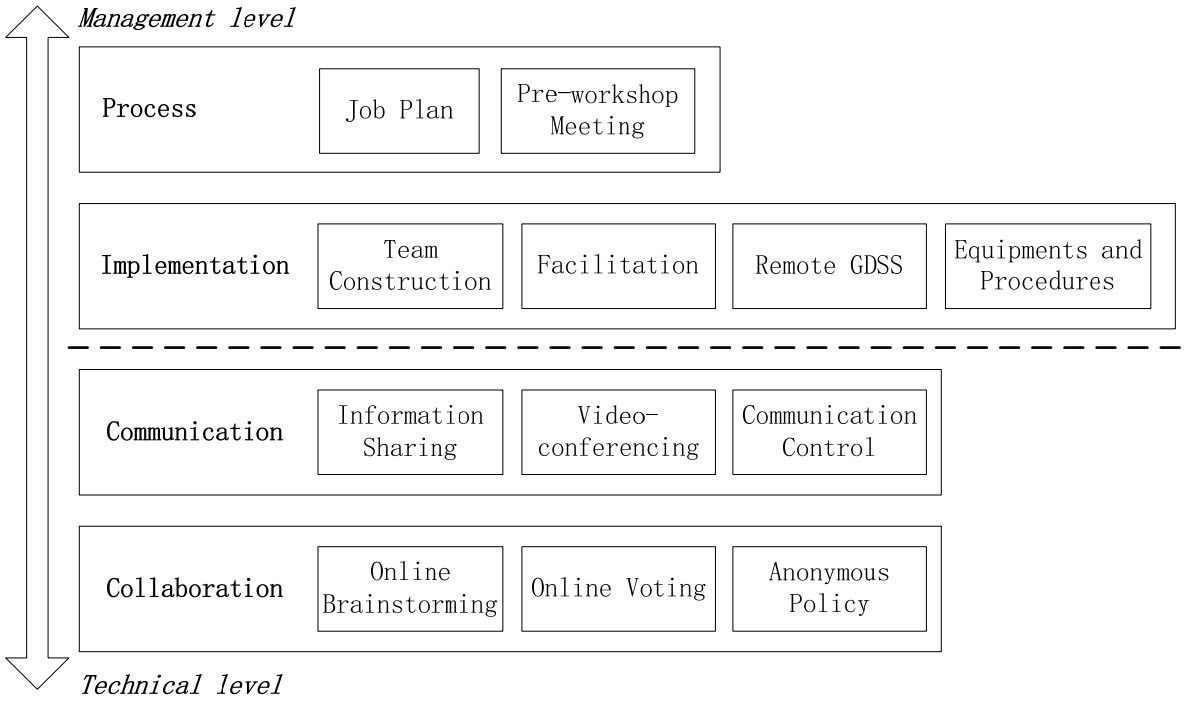

Figure 4.2 Overview of conceptual framework of virtual VM workshops

4.4.1 Process

Process structure describes the essential flow of VVM workshops, including the features of both virtual and non-virtual workshops. The **VM job plan** lays down the procedure of a VM workshop explicitly (Luo et al., 2010) and includes seven main phases, which are pre-workshop, information, function analysis, creativity, evaluation, development, and post-workshop. A well-designed job plan is a structural process that clearly defines the VM process for each workshop at different stages of a project, and

defines the beginning and end of VM workshops (Yu, 2007). In the current study, a typical one-day job plan was adopted for the design of the VVM framework and for the experiment (Figure 4.3).

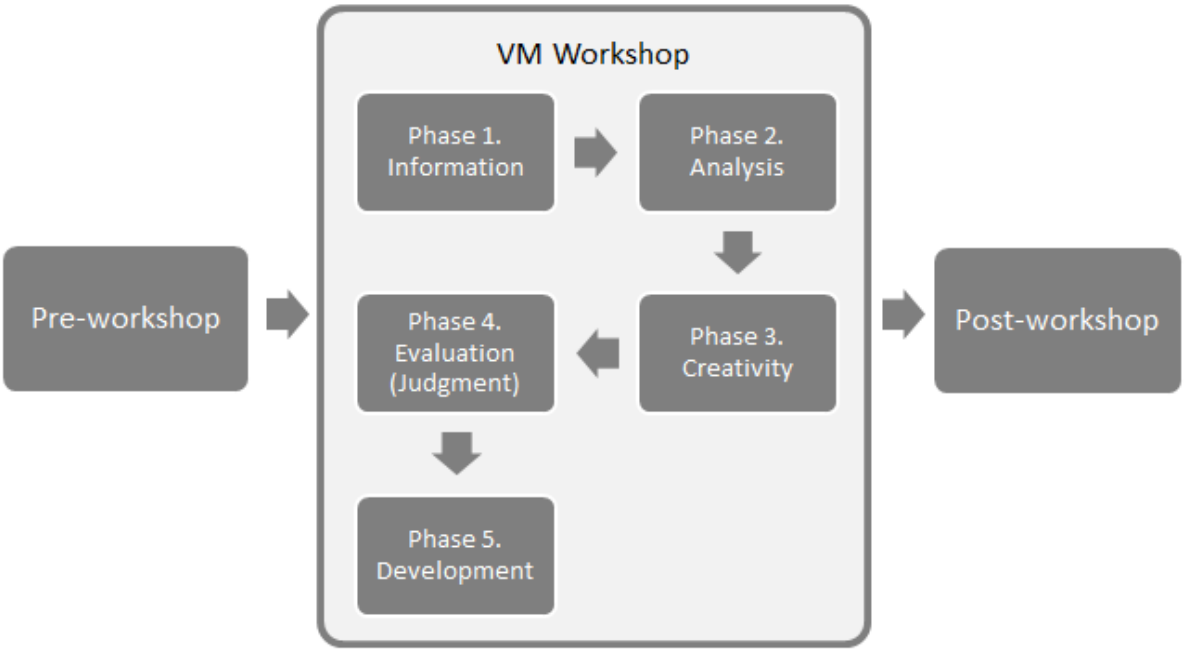

Figure 4.3 A typical one day VM job plan

(Adapted from: Shen and Chung, 2003)

Note that the pre-workshop phase includes the awareness of project objectives, but with no emphasis or requirements on the participation and content in their form (Shen et al., 2004a; Fan et al., 2008; Luo et al., 2010). In addition, an independent **Pre-workshop meeting** must be conducted to provide the technical training about the system used in the VVM workshop, together with the training for the appropriate communication style in a virtual environment for all participants. The training will lead to better performance in the real virtual workshops.

4.4.2 Implementation

Workshop implementation mainly addresses problems from the following aspects, namely, team construction, facilitation, remote GDSS, and equipment and procedures. The construction of VTs affects the outcomes of virtual workshops directly (Rezgui, 2007). Therefore, a VT should be established on a multi-disciplinary basis to ensure the success of the workshop. Virtual facilitation skills are new challenges to VM facilitators, and their facilitation style should be improved to adapt to virtual settings. Remote GDSS is a platform that carries all activities of VVM workshops. A user-friendly and powerful system can effectively improve the performance of the workshop. However, providing basic hardware for all participants might be impossible for the organizer, and thus, preparing the facilities to meet the workshop standard and complying strictly with workshop procedures are among the basic requirements for VVM workshop participants.

4.4.3 Communication

The importance of communication among workshop members is stressed significantly in virtual settings. Communication stimulates cooperation between VT members, and connects the participants during the VVM workshops (Schweitzer and Duxbury, 2010; Rezgui, 2007). The manner of information exchange also changes in the communication environment. For instance, a virtual presentation, instead of F2F presentation, will be conducted in presenting the clients' requirement. To this end, web-conferencing, including audio and video support, will be adopted as one of the

most important components of the VVM workshops. However, during the experimental workshop, we observed that the instability caused by technical problems, such as echoes among participants, affected the workshop performance seriously. Therefore, to ensure optimal performance, a mechanism for intervention by the facilitators to control the range and pattern of communication during different stages of the workshop is introduced to the VVM workshop framework.

4.4.4 Collaboration

Collaboration in VVM workshops includes three major mechanisms, which are online brainstorming, online voting, and anonymity. In VM methodology, brainstorming is used to generate alternatives and accomplish functions during VM workshops (Fan and Shen, 2011). The collaboration process is fully supported by the remote GDSS in VVM workshops. However, VT members have difficulty in agreeing on the evaluation of the generated alternatives. Therefore, an independent voting process must be formulated to ensure efficiency and to achieve the objective of the evaluation process. In addition, as discussed in the previous section of this paper, a dual anonymity policy is also an important mechanism to guarantee the quantity and quality of ideas in the creativity phase as well as equity and efficiency in the evaluation phase.

4.5 Summary

In this chapter, a conceptual framework of VVM workshops is proposed as a guide in

the implementation of VVM studies. The development of the framework is based on the features of virtual teams and virtual collaboration. In addition, key characteristics of VVM are also identified in this chapter. Subsequently, a new job plan is developed for VVM workshops, which includes specific procedures for implementing VVM studies.

Based on the expected characteristics of VVM and the job plan, the conceptual framework is presented in four levels of process, implementation, communication, and collaboration. Each level has several sub-components that reflect the requirements or key functions of VVM workshops. This framework emphasizes that VVM studies could be described from two perspectives of management and technology, which reflect virtual features and concerns of VVM. The next chapter introduces the VVM system based on the conceptual framework.

Chapter 5: Virtual Value Management System (VVMS)

5.1 Introduction

This chapter describes a web-based GDSS developed for the implementation of VVM workshops, which is named the Virtual Value Management System (VVMS). The VVMS is designed to support the full process of VVM workshops with GDSS features. This chapter introduces the VVMS architecture with the system requirements, and presents the implementation of the VVMS in VVM workshops. Finally, the chapter discusses how to dispose the system, the preparation work before the workshop, and the method of data collection and management.

5.2 System design

5.2.1 Overall requirements and system structure

To realize a VVM workshop and support its whole process in the construction industry, the VVMS was developed based on the conceptual framework. The VVM workshops will be conducted as the experiment part of this research. Departing from a traditional client/server structure, the VVMS is a complete web-based system that liberates users from the "bondage" of client software and a complex installation process. Through the system, participants can be invited to join the VVM workshop without having to leave their respective physical locations.

The VVMS was developed based on the GDSS. Unlike the GDSS-supported traditional VM workshops and any other kind of computer-aided F2F workshops, the

GDSS is not merely an alternative tool for enhancing workshop performance, but is an essential component of the VVM workshops where the participants can join the workshop virtually through the system's CSCW features (Figure 5.1). In their benchmarking research, Desanctis and Gallupe (1987) defined a three-level model to describe GDSS systems from an information exchange perspective :

Level 1 GDSSs provide technical features, such as large screens for instantaneous display of ideas, voting solicitation and compilation, anonymous input of ideas and preferences, and electronic message exchange among members. These features are aimed at removing common communication barriers. Level 1 GDSSs focus on improving information exchange among participants. Most of the systems in the early stage of GDSS development, such as electronic boardrooms and computer-mediated conferencing, belong to this category.

Level 2 GDSSs provide decision modeling and group decision techniques that are aimed at reducing uncertainty and noise during the group's decision making process. Groupware is emphasized in this level of GDSS. A level 2 GDSS might provide basic functions to support individual decision making processes for group members to work on and review simultaneously, as against using a large common screen. The functions satisfied by level 2 GDSSs include, but are not limited, to computer-mediated creativity, risk analysis, anonymous rating, electronic voting, and multi-criteria evaluation. The Delphi method and NGT are incorporated in this level (Luo, 2010).

Level 3 GDSSs are characterized by machine-induced group communication patterns and can include expert advice in the selection and arrangement of rules to be applied during a meeting. A level 3 GDSS should have a rule-based discussion and automatically arrange the communication and speaking order to avoid group conflict among virtual team members.

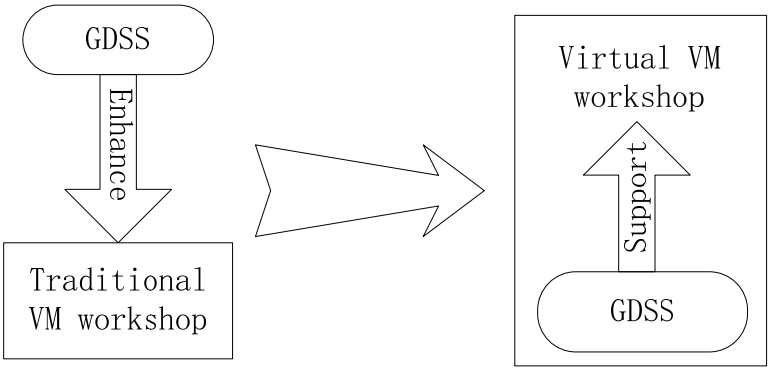

Figure 5.1 The change of mechanism of GDSS in virtual VM workshop

In a VVM workshop, participants should have equal opportunities to present their requirements and ideas, and have equal rights in the evaluation. Based on this rule, VVMS is designed as a level 3 remote GDSS. VVMS consists of two parts, which are the GDSS part and the web-based platform. Figure 5.2 shows the structure of the VVMS.

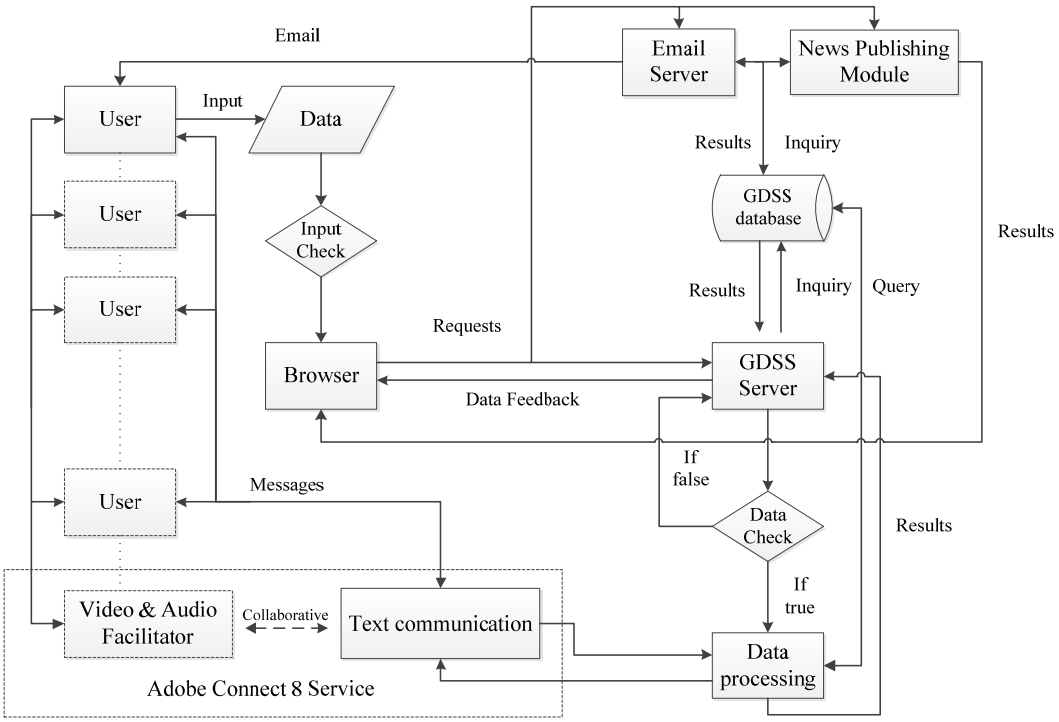

Figure 5.2 Structure of the VVMS

5.2.2 System architecture

The VVMS consists of three modules, which are a web-conferencing platform that provides audio and video connection to participants, a creativity tool for idea generation, and an evaluation tool for selecting alternatives. Figure 5.3 illustrates the system architecture, where the arrows indicate the execution logic between functions and objectives.

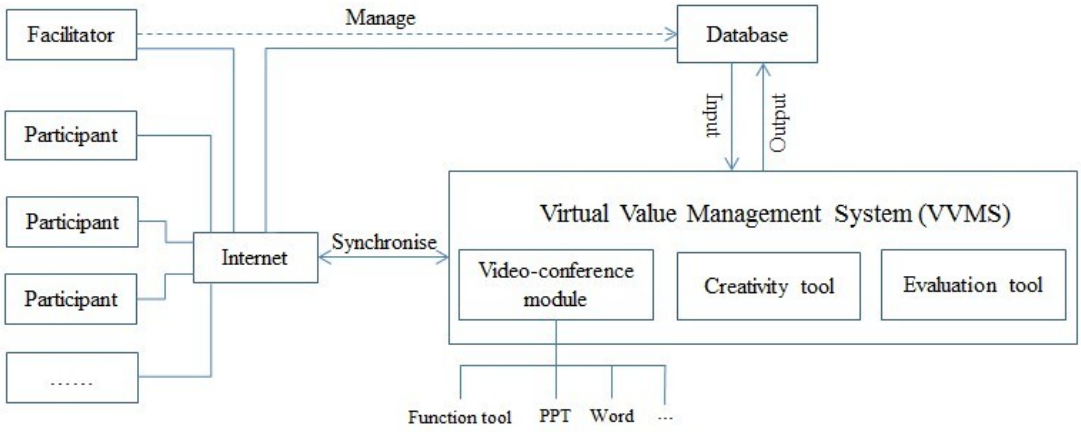

Figure 5.3 System architecture

Table 5.1 explains each module that is served in VM processes and corresponding tasks. The information and data produced in one workshop phase can be automatically transferred to the next phase through these modules.

Table 5.1 Modules used in virtual VM process

(Yuan et al., 2013)

Modules	VM process	Tasks
Video-conferencing module	Pre-workshop stage	• Briefing session
Video-conferencing module	Information phase	• Background information acquisition • Key stakeholders presentation
Video-conferencing module Function tool	Function analysis phase	• Function identification • Sort of functions • Function hierarchy

Video-conferencing module, Creativity tool	Creativity phase	• Idea generation
Video-conferencing module Evaluation tool	Evaluation phase	• Idea evaluation
Video-conferencing module	Development phase	• Preparation of action plan, Resolution of outstanding issue

The video-conferencing module can support up to 25 video access points at the same time such that all participants can see one another on one screen on the video wall. This feature reduces the sense of isolation that participants might feel. The VVMS provides full support for each phase of a typical VM workshop in a virtual environment. In the pre-workshop stage, the VVMS provides document management and file sharing functions that help participants manage and share background information. In the information phase, the VVMS provides a powerful online presentation tool with video and audio features, which make the online presentation similar to a live one. In the function analysis phase, the VVMS provides a desktop sharing tool that can share visualized functioning processes to give participants an illustration of the recognized functions. In the creativity phase, unlike the group method of the GDSS, the VVMS provides an equal opportunity for every participant to forward ideas during the creative process. This feature can encourage creative thinking by allowing the participants to share ideas while limiting direct communication to avoid excessive exchanges. In the evaluation phase, the VVMS

provides an online voting function to ensure that the participants have equal opportunities to express their ideas during the workshop. In the development phase and the post-workshop stage, a record of the workshop is automatically provided by VVMS such that participants can easily review the whole process and the workshop outcomes.

5.2.3 System development

Three potential options for the development of the VVMS are presented. The first option is to adopt and to customize commercial applications. The second option is to program the VVMS independently based on a C/S or B/S structure. The third option is to integrate existing resources and independently developed modules with non-existing features. The study adopts the third option based on four considerations. (1) No existing commercial applications can support the whole process of a VVM workshop. (2) An independent development of VVMS is the best solution for VVMS and can perfectly support the full features with VVM requirements. However, the time and finance costs to this solution are quite high. (3) Based on the system architecture (see Section 5.2.2), the system consists of three main modules, which contain distributed VM features. Some of these VM features can be supported by existing commercial applications. For instance, some online video and audio conference software programs in the market, such as the Cisco WebEx and Adobe Connect, have web-conferencing features that can support the information exchange process and virtual presentation features for VVM workshops. Purchasing these

advanced products for the video-conferencing module of VVMS is a more economical solution than developing a new module through programming. (4) Existing commercial GDSSs cannot support the characteristics of VVM workshops, such as a countering anonymity policy and a dedicated individual voting process in the evaluation phase of VVM studies.

Two commercial applications are adopted to support video-conferencing features, information exchange, and the creativity phase of VVM workshops. In addition, an independent evaluation tool is developed using PHP language, which is based on Browser/Server (B/S) architecture, to allow asynchronous voting for idea evaluation. Table 5.2 summarizes the implementation of modules in correspondence to each phase in the VM agenda. Table 5.3 shows the development and use environments of the VVMS variables.

Table 5.2 Modules used in each workshop phase

ACTIVITY	**BY WHOM**	**Modules used in workshop**		
	Facilitator / **A**ll participants	Video-conferencing	Creativity Tool	Evaluation Tool
1. WELCOME AND INTRODUCTION				
• Welcome and agenda of the day	**F**	√		
• Participants self-introductions	**A**	√		
• Facilitator role and rule of the game	**F**	√		
• Confirmation of VM study objectives	**F**	√		
2. INFORMATION PHASE				

• Presentations by key stakeholders	**A**	√		
• Q&A session	**A**	√		
• Debriefing	**F**	√		
Tea and Coffee				
• Issue Analysis (Sustainability issues)	**A**	√		
3. FUNCTION ANALYSIS PHASE				
• Identify functions of Hotel ICON	**A**	√		
• Sort out functions	**A**	√		
• Construct function hierarchy	**A**	√		
• Debriefing	**F**	√		
Lunch				
4. CREATIVITY PHASE				
• Introduction	**F**	√		
• Identification of key functions for the achievement of our objectives	**A**	√		
• Generation of ideas to the satisfy functions for the achievement of our objectives	**A**	√	√	
• Debriefing	**F**	√		
Tea and Coffee				
5. EVALUATION PHASE				
• Review information	**A**	√		
• Put ideas in P1, P2, P3 categories	**A**	√		√
• Cluster related P1 ideas together	**A**	√		√
• Evaluate and select clustered ideas	**A**	√		√
• General discussion	**A**	√		
• Debriefing	**F**	√		
6. REPORTING PHASE				
• Preparation of action plan	**A**	√		
• Resolution of outstanding issues	**A**	√		
• Review of workshop objectives	**A**	√		
• Debriefing	**F**	√		
7. WORKSHOP CLOSING				
• Sum up	**A**	√		
• Feedback	**A**	√		
• Questionnaire survey	**A**	√		

Table 5.3 Development and use environments of the VVMS

Item	Development environment			Use environment
	Module A	Module B	Module C	VVMS
Hardware	**PC** - Intel Core i5-3317U 1.7G, 6 GB of RAM **Mobile** - iPad2 and Android Mobile Phones			**PC** - Intel Core2 Duo CPU 2.XX GHz or AMD processor. (2 GB of RAM recommended) **Mobile** - iOS or Android devices
Software	Cisco WebEx	Adobe Connect	Microsoft Windows 7 Home Premium Service Pack 1 (64bit) Apache HTTP Server 2.2.22 (32bit) PHP 5.3.10 (32bit) MySQL 5.5.20 (32bit)	Browser with JavaScript, Cookies and Active X enabled Adobe Flash Player 11.2+
Programming language		Adobe Connect	PHP+MySQL	

5.2.3.1 Video-conferencing module

The video-conferencing module is an essential component of VVMS due to its contribution to the whole process of supporting a VVM workshop (see Table 5.1). VVMS is designed to provide video-conferencing and online presentation functions for participants of VVM workshops. This module should provide advanced control of participants' audio, which allows facilitators to arrange presentations under a communication rule.

The video-conferencing module was developed based on existing commercial web-conferencing software due the consideration of time and cost. For the selection of software, several commercial applications can provide multi-line online video-conferencing features. After a comprehensive study by reviewing online user comments, comparing features, and experiencing trial versions, two products were finally selected, namely, Adobe Connect and Cisco WebEx. Table 4 presents the comparison of these two products.

Table 5.4 Features comparison of Adobe Connect and WebEx

Item	**Adobe Connect**	**WebEx**
Service provider	Adobe	Cisco
Compared Version	9.1	Premium 25
Trail version	√	√
Annual Fee	540USD	468USD

Number of users per meeting	25	25
Number of users per meeting for Trail version	3	5
Video features:		
High-definition video	√	√
Number of video allowance in a meeting	25	25
Audio features:		
VoIP (internet)	√	√
Phone call-in		√
Audio control by facilitator	√	√
Signal stability	Fair	Good
Sharing features:		
Desktop	√	√
Whiteboard	√	√
Documents	√	√
Applications	√	√
Remote Control	√	√
Collaboration features:		
Interface customise	√	
Breakout room	√	
Discussion board	√	

Both products provide high-quality video and audio conferencing features, powerful sharing functions, and both performed well during the trial. However, Adobe Connect

provided highlighted features on collaborative functions that WebEx lacked. Therefore, we first adopted Adobe Connect and conducted a series of high loaded testing workshops to assess its performance and stability in virtual workshops. However, when the number of participants who used the video function at the same time was over 20, the system ceased to be reliable because of technical problems. The system jammed under high pressure and some participants were disconnected from the server randomly during the test workshop. Therefore, we changed the system for the video-conferencing module to WebEx because of its stable online video conferencing servers. Compared to Adobe Connect, WebEx can support phone call-in audio. Hence, the workshop participants who could not access the audio through VoIP could join the VVM workshop as well.

Online sharing is another important feature of the VVMS, through which facilitators can share local files, such as those from Word, Excel, and the function tool to all participants during the workshop. WebEx supports a video-conferencing module that includes multiple forms of sharing functions, such as document sharing and desktop sharing, which can support information exchange between stakeholders (Figure 5.4).

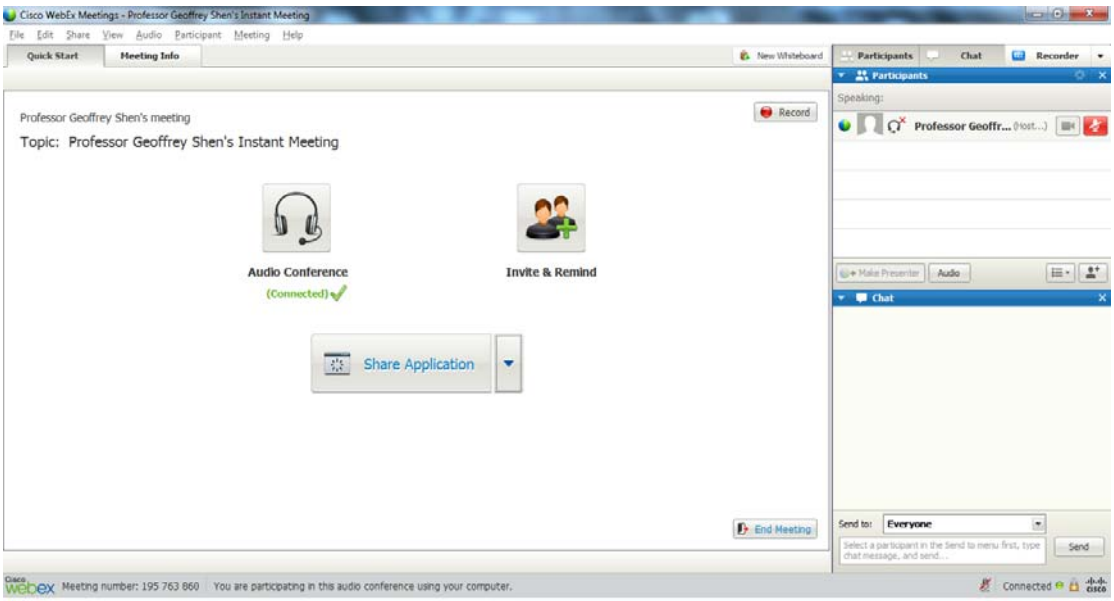

Figure 5.4 Interface of the video-conferencing module

The video-conferencing module is designed as the supporting tool for functional specification in the VM process. Through the application sharing feature of the module, participants can finish all functional work together in the function tool. This tool is adopted from the IVMS, which was developed by Luo et al in 2010, and supports the drawing of a function hierarchy (Luo et al., 2011). During the function analysis phase, the participants identify key functions together and a picture of each function is drawn to show the hierarchy of such functions (Figure 5.5).

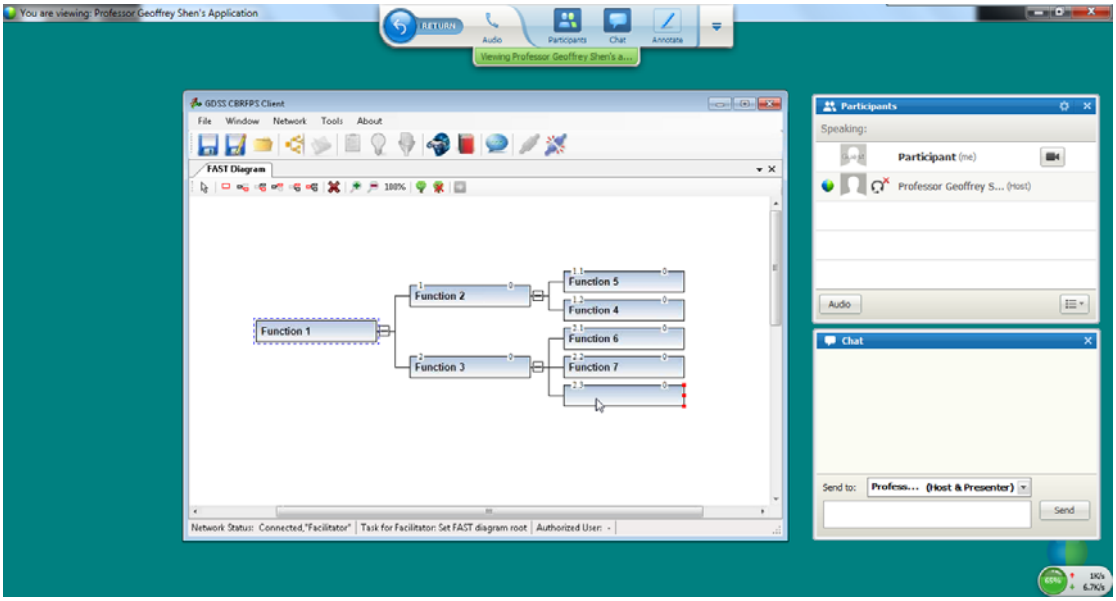

Figure 5.5 Function tool for function analysis

The effectiveness and stability of the video-conferencing module have been validated by experimental workshops that were conducted with a real project (the experimental studies are introduced in Chapter 6). The module can support the implementation of VVM workshops with video access to up to 25 sessions, communication, and information sharing between the participants.

5.2.3.2 Creativity tool

The creativity tool was designed to support the creativity phase in particular. The purpose of the creativity phase is to create several alternatives for selected functions. Figure 5.6 shows the working flow of this phase. First, ideas are generated by the participants in separate groups in the idea generation phase. Second, the generated ideas are clustered together. Finally, the duplicated ideas are eliminated by the VT as a

whole.

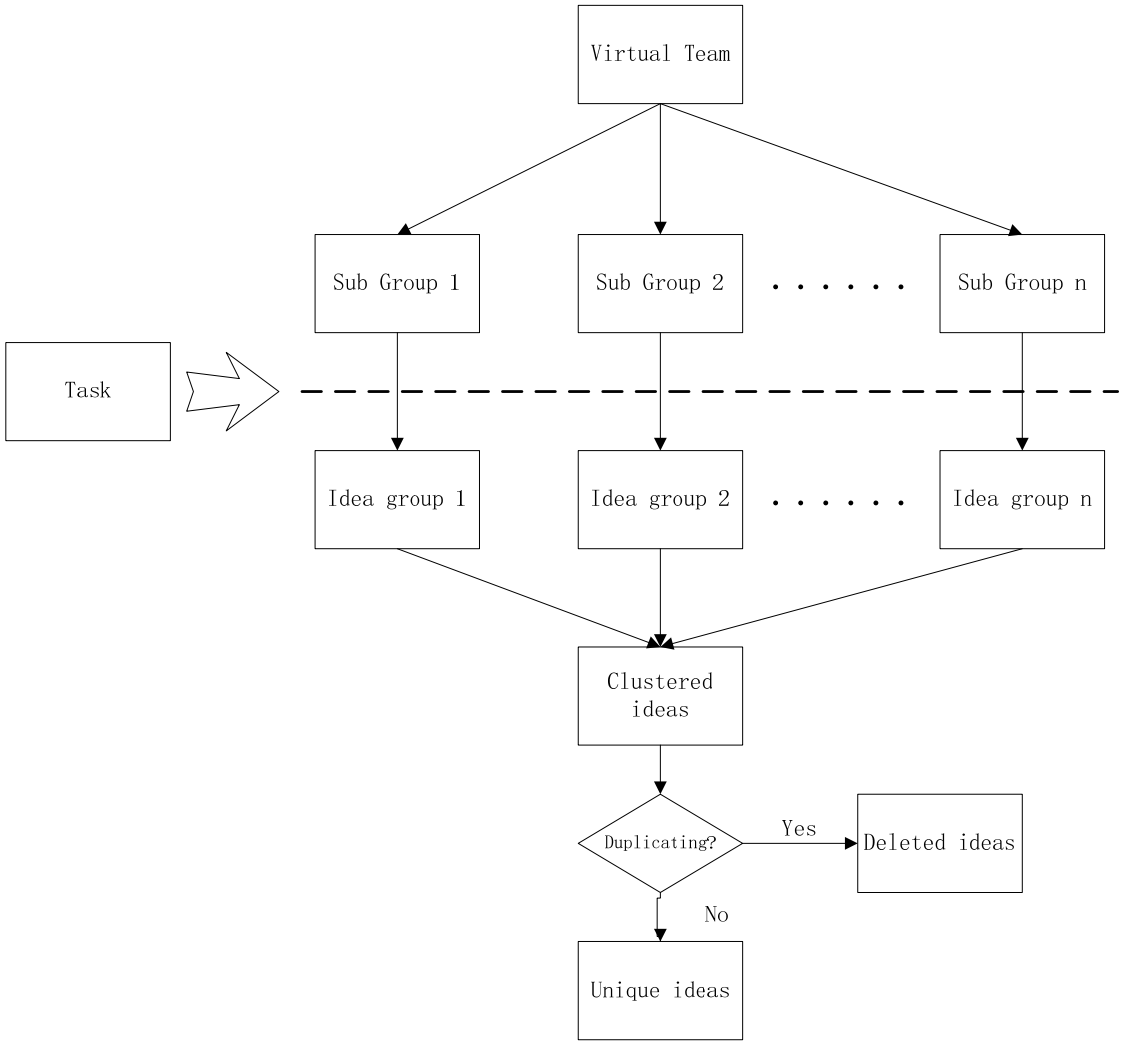

Figure 5.6 Working flow of creativity phase

Five key functions for the development of the creativity tool are indicated in the working flow, namely, (1) publishing tasks, (2) grouping participants, (3) generating ideas in groups, (4) clustering ideas, and (5) consolidating ideas. Because of its

powerful function in group management in collaboration, Adobe Connect 9 was adopted to establish the creativity tool, which provided online discussion and idea generation for VTs in breakout groups. Although Adobe Connect may not be stable in multiple video conferencing, the product is reliable as an online collaboration tool without video and audio features. Particularly, Adobe Connect supports secondary development that allows the customization of functions and interface.

Following the development on Adobe Connect, the creativity tool can support the full process of the creativity phase in accordance with the VVM requirements. Figure 5.7 shows the interface of the creativity tool.

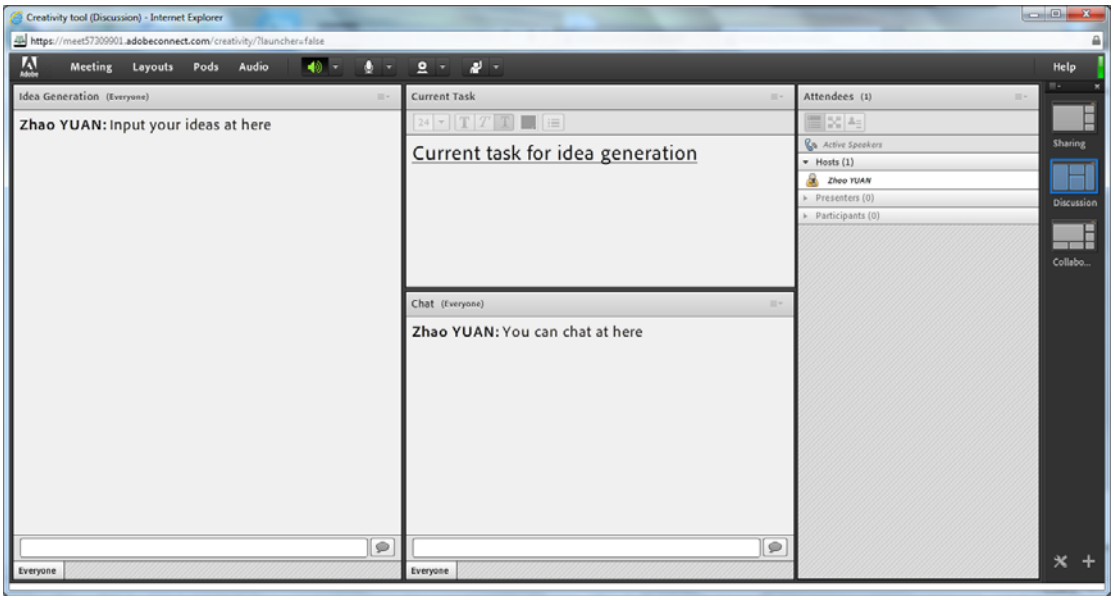

Figure 5.7 Interface of creativity tool

5.2.3.2 Evaluation tool

The evaluation tool provides an independent voting facility for all participants in an equal environment. The tool was developed with the PHP programming language and MySQL database. PHP is an advanced web programming language that was developed based on GCI, but it has higher efficiency than traditional CGI programs. Being open source is one of the most attractive features of PHP. This feature allows the sharing of codes online, and therefore, significantly improves programming efficiency.

To allow access from anywhere, the evaluation tool is designed as a browser/server (B/S) program. Compared to the traditional Client/Server (C/S) program, a B/S program has the strengths of platform compatibility and lower system requirements. In a B/S architecture program, the operation side for users involves a web page that allows the user to connect to the server side through an internet browser from anywhere and on any platform, even on smart mobile devices.

Figure 5.8 shows the three layers of the B/S architecture, which are (1) presentation, (2) function, and (3) data.

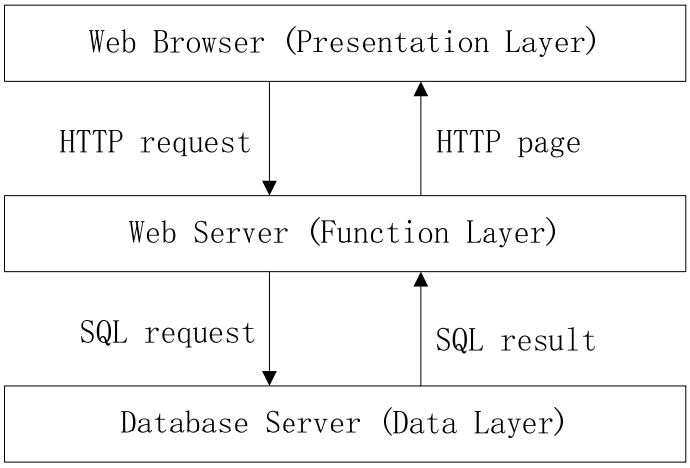

Figure 5.8 B/S technical structure

(Adapted from Shuchun et al., 2000)

Figure 5.9 illustrates the system structure of the evaluation tool. This evaluation tool includes two parts, namely, account and project management. Account management recognizes users through a login mechanism, and the facilitators can create and assign accounts for the participants. The project part includes the main functions of the tool, which were designed to support the function-oriented idea generation process. Figure 5.10 shows the interface of the function management page of the tool, which is divided into four procedures in line with the process of the evaluation phase.

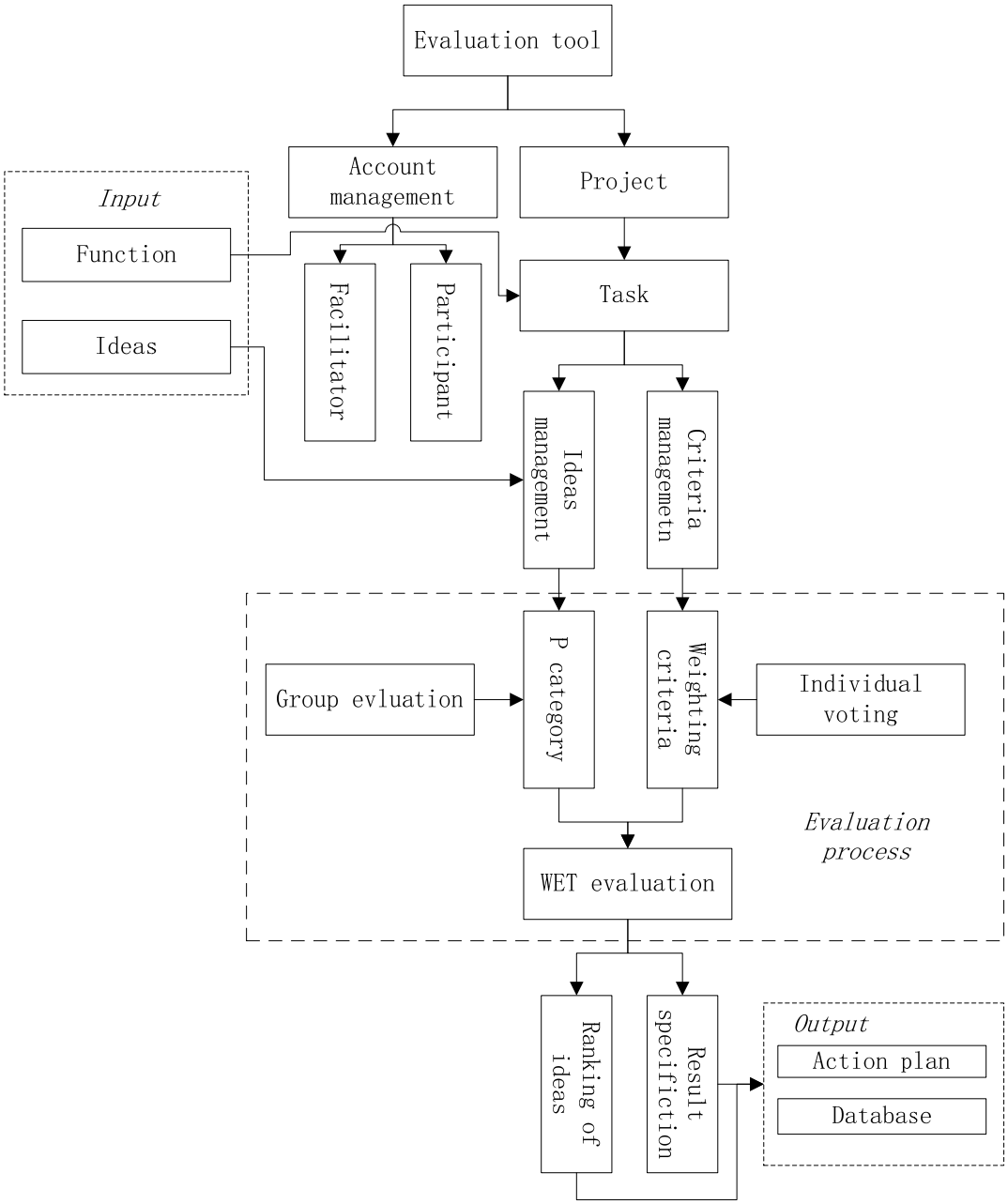

Figure 5.9 System structure of the evaluation tool

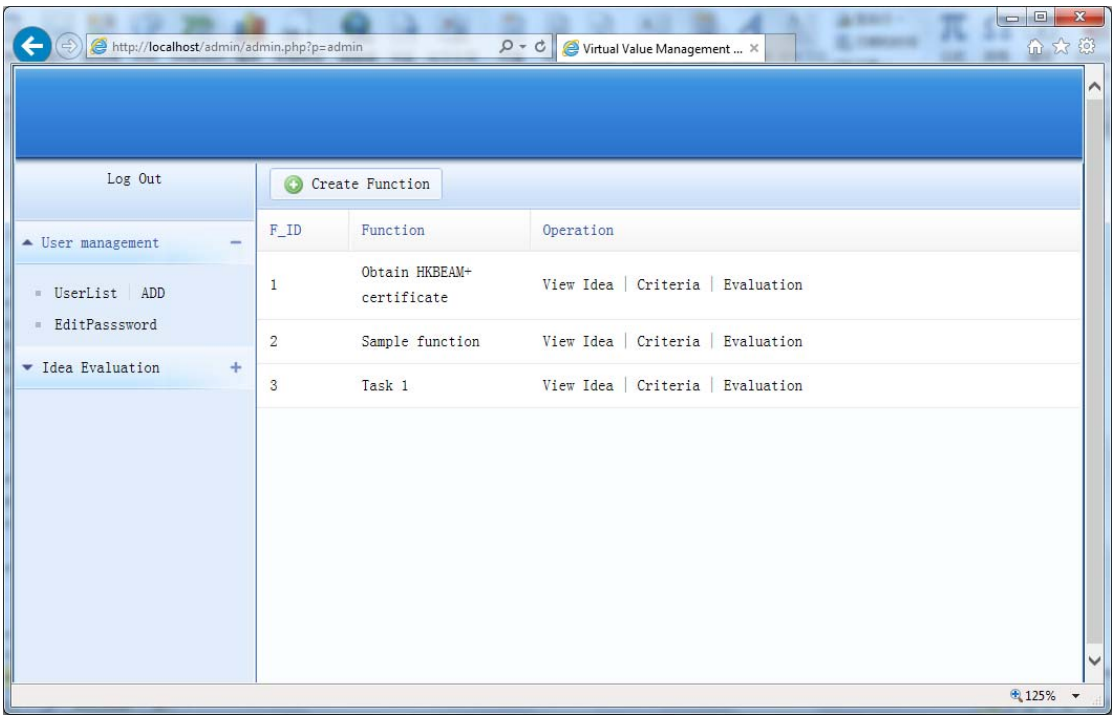

Figure 5.10 Interface of the function management page

Importing data. As one of the key processes of the VM methodology, ideas generated from the creativity phase will be evaluated in the evaluation phase. The functions and corresponding ideas are the data imported into the evaluation tool. These ideas are then automatically exported to RTF files by the creativity tool. Such file can be read by the system, which therefore completes the data input of the evaluation tool.

Evaluating alternatives. In the VM methodology, WET is adopted to evaluate ideas. WET is an evaluation method based on weighted criteria and weighting technique. In the evaluation tool, two steps are performed before applying WET evaluation. First,

imported ideas are reviewed in the idea management module and are classified into P categories, where P1 is “realistically possible,” P2 is “remotely possible,” and P3 is “fantasy” (Luo et al., 2011). Only P1 ideas will be evaluated in the succeeding stage. For each particular function, several criteria will be proposed by the group together to evaluate ideas corresponding to the conditions of the function. Then, the criteria are compared in pairs by the participants individually to produce a weighting of each criterion. The rule of criteria evaluation is that (1) the more important criterion is given a score of 4 and the less important one is given a score of 1, and (2) if the two criteria are equally important to the function, both will gain a score of 2 (Luo, 2010).

Recommended solutions. At the end of the evaluation phase, the high-ranking alternatives will be automatically highlighted by the system, and the facilitator will be able to review the detailed votes for development. The ideas that received high scores and ranked on the top are the recommended alternatives that are most suitable solutions for the particular function. The evaluation details are presented in four perspectives, which are number of participants who voted, average score for each specific criterion, number of votes on specific criterion, and each participant’s votes. These data can help the facilitator manage the evaluation process to achieve objective results.

Exporting results. After the evaluation process, the identified best alternatives are

prepared for the development phase. A detailed action plan will be formulated to explain the questions, “how do we implement these ideas to the project?” and “who is responsible for the specific alternatives?” Therefore, the evaluation results should be stored and exported to files to be used in the next workshop stages. The evaluation tool provides two ways for exporting results. First, a function of “save to file” is provided to export evaluation results into a Word file in detail. Second, all data produced in the evaluation process will be backed up automatically in the database by the system for review and further use.

5.2.4 Modules integration

The objective of developing the VVMS is to create an effective and efficient GDSS to support the implementation of VVM workshops. Considering the time and financial resources allocated to this project, a method of integrating existing resources and independently developed modules with non-existent features was adopted for designing the VVMS. Three modules were developed separately, and were later integrated through process control and data input and output to become a unique system. Figure 5.11 illustrates the system integration of the three modules of VVMS and the modules used in the structured job plan.

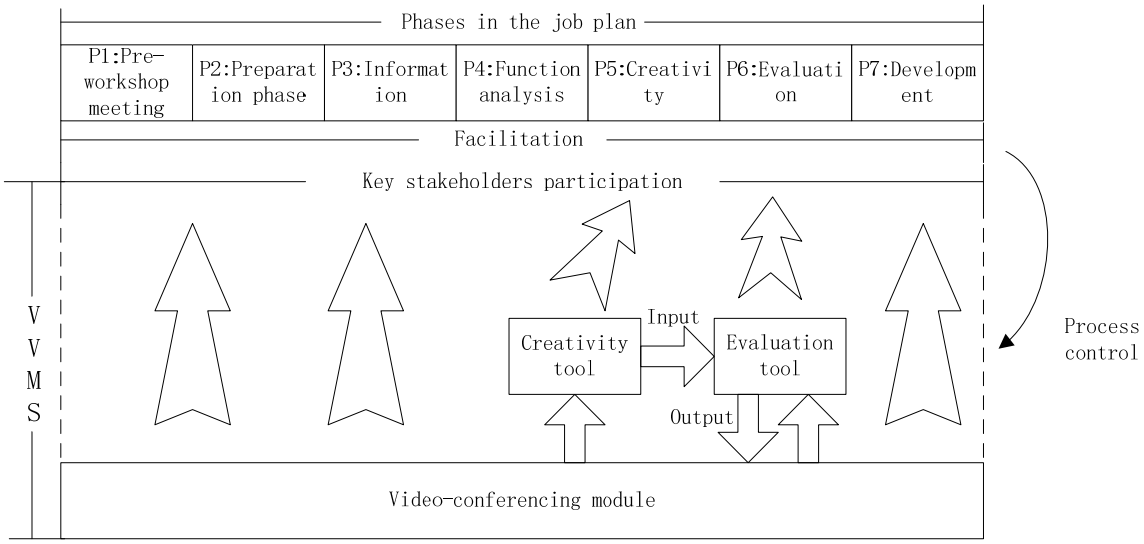

Figure 5.11 System integration of VVMS

The integrated VVMS has two main benefits. First, the system provides a platform for the participants' virtual participation, communication, and collaboration in VVM workshops. Second, the system improves the efficiency of the decision-making process by using computer-based functions.

5.3 System implementation

A traditional GDSS usually consists of a client end and a server end with a database, as shown in Figure 5.12. Every participant has to install a client end application and access the server end to obtain the authority for group activities. Therefore, the user must participate by using the computer in which the client end application is installed. Moreover, the whole system depends on a proprietary communications network,

which is usually a local area network (LAN). Desanctis and Gallupe (1987) defined this kind of system as a level 2 GDSS, and the internet is an optional item for it. In addition, because the system is running on both client and server ends, the system requires a level of system performance from the user's computer.

Compared to the traditional GDSS, the VVMS was developed as a level remote GDSS that can support online communication and collaboration for GDSS implementation in a virtual environment. The internet plays a key role in the VVMS architecture and serves a bridge that connects the user's browser and the remote GDSS server in the B/S architecture, as illustrated in Figure 5.13. The browser is only responsible for "display," whereas all data calculation occurs on the server end. Therefore, users can use the system on any device, such as a low-performance netbook or even an iPad.

As identified in Table 5.3, the VVMS is implemented on Microsoft Windows 7 and MySQL database for the server end. For the browser end, any operation system-based browser with JavaScript, Cookies, and Active X enabled and Adobe Flash Player 11.2+ installed is supported. The facilitator configures the operating environment of the online server for the VVMS ahead of the VVM workshop to make sure that the server is accessible and can respond to browser requests correctly.

When the key stakeholders have been identified, they are invited to be the participants of the VVM workshop. This system allows access to a maximum of 25 users, consisting of a facilitator, a co-facilitator, and 23 participants.

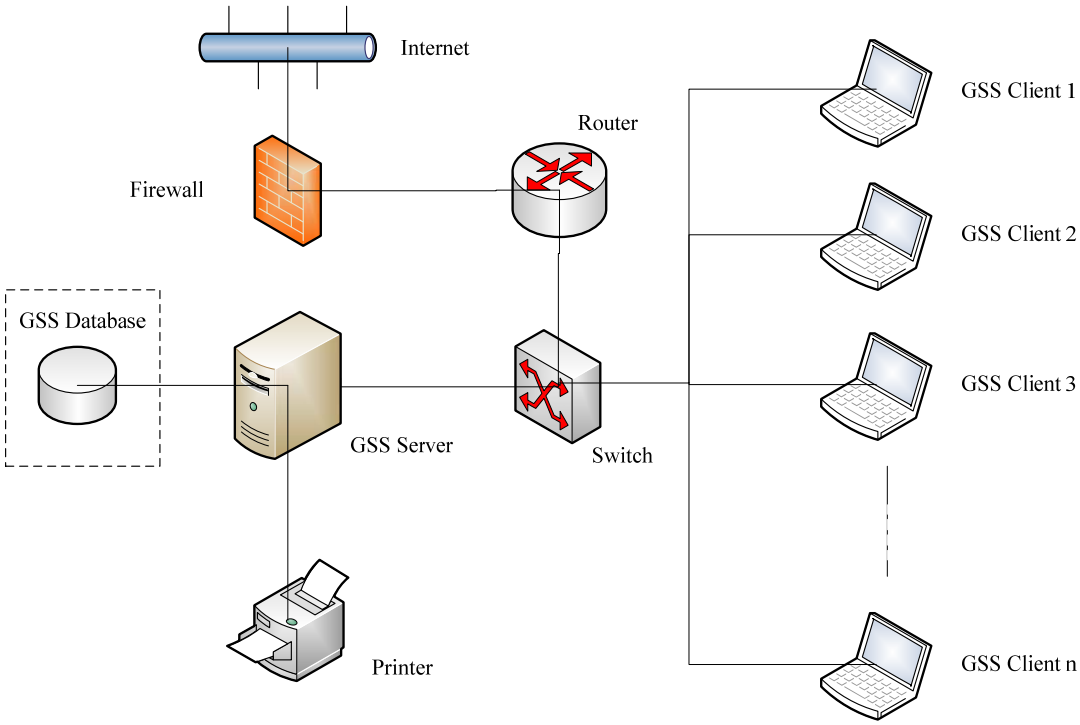

Figure 5.12 Traditional GDSS architecture

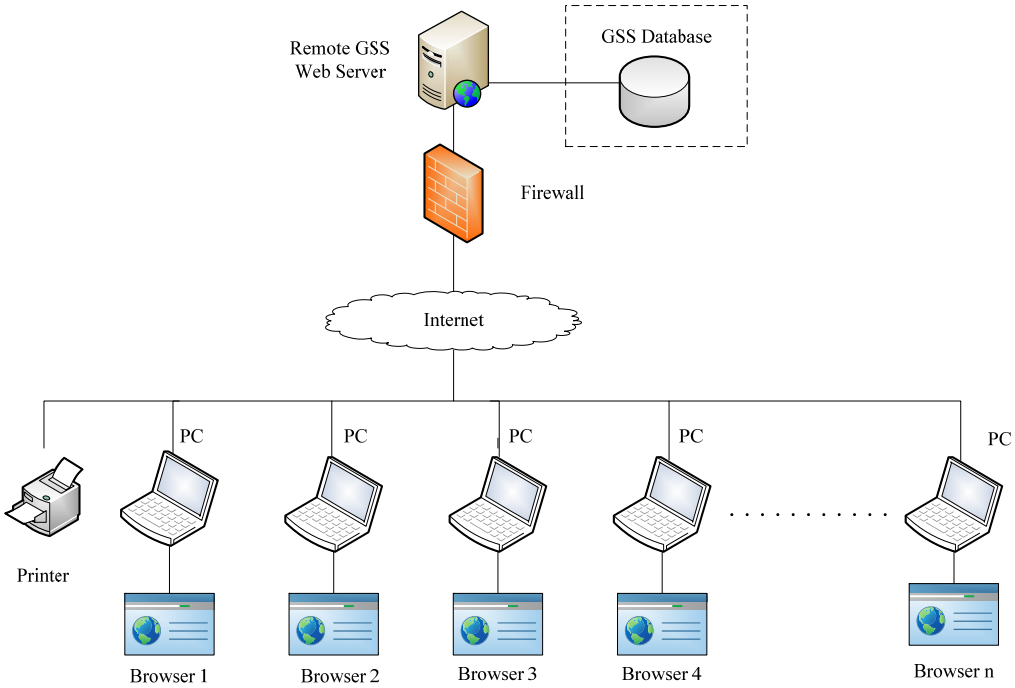

Figure 5.13 Remote GDSS architecture

5.3.1 Pre-workshop meeting

Considering that the participants may not be familiar with the VVM process and the use of VVMS, a pre-workshop meeting is necessary to ensure their participation and workshop performance. This stage has five objectives:

(1) To introduce preliminary knowledge about the VVM workshop process to participants;

(2) To introduce the functions and the operation method of the VVMS;

(3) To test compatibility and stability of the participants' equipment;

(4) To test facilitation; and

(5) To eliminate strangeness between participants.

The pre-workshop meeting is conducted online using the video-conferencing module of the VVMS. To ensure the successful participation of all invited stakeholders, they are required to participate in the pre-workshop meeting. The participants are provided with a quick guide for the VVM workshop, including the equipment requirements, the functions and operation method of the VVMS, technical FAQs, and identification rules in the virtual environment.

5.3.2 Preparation phase

The first step in using the VVMS in the workshop stage is to establish the virtual environment for communication and collaboration. The preparation phase is important because of the high technology dependence of virtual workshops and the resulting technical instability. Generally, participants need half an hour or more to prepare their equipment and to login to the system using their browsers.

Every participant has a unique login ID for identification in the virtual environment. The ID is established by following the format "*Xi(P)_name*," where "*X*" is the group ID, "*i*" is the participant number, and "*P*" means that the participant is a presenter of the stakeholder's representatives. Using this system, the participant can be recognized by other participants and facilitators.

After all participants are successfully connected to the virtual environment, they are

led to learn basic knowledge about the VVM process and the tasks in each phase. Meanwhile, several icebreakers will be conducted to eliminate further the strangeness and to build trust among participants.

5.3.3 Information phase

The objectives of this phase are to clarify the scope and the objectives of the VVM workshop through the presentation of the stakeholders' respective representatives. The video-conferencing module is used to support the presentation and sharing of documents and information during this phase. Figure 5.14 shows a screen snapshot during a presentation by a stakeholder.

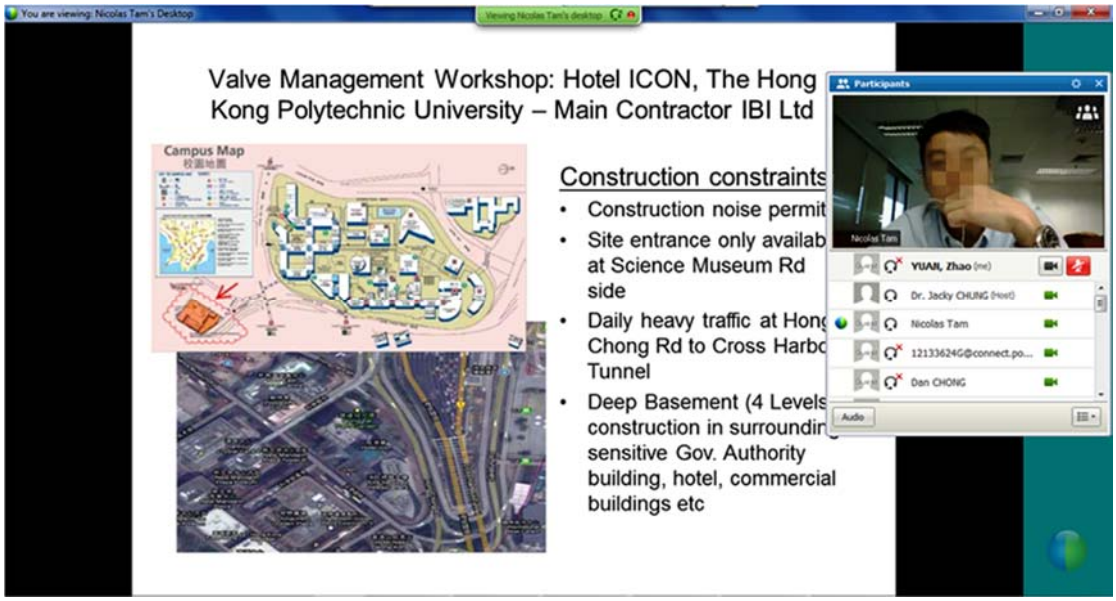

Figure 5.14 Screen snapshot of the presentation phase

In the presentation phase, a presenter is authorized as "Presenter" by the facilitator, and is then given the right to share presentation documents to all participants. Only

one participant can be authorized as the “Presenter” at one time. Therefore, the facilitator can control the presentation process and maintain order through the “Presenter” authority function. Moreover, each participant may speak during the information phase. In a traditional F2F environment, one person speaking will not be a threat to team communication. However, the communication quality will be dramatically influenced by two or more voices speaking at the same time. The best communication rule in virtual environments is to speak one by one, where only one voice is allowed at a time. The module used in this phase has the function that allows voice control for all participants. By using this function, the facilitator can control the voice of one or all participant/s and switch between mute and speech modes.

In addition to the communication function, the VVMS supports multiple types of sharing, such as documents sharing, desktop sharing, and application sharing. The sharing function increases flexibility and enhances the efficiency of information exchange between participants.

5.3.4 Function analysis phase

The FAST diagram is used in function analysis phase (Figure 5.15). In this phase, the facilitator starts to share the tool through the application sharing function of the VVMS, and all participants can see the same screen as the facilitator such that they can go through the same process together.

The FAST diagram is developed in two steps, which are identification and sorting of functions. First, the participants identify key functions for the target project together, and a secretary, who is elected from the participants, collects the identified functions as items in the function tool. Participants can see all functions that have been identified by the whole team on their respective screens.

Following the function identification process, the VT is invited to rank the functions by placing the higher-priority needs at the left side and the lower-priority functions at the right side. By identifying primary and secondary functions, all functions are sorted into a hierarchy that reflects the “How-Why” relationship among functions.

After the two steps, the main functions for the particular project will be selected for the next phase to generate numerous alternatives.

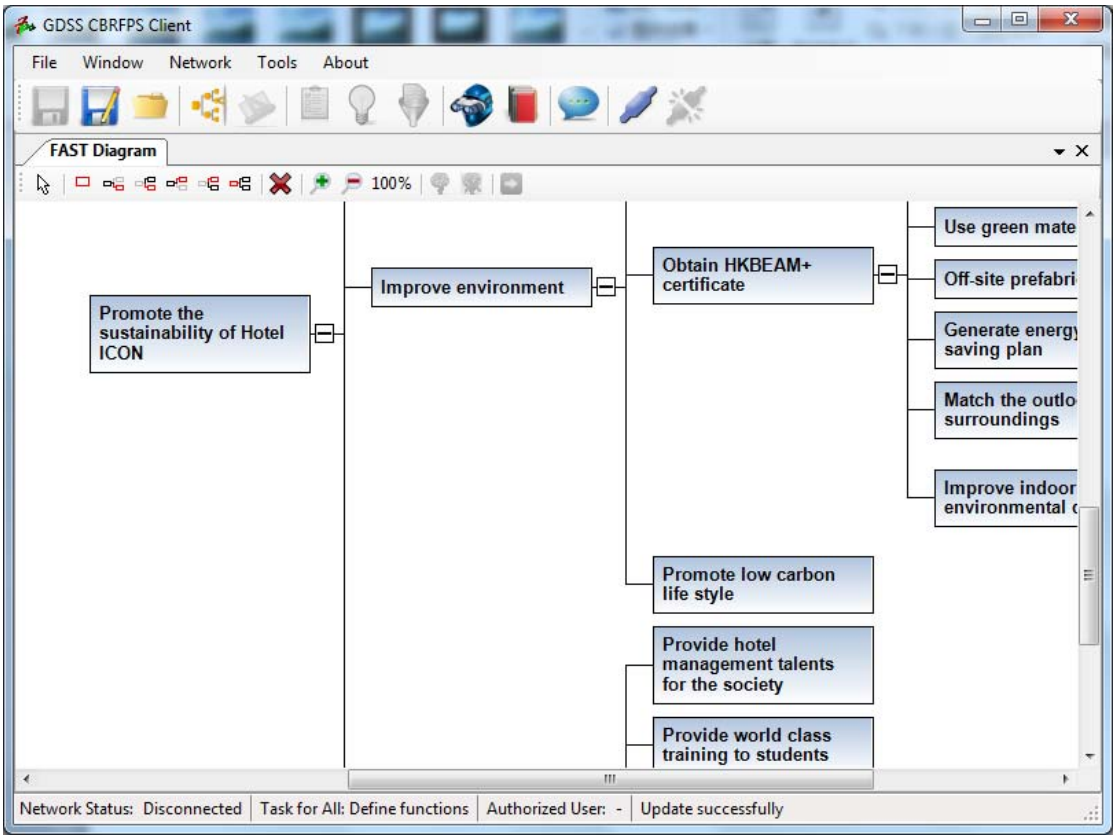

Figure 5.15 Screen snapshot in the function analysis phase

5.3.5 Creativity phase

The creativity phase is the process of producing several alternatives for the functions selected in the previous phase. The creativity tool of the VVMS is used in this phase to support the idea generation process. When the facilitator inputs the function as a task for idea generation, the VM members are requested to switch to the creativity tool and login with their IDs.

Idea generation for a specific task is implemented by the VT members individually. All the members have the equal right to input their ideas, and the process is not

conducted in anonymity. Unlike the same process in F2F conditions, the major concerns in the virtual creativity phase are no longer about the domination of expression in creativity or the reluctance to contribute due to the shame of speaking in public, but about the demonstration of one's participation and the size of one's contribution. Therefore, a brainstorming technique featuring visible IDs of all participants is adopted in the creativity process.

Another important feature of the VVM workshop is the virtual sub-group. The creativity tool has the "break out" function that splits the VT to several sub-groups in different virtual rooms. To improve the efficiency of creativity and to create more alternatives, the sub-groups execute the same tasks separately. During the process, one participant can review other ideas that have been proposed within the same sub-room. However, this action cannot be taken across different groups. The facilitator has the right to join any sub-group as an observer to monitor the progress of the idea generation process.

The generated ideas will then be clustered on an "ideas panel" after one task is finished. Afterwards, the VT continues to work on the next tasks one by one until all the tasks are finished. After the brainstorming process, several ideas are collected. However, some of these ideas are repeated due to the grouped idea generation process. An idea consolidation process is therefore necessary to narrow down the clustered

ideas by eliminating repeated ideas and ambiguous sentences. Therefore, only the truly meaningful alternatives for the specific task remain after the idea consolidation. These unique ideas are then exported to RTF files, which can be reviewed in Microsoft Word and opened by using the evaluation tool for idea evaluation in the next phase. Figure 5.16 illustrates the interface of the creativity tool used in the creativity phase.

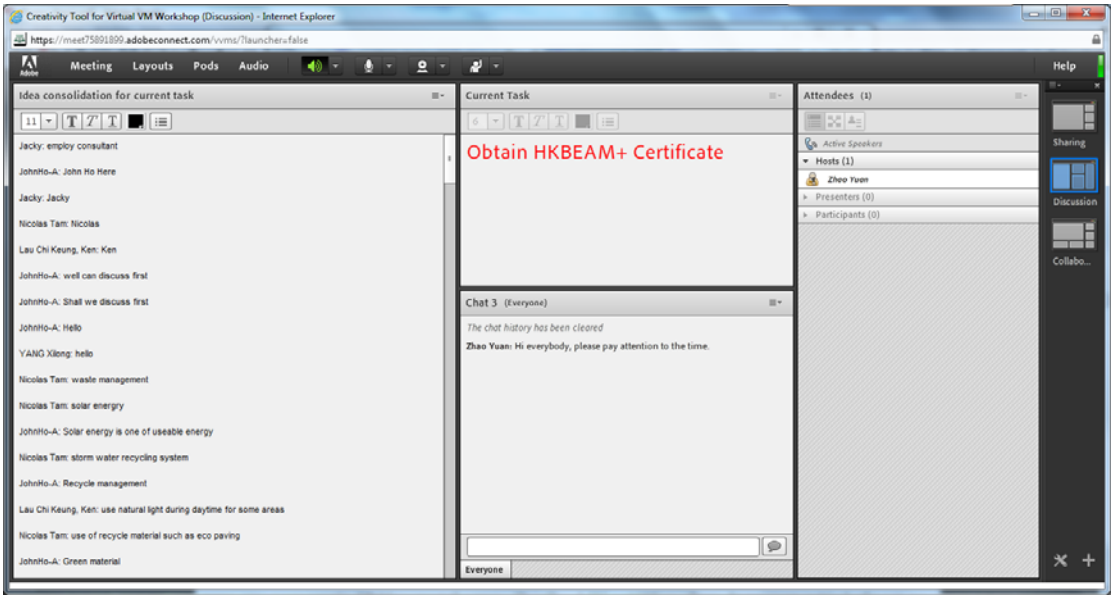

Figure 5.16 Screen snapshot in the creativity phase

5.3.6 Evaluation phase

In the evaluation phase, an evaluation tool is used to support the implementation of the idea evaluation process. The first step is to import ideas generated during the creativity phase from RTF files to the evaluation tool. This action is conducted by the facilitator by using the “import ideas from file” function. Given that the work of

importing ideas and setting tasks takes about five minutes, this procedure is suggested to be done during the tea break following the creativity phase.

After the preparation work, all VT members will be requested to access the evaluation tool. For participants, the function management page is the home page after their login (Figure 5.10). All evaluation functions and main operation buttons are displayed in this page such that the participants can easily access ongoing tasks.

The P category evaluation is implemented on the idea management page, as shown in Figure 5.17. Every participant gives a feasibility score to each idea in an independent page. Therefore, an individual's evaluation process is not visible to others. In this manner, the domination in judgment and pressure from working relationships can be effectively avoided. The same setting is repeated in the criteria and the WET evaluations.

Figure 5.18 shows the interface of criteria management. The facilitator has the right to manage the criteria for a particular task by using the add, edit, and delete functions in the criteria list. When the facilitator confirms the criteria, the criteria management function is opened to all participants for criteria evaluation. Everyone who logs in to the system can review the results of the comparison of importance between each pair of criteria.

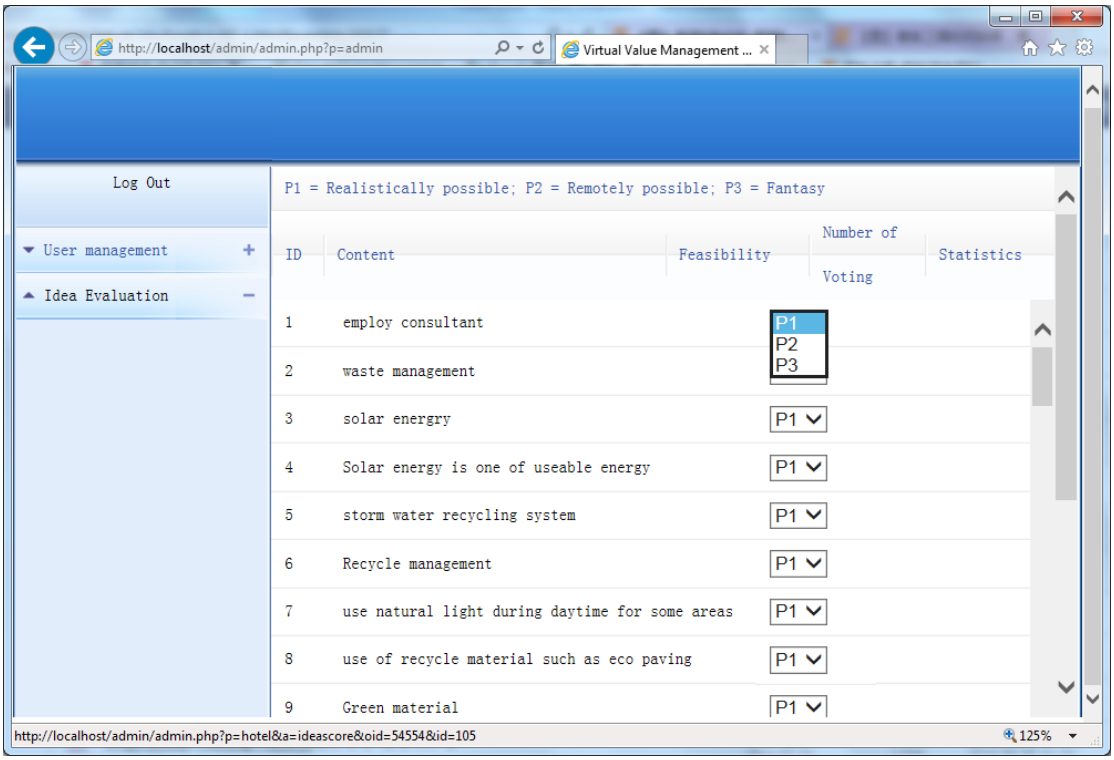

Figure 5.17 Interface of idea management

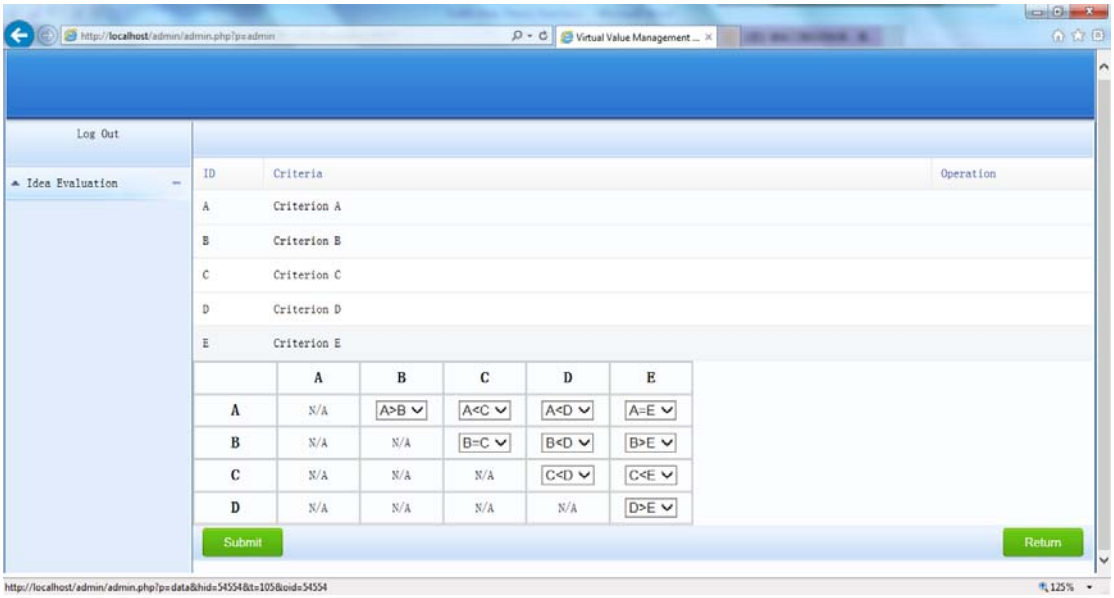

Figure 5.18 Interface of criteria management

To create a user-friendly evaluation environment and to establish a clear voting process, the WET form is split into several sub-pages based on the different criteria, as shown in Figure 5.19. In these sub-pages, the participants have to complete the evaluation with one criterion, and then move to the next according to the manner of evaluation in the traditional method. The final score for an idea is the sum of the scores in the evaluation for each criterion. As Figure 5.20 shows, the recommended solutions are produced by the system automatically after the idea evaluation.

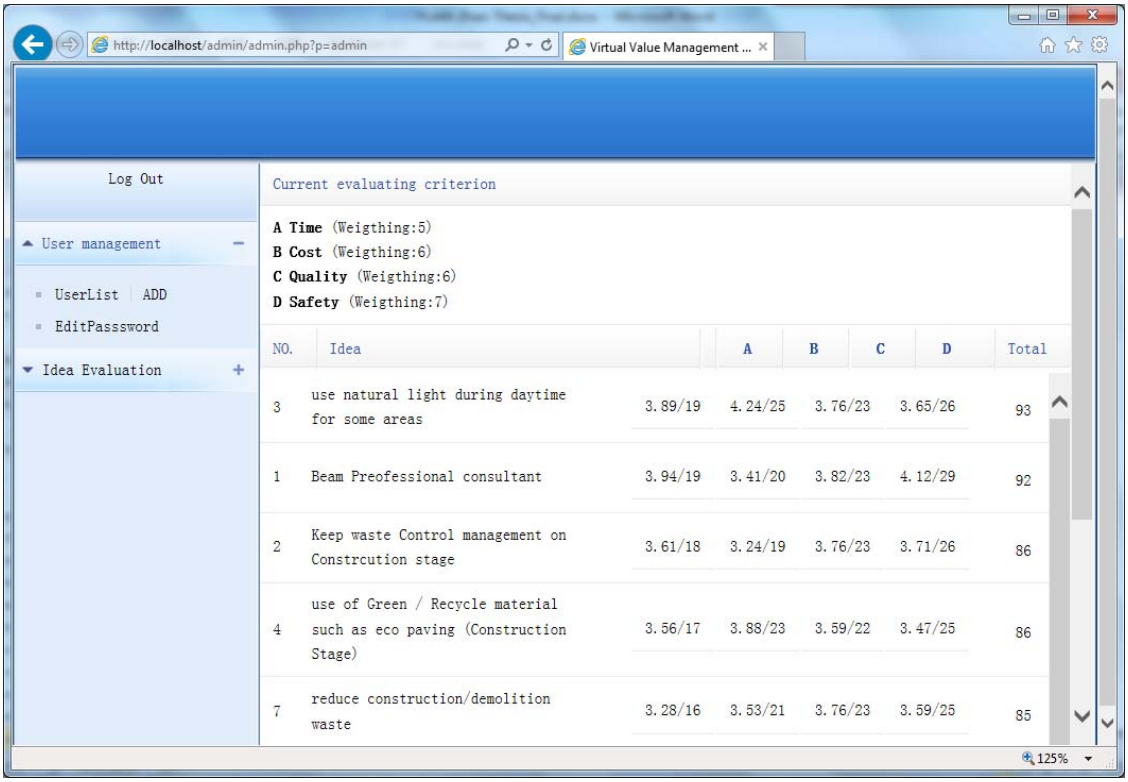

Figure 5.19 Interface of the WET evaluation

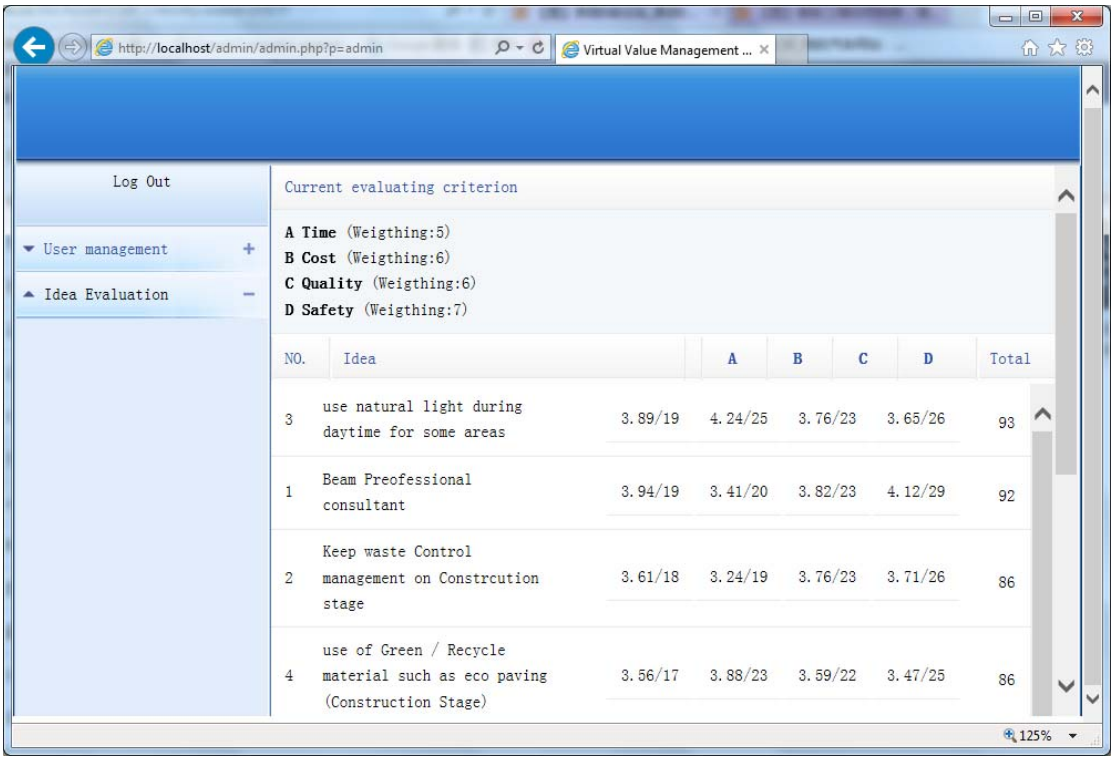

Figure 5.20 Example of the recommended solutions to “Obtain BEAM+ Certificate”

5.3.7 Development phase

The main task of the development phase is to enable the VT to form an agreement and to create an action plan through virtual communication. Therefore, the activities in this phase are conducted by using the video-conferencing module. The action plan is made by the facilitator and team leader using Microsoft Word and Excel and can be broadcasted to all participants through the application sharing function.

5.4 Data management

Data management is an important component of GDSS through which workshop results can be saved, reviewed, and extracted. Most data-oriented GDSSs have very

limited capabilities for transferring data into useful information (Liang, 1985). This limitation occurs because the GDSS data are based on a large data input and have limited data analysis functions. Furthermore, GDSS has poor ability in recording the decision process. Nevertheless, the information used by decision makers to review the results of a VVM workshop is collated in detailed statistics and the recording of the workshop process is completed.

Data management in VVMS is designed in accordance with the above requirements of VVM workshops from the following three aspects:

(1) **Data integrity**. An input check mechanism is provided in the VVMS to ensure the integrity of data. A significant feature in VM workshops is that several ideas can be generated in the creativity phase, which makes the evaluation process complex and lengthy. Therefore, some input may be missing when the participants conduct the evaluation process. The input check mechanism can determine data integrity when the participants submit their evaluation forms, and can give a warning to remind the participants about missing evaluation items to prevent data omission.

(2) **Data analysis and processing**. Data acquired in different phases during the workshop are entered in different forms in the database. A daemon module of the VVMS is responsible for analyzing and processing the data, and generating output

as statistic results. These results will then be stored in new forms for further application. For example, the functions identified in the function analysis phase are saved in a form named “Fnc_P4” with the function ID, relationships, and attributes. Meanwhile, a picture of the function hierarchy will be generated by the system automatically.

(3) **Process recording**. In addition to the quantitative data that can be obtained from workshop outcomes, qualitative data from workshop observation are important. The VVMS provides a process recording function through the video-conferencing module, which can record the whole process of the VVM workshop. Such recording is helpful in reviewing participant performances and possible problems during the workshop.

5.5 Summary

This chapter introduces the VVMS, which was developed to support VVM workshops. The VVMS was built based on B/S system architecture, and an integration method was adopted to consolidate the system with commercial applications and an independently developed module. The development of the modules and the use environment of the system are discussed in this chapter. The module integration is introduced as well.

The implementation of each phase of the VVM workshop is explained in detail, which included the preparation and operation of the system, management of participants, establishment of a dual-anonymity policy, and so on. In addition, the rules and methods for managing workshop data are also introduced.

The VVMS satisfies the requirements in each phase of the VVM workshop and provides an internet-based virtual communication and collaboration environment for VM workshops. Hence, the most highlighted virtual feature is that the system can be used anywhere by using a computer with internet access. This feature frees the participants from the burden of a limited location and extends the workshop to a wider geographical scope.

Chapter 6: Validation of the Proposed Framework

6.1 Introduction

This chapter investigates the extent to which the process and the outcome of the VM study can be affected by the virtual setting of VM workshops through two rounds of experimental VVM workshops. The workshops were conducted as comparative studies of GDSS-supported traditional VM workshops and VVMS-enabled virtual workshops. By recording workshop outcomes and through observations of the workshop process as well as through a questionnaire survey, the results of the aforementioned experiment were used to analyze the effects of using the proposed system on VVM workshops for major construction projects.

6.2 Validation methods

Dennis et al. (1989) reported that laboratory experiments are the most commonly used method of validating GDSS systems. Despite the longstanding debate on the reliability of adopting students as participants in such laboratory experiments, engaging actual construction personnel who have plenty of experience in the construction industry in one or two days of experimental VM workshops is difficult to achieve due to limited time and research funding. Hence, how to evaluate the effect of using the VVMS on VVM workshops while ensuring the reliability of the workshop results was carefully considered in this study.

The effectiveness of recruiting part-time students who have industrial working experiences as participants in experimental VM workshops was reported by Fan and Shen (2011) and Luo et al. (2011). These researchers proved that reasonable settings and methods of selecting qualified part-time students as workshop participants will minimize the negative effects of using students on workshop outcomes. The two experimental workshops were conducted in separate years and each workshop involved part-time postgraduate students in similar backgrounds.

Three major factors in evaluating workshop performance are revealed from literature review: (1) effectiveness is defined by decision quality or the number of generated ideas, (2) efficiency is defined by the time used to complete the task, and (3) participants' satisfaction with the process or outcomes (Dennis and Wixom, 2002). A study of KPIs in VM workshops was conducted by Lin and Shen (2007), in which the three factors are also used as major KPIs to assess VM performance. Following this approach, Fan et al. (2012) conducted a comparative study of traditional and GDSS-supported VM workshops, and recorded the number of ideas generated in the creativity phase and the time to complete tasks through workshop outcomes and observation of the workshop process. The study also used a questionnaire survey to measure the satisfaction of participants. They further reported the number of ideas generated per minute during the creativity phase to evaluate the efficiency of idea generation.

Based on the above studies, the three factors (effectiveness, efficiency, and participants' satisfaction) that reflected outcomes, process, and participants' satisfaction were adopted in the current study to evaluate the performance of the VVMS-enabled VVM workshops. Outcomes can be measured by the quantity of ideas, quality of decisions, and the efficiency of idea generation (Fan et al., 2007), process, and participant satisfaction can be measured through the questionnaire survey and observations. Moreover, a workshop recording by the VVMS, which automatically recorded the entire workshop process, could be used to help the authors achieve the said factors.

6.3 Experimental virtual VM workshop I

The experiment for this study was designed as a one-day VM workshop for a real-life project. Compared with other short term brainstorming sessions in the VM process, a one-day job plan includes several important VM stages, which can result in more convincing outcomes (Shen et al., 2004a). A workshop flow was developed for this study based on a comprehensive job plan that was suitable for adoption in both the GDSS-supported traditional workshop and the VVMS-enabled virtual workshop (see Figure 6.1).

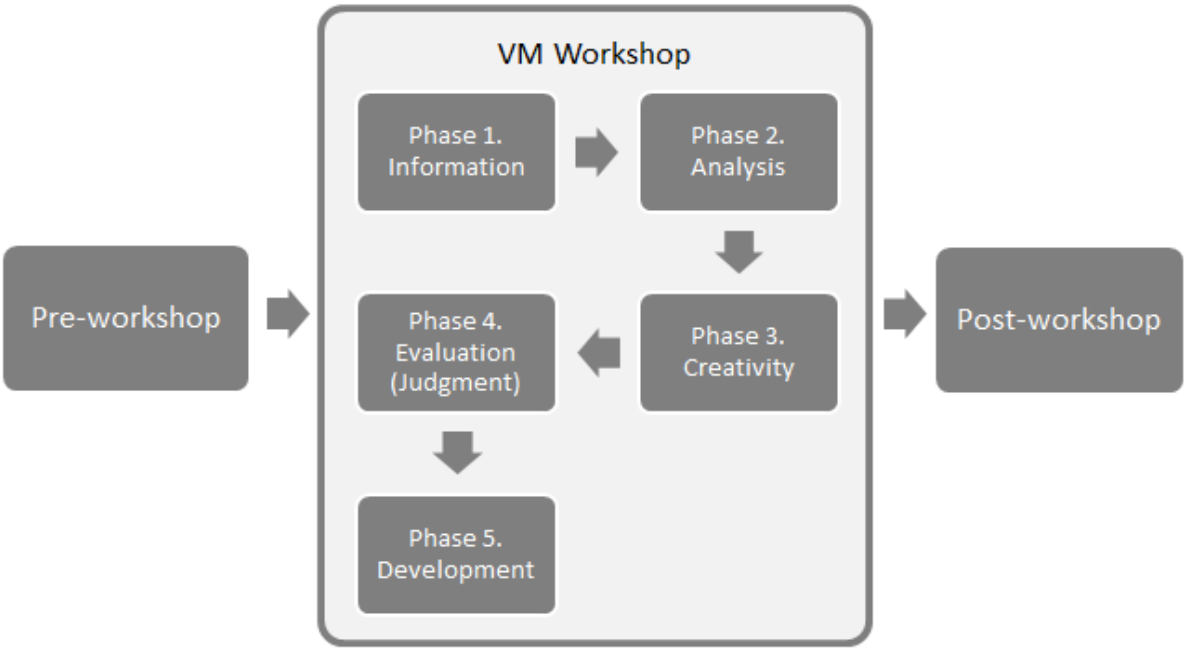

Figure 6.1 VM Workshop Flow for this Research

(Adapted from: Shen and Chung, 2003)

In order to get the comparative data, two scenarios were designed for the different modes of workshop but with the same tasks. There were eight groups with six members in each, making a total of 48 participants who were involved in this experiment. Among the eight groups, groups 1, 2, 3 and 4 participated in Session A, which involved the use of the GDSS in a traditional workshop, and groups 5, 6, 7 and 8 participated in Session B, which involved conducting a virtual workshop by using the VVMS. Session A was arranged in a big meeting room and the members worked together in the same environment consistent with traditional VM methods. In contrast, in order to obtain the maximum possible difference between the two modes of VM workshop, the experimental workshop for Session B was conducted completely

virtually where members were geographically dispersed and had no actual workshop venue. Hence, in Session B, members could not see and communicate with each other directly but did so online by using the VVMS. The grouping arrangement is presented in Table 6.1 below.

Table 6.1 Experiment Grouping Arrangement

Session	Group	Mode	Place
A	1~4	GDSS-supported	An assigned meeting room
B	5~8	VVMS-enabled	Home/Office/Other place with internet access

Four tasks were abstracted from a real-life project: a new teaching building for The Hong Kong Polytechnic University. The four tasks were: 1. Obtain HK-BEAM plus certification; 2. Create identity; 3. Ensure comfort, and 4. Enhance appearance. In this context, a task refers to a function of VM theory. All of the tasks were hot topics in real-life projects and related to the participants' professions. Before the workshop, sufficient background information about the project was provided to all participants. The participants were then asked to generate ideas for the tasks in the workshop. The number of generated ideas during the workshop was recorded for analysis.

Four trained facilitators with professional knowledge and VM workshop experience

were invited to facilitate the workshops. Each Session was assigned two of these facilitators along with a technician to deal with possible technical problems. To avoid variability in facilitation that may impact the results of the study, the same material was used for Session A and Session B. The material was physically distributed to the four groups in Session A and broadcast via the VVMS to the four groups in Session B. Meanwhile, the actions of technician assistants were designed not to affect the performance of participants. Hence the facilitation in Session A and Session B did not differ throughout the experiment.

All the participants involved in the experiment were full-time and part-time Masters level students from the Department of Building and Real Estate at The Hong Kong Polytechnic University. They were all enrolled in a value management subject conducted by the department of BRE. Most of the participants were working in the construction industry or studying within the field. Nearly 64 per cent of them were over 30 years old and had more than one year of relevant working experience, while approximately 74 per cent were middle level professionals or above (see Table 6.2) (Yuan et al., 2013). Although there is a question of validity in using students as workshop participants (Lorge et al., 1958), the constitution of participants was considered appropriate for this specific experiment. The chosen project was a university teaching building under construction and the constitution of stakeholders in this project was to a large extent similar to the experiment participants. Composition

and grouping principles were carefully considered to ensure the credibility of the experiment. For each Session, individuals from different disciplines and professions were enrolled, including clients, consultants, contractors and end users (teachers and students). Participants from the same profession were separated into different groups so that the impact of the participants' background and differences between groups was minimized.

Table 6.2 Background Information of Participants

Statistics of participants' composition			
Senior/Managerial Level	Professional/Middle Level	Technical/Operational Level	Total Number
10	26	12	48

Design of the experiment

Before the workshop started, a short self-introduction section was conducted in both Session A and Session B to provide a degree of familiarity with each of the participants. A name tag which could be seen by everyone was placed in front of each participant in Session A. In Session B, everyone could check the dynamic participants list and the ID under their video avatar to recognize each other. In the first phase of the workshop for both Sessions, the facilitators gave a brief introduction to the workshop and target project and then led all participants through each of the

workshop processes. While the interface of the VVMS was designed to be user-friendly, in order to avoid the potential impact of system unfamiliarity on online participants, Session B participants completed two rounds of online tutorials.

An agenda was provided for the workshop, so that both Sessions used the same time to finish the same tasks. The GDSS supported group tasks in Session A, while the VVMS enabled group tasks in Session B to be accomplished. It is noteworthy that completion of each task on time was one of the factors used to evaluate the performance of the workshops. This evaluation is presented in the discussion section of the research.

Because the workshop was quite long for an experiment, there was a break every two hours. Session A was served refreshments in the meeting room. However, in Session B, catering could not be provided due to the geographic separation of participants. It was therefore suggested to members in Session B that they prepare some refreshment for themselves and have them on hand for the breaks. During the break, all participants were encouraged to communicating with others in their own Session, but communication across Sessions was strictly prohibited.

Session A

Session B

Figure 6.2 Workshops Site of Session A and B

The entire workshop was recorded by VVMS automatically for Session B, but in Session A, a wide-angle video camera was used to record the workshop. All participants were informed of and agreed to the recording arrangement before the workshop started.

6.3.1 Quantitative and qualitative comparison

Both quantitative and qualitative analytical methods were used to assess the outcomes of the GDSS-supported traditional workshop and the VVMS-enabled virtual workshop. The quantitative data collected in this experiment was the ideas put forward in the creativity phase of the workshops using the idea generation method. Idea generation is one of the most important parts in the value management process and is the primary means of achieving value for money. Hence, the quantity and quality of generated ideas in value management workshops is a principal indicator for evaluating the outcomes of a value management workshop. For each specific task,

three detailed factors were established for evaluation: the number of total generated ideas, the number of unique ideas, and the number of unique P1 ideas. P1 is a standard description of the feasibility of ideas. In VM workshops, ideas are sorted into "P Categories", where P1 refers to "Realistically possible", P2 refers to "Remotely possible" and P3 refers to "Fantasy" (Shen and Chung, 2003). This work was done by members of both Session A and Session B in accordance with the facilitators' instructions. Only P1 ideas were transferred to the next phase for evaluation, which involved assessing the quality of ideas generated in the creativity phase of the workshops.

Quantitative data alone is insufficient to describe the outcomes and answer the research questions. Therefore, qualitative data was collected by using in this study via a questionnaire survey. The results of the survey answer two important questions: "whether differences in the participants in the two Sessions will result in significant differences to the outcomes" and "whether participants in both Sessions were satisfied with the performance and process of the VM workshop". The findings are shown and discussed in the following sections.

Because the test of quantitative data in this study was taken to verify differences between the two approaches of VM workshop with the same tasks in idea generation, a paired-samples t-test was used. However, In order to verify the sampling error in the

samples and compare the differences of the qualitative data, an independent-samples t-test was used to test the results acquired in the questionnaire survey to find any significant differences between the GDSS-supported traditional workshop and VVMS-enabled virtual workshop.

6.3.2 Comparing the brainstorming outcomes from the VVMS-enabled virtual workshop and the GDSS-supported traditional workshop

During the creativity phase of the VM workshop, the participants in both Sessions were asked to generate ideas on four independent tasks. The four tasks were designed to be of different difficulty levels and there was no obvious relationship between them. The total time for the creativity phase was one hour, or 15 minutes for each specific task. The results from the two Sessions are presented in Table 6.3, which shows that the number of generated ideas in the VVMS-enabled Session was larger than the number generated in the GDSS-supported Session. This trend of factors is consistent for the four different tasks. Hence, it can be concluded that differences between the selected four tasks will not obviously affect the quality of the experiment's results.

Table 6.3 Number of Generated Ideas in the Creativity Phase

Workshop approach (Sessions)	Total generated ideas		Unique ideas		Unique P1 ideas	
	VVMS-enabled (Session B)	GDSS-supported (Session A)	VVMS-enabled (Session B)	GDSS-supported (Session A)	VVMS-enabled (Session B)	GDSS-supported (Session A)
Task 1	107	71	70	45	59	34
Task 2	66	44	55	41	45	23
Task 3	104	115	85	72	73	49
Task 4	84	98	84	52	46	23

In-depth statistical results of the generated ideas are shown in Table 6.4 below. The table shows the mean number of generated ideas in the VVMS-enabled virtual workshop was slightly larger than that of the GDSS-supported traditional workshop (90.25>82). However, the analysis shows no significant statistical difference between the two VM approaches, p>.05. The number of ideas generated per task, is a factor that reflects the level of activity of participants in the creativity phase. (The reason will be discussed in the discussion section).

The “Unique ideas” factor is also presented in Table 6.3. Participants in the VVMS-enabled virtual workshop generated more unique ideas than groups in the GDSS-supported traditional workshop (73.5>52.5), a difference that is statistically

significant, p<.05.

Table 6.3 also shows the number of unique P1 ideas. The result is similar to the number of unique ideas. The number of P1 ideas obtained by the VVMS-enabled groups was statistically significantly more than that obtained by the GDSS-supported groups (55.75>32.25), p<.001. The statistical result is consistent with direct observations; the significance is at a very low level (<0.0005).

Table 6.4 Statistics of Generated Ideas in the Creativity Phase

Workshop approach (Sessions)	Total generated ideas		Unique ideas		Unique P1 ideas	
	VVMS-enabled (Session B)	GDSS-supported (Session A)	VVMS-enabled (Session B)	GDSS-supported (Session A)	VVMS-enabled (Session B)	GDSS-supported (Session A)
Mean	90.25	82	73.5	52.5	55.75	32.25
Std. deviation	19.12	31.14	14.11	13.77	13.15	12.31
T	0.669		4.601		36.406	
Significance [a]	P=0.551>0.05		p=0.019<0.05		P=0.000[b]<0.05	

[a] Significant at the 0.05 level

[b] The value is smaller than 0.0005 level

6.3.3 Comparing VM processes in the VVMS-enabled virtual workshop and the GDSS-supported traditional workshop

The questionnaire survey was conducted after the workshop stage and the result was collected over three days. Two parts of the questionnaire were used to assess the qualitative outcomes. Part A was "Background of participant" to investigate the participant's industry experience and level of professional knowledge. Part B was "Performance of the VM workshop", which included five specific sections. All questions in this part were designed to evaluate both the VVMS-enabled groups and the GDSS-supported groups. The results of the questionnaire survey were converted to countable data for statistical analysis.

Table 6.5 shows the results of the questions in Part A. Q1 aimed to identify the levels of professional of participants. Q2 was a question about respondents' ages which was related to their working experiences. Because the significances of the two questions are both higher than 0.05 by statistical analysis, the result suggest that there is no significant difference of participants between the VVMS-enabled groups and the GDSS-supported groups. Hence, the participants in the two different Sessions can be regarded as the same.

Table 6.5 Statistics of Questions in Part A

Questions in Part A	Session (Num. of responses)[c]	Mean	Std. deviation	Significance
Q1[a]	A (22)	1.91	0.610	
	B (21)	2.24	0.625	P=0.088>0.05
Q2[b]	A (23)	1.61	0.839	
	B (24)	2.04	0.806	P=0.078>0.05

[a] Q1=What is your current profession in your organisation? 3=Senior/Managerial Level; 2=Professional/Middle Level; 1=Technical/Operational Level

[b] Q2=What is the range of your age? 4=More than 50 years old; 3=41-50 years old; 2=31-40 years old; 1=21-30 years old

[c] Total number of respondents was 48, 24 for each Session.

In Part B, there were 28 detailed questions covering the following 5 major phases of the VM workshop and objectively describing its performance: overall, information phase, function analysis phase, creativity phase, and evaluation phase.

6.3.3.1 Analysis of overall survey results

Table 6.6 Statistics of Questions on Overall Performance

Questions					Agree/Disagree	
Number	Statements in **Overall** section	Session	Mean	Standard deviation	with the given statement	Significance
Q1	I am satisfied with the VM workshop.	A	4.29	0.550	Agree	
		B	3.42	0.717	Neutral	P=0.000[a]<0.05
Q2	My team members are able to actively interact with each other.	A	4.17	0.702	Agree	
		B	3.67	1.049	Agree	P=0.059>0.05
Q3	The workshop processes has accelerate the decision making process.	A	4.13	0.448	Agree	
		B	3.42	1.018	Neutral	P=0.004<0.05
Q4	The workshop environment enhanced the communication and understanding among the stakeholders.	A	4.25	0.532	Agree	
		B	3.46	1.021	Neutral	P=0.002<0.05

Note: 5=Strongly Agree; 4=Agree; 3=Neutral; 2=Disagree; 1=Strongly Disagree

[a] The value is smaller than 0.0005 level

As Table 6.6 shows, the results of Session A were significantly different from that of

Session B in overall satisfaction with the workshop. The participants in Session A agreed on all four statements but only Q2 was agreed with by Session B members. Participants in the VVMS-enabled groups held different opinions in Q1, Q3 and Q4 from members in the GDSS-supported groups. These differences were statistically significant, $p<.05$. However, it is noteworthy that the standard deviations of results of Session B were extremely different from that of Session A. The values were over 1.000 in three questions. This indicates that the respondents were highly variable in their agreement with these statements. The reason for this phenomenon is discussed in detail in the discussion section of the research.

6.3.3.2 Analysis of information phase survey results

Table 6.7 Statistics of Questions on Information Phase

Questions					Agree/Disagree	
Number	Statements in **Information Phase** section	Session	Mean	Standard deviation	with the given statement	Significance
Q5	My team managed to clarify the client objectives.	A	4.17	0.565	Agree	
		B	3.83	0.702	Agree	P=0.076>0.05
Q6	My team managed to identify the project requirements.	A	4.17	0.702	Agree	
		B	3.88	0.680	Agree	P=0.150>0.05
Q7	My team managed to identify the project constraints.	A	4.08	0.584	Agree	
		B	3.58	0.654	Agree	P=0.008<0.05

Q8	My team managed to clarify the project given/assumptions.	A	3.91	0.793	Agree	
		B	3.67	0.702	Agree	P=0.265>0.05
Q9	My team managed to deliberate the sustainable issues regarding the project.	A	4.21	0.658	Agree	
		B	3.67	0.637	Agree	P=0.006<0.05
Q10	My team managed to complete the task on time.	A	3.92	0.654	Agree	
		B	3.50	0.780	Agree	P=0.051>0.05

Note: 5=Strongly Agree; 4=Agree; 3=Neutral; 2=Disagree; 1=Strongly Disagree

The results shown in Table 6.7 are ratings on questions related to the performance of the information phase of the VM workshop. In contrast to the Overall results, participants in both Sessions agreed on all six statements in the information phase of the workshop. While the opinions from the GDSS-supported groups differed slightly from the VVMS-enabled groups on most questions, these differences were not statistically significant. They, however, differed significantly in their agreement with the statements "My team managed to identify the project constraints" and "My team managed to deliberate the sustainable issues regarding the project", even though both groups generally agreed to the statements. This may be because the traditional F2F communication of the GDSS-supported workshop was popular and accepted by most people for exchanging their views unlike the virtual communication required in the VVMS-enabled workshop. Hence, the number of respondents who selected "Strongly

agree" in Session A was larger than those in Session B.

6.3.3.3 Analysis of function analysis phase survey results

Table 6.8 Statistics of Questions on Function Analysis Phase

Questions					Agree/Disagree	
Number	Statements in **Function Analysis Phase** section	Session	Mean	Standard deviation	with the given statement	Significance
Q11	My team managed to identify the primary functions.	A	4.17	0.565	Agree	
		B	3.83	0.702	Agree	P=0.076>0.05
Q12	My team managed to identify the secondary functions.	A	3.96	0.624	Agree	
		B	3.96	0.690	Agree	P=1.000>0.05
Q13	My team managed to develop the FAST diagram.	A	4.25	0.608	Agree	
		B	3.71	0.908	Agree	P=0.019<0.05
Q14	My team managed to prioritise the functions.	A	4.13	0.694	Agree	
		B	3.63	0.770	Agree	P=0.023<0.05
Q15	My team managed to complete the task on time.	A	4.21	0.833	Agree	
		B	3.33	0.963	Neutral	P=0.002<0.05

Note: 5=Strongly Agree; 4=Agree; 3=Neutral; 2=Disagree; 1=Strongly Disagree

Function analysis is one of the most important components of value management theory. Table 6.8 presents the survey results of the function analysis phase of the

workshop. Functions were identified by both Sessions separately. The scores of Q11 and Q12 suggested that the process and results are very similar for both groups in the function identification process. This is shown in the mean ratings for Q12 which shows no difference between the two Sessions for the identification of secondary functions. However, the differences in the ratings from the two Sessions differ significantly on Q13, Q14 and Q15. The Function Analysis System Technique (FAST) is one of the most effective techniques to manage and prioritise functions in VM methodologies. At the same time the two Sessions used different ways to develop the FAST diagram and to prioritise the functions. The GDSS supported the process for each group in Session A. However, the facilitators developed the FAST diagram by asking the ideas of participants in Session B. Therefore, the process was more recognized in groups in Session A, which is reflected in the responses to Q13 and Q14. The only statement that was neither agreed nor disagreed on by Session B members was “My team managed to complete the task on time”. Completion of the task on time is one of the key factors that affected the performance of the workshop. The reason and impact of this issue is discussed in a later section.

6.3.3.4 Analysis of creativity phase survey results

Table 6.9 Statistics of Questions on Creativity Phase

Questions					Agree/Disagree	
Number	Statements in **Creativity Phase** section	Session	Mean	Standard deviation	with the given statement	Significance
Q16	My team managed to generate ideas to achieve the identified functions.	A	4.21	0.658	Agree	
		B	4.00	0.834	Agree	P=0.342>0.05
Q17	My team managed to avoid criticism to other participant ideas.	A	4.00	0.722	Agree	
		B	3.96	0.806	Agree	P=0.851>0.05
Q18	I managed to develop new ideas based on other participant ideas.	A	4.00	0.590	Agree	
		B	4.04	0.908	Agree	P=0.851>0.05
Q19	My team managed to complete the task on time	A	4.13	0.741	Agree	
		B	3.58	0.717	Agree	P=0.013<0.05

Note: 5=Strongly Agree; 4=Agree; 3=Neutral; 2=Disagree; 1=Strongly Disagree

The creativity phase of the workshop referred to ideas generation and classification. Most of the outcomes of the workshop were produced in this phase. Table 6.9 shows the analytical results of qualitative outcomes of this phase. These results in addition to

the quantitative outcomes describe the performance of the creativity phase in the VM workshop. From the table, it can be seen from ratings on Q16 to Q18 that the members were satisfied with the performance of the creativity phase in both Sessions and there was little difference among them, p>.05. Nevertheless, the significantly different rating on Q19 (p=0.013<0.05) suggests that the contentment of participants from the VVMS-enabled groups on the time management of this phase was still less than the GDSS-supported groups, even though both groups slightly agreed with the statement in Q19.

6.3.3.5 Analysis of evaluation phase survey results

Table 6.10 Statistics of Questions on Evaluation Phase

Questions					Agree/Disagree	
Number	Statements in **Evaluation Phase** section	Session	Mean	Standard deviation	with the given statement	Significance
Q20	I am managed to express my ideas/views without any pressure.	A	4.08	0.717	Agree	
		B	4.00	0.834	Agree	P=0.712>0.05
Q21	My team was not dominated by any of the team members.	A	4.08	0.717	Agree	
		B	3.67	0.702	Agree	P=0.048<0.05
Q22	My team managed to develop the evaluation criteria effectively.	A	4.00	0.722	Agree	
		B	3.67	0.702	Agree	P=0.112>0.05
Q23	My team managed to develop the	A	4.04	0.464	Agree	

	evaluation criteria efficiently.	B	3.71	0.690	Agree	P=0.056>0.05
Q24	My team managed to rank the	A	4.04	0.624	Agree	
	idea effectively.	B	3.67	0.761	Agree	P=0.068>0.05
Q25	My team managed to rank the	A	4.00	0.511	Agree	
	idea efficiently.	B	3.67	0.702	Agree	P=0.067>0.05
Q26	My team managed to shortlist the	A	3.79	0.509	Agree	
	ideas for development effectively.	B	3.71	0.751	Agree	P=0.655>0.05
Q27	My team managed to shortlist the	A	3.92	0.504	Agree	
	ideas for development efficiently.	B	3.63	0.647	Agree	P=0.088>0.05
Q28	My team managed to complete	A	3.96	0.751	Agree	
	the task on time.	B	3.42	0.830	Neutral	P=0.022<0.05

Note: 5=Strongly Agree; 4=Agree; 3=Neutral; 2=Disagree; 1=Strongly Disagree

As Table 6.10 shows, both groups agreed to almost all of the statements about the evaluation phase. There was no significant difference in the ratings between the groups for of Q22, Q23 and Q24, Q25. These questions pertained to the processes of developing the evaluation criteria as well as ranking the ideas. This was also true for Q20, Q26 and Q27. In addition, in line with the results of previous sections, completing the task in this phase on time was proven again to be the major problem of the online workshop. While both groups tended to agree to the statement “My team was not dominated by any of the team members”, there was slight difference in the

level of agreement ($p=0.048<0.05$) between the two types of workshop,

The results described above show that while there was no evident difference between the two Sessions on most of the items of the questionnaire, there were differences in the ratings between the VVMS-enabled groups and the GDSS-supported groups.

6.4 Experimental virtual VM workshop II

6.4.1 Workshop design

For validating the proposed framework, an experimental one-day virtual VM workshop was held on 21 April 2013 to consider a new development project, namely the "Hotel ICON" at the briefing stage for The Hong Kong Polytechnic University (PolyU). The tasks of the workshop were:

- To clarify the functional requirements of "Hotel ICON" project.
- To ensure sustainability of the project for PolyU as its future owner.
- To recommend proposals to achieve value for money for "Hotel ICON" project.

Eighteen postgraduate students who were enrolled in a value management subject conducted by the University were involved in this experimental workshop with the VVMS supported. All of them have been trained with VM methodology and were familiar with implementation of traditional VM workshops. According to the results of the questionnaire survey which was conducted after the workshop, nearly two third

of participants had more than five years working experience in construction and relevant industries. The remaining had less than five years' experience. They formed a VT to join the virtual workshop, and each of them acted as a role play representative of one of the stakeholders of this particular project. Some VM researchers emphasised that a multidisciplinary team of participants is a Critical Success Factor (CSF) to VM studies (Dell'Isola 1997; Shen and Liu 2003). Therefore, they were as far as possible assigned roles matching their original occupations. The stakeholder roles involved in the workshop were Client (PolyU Campus Development Office), consultant team (architect, structural engineer, quantity surveyor, building service engineer, contractors, etc.), end user groups (department representative and student representative from SHTM, and operation manager from Hotel ICON) and district councillor.

An experienced VM facilitator was invited to facilitate the virtual VM workshop, and a co-facilitator who is familiar with the VVMS and ICT was also involved to provide technical support to solve possible technical problems.

All participants and facilitators joined the workshop completely in a virtual environment via computers with webcam and microphones. Participants were encouraged to join the workshop at their home or office for a comfortable and relaxed environment. Because most of the participants were first time in attending a virtual

VM workshop, they worried about facing possible ICT problems and need for technician's F2F support. Therefore, four adjacent classrooms in the PolyU campus were provided to them as alternative choice for their convenient and effective participation. Finally, 15 participants came to the campus; the remaining joined the virtual workshop at their own places.

In order to ensure the virtual setting of the workshop, the 15 participants in the campus were assigned randomly into four classrooms. That means only 3 to 4 participants were assigned in the same room. They were placed in the corners of the classroom and the distance between each other was as far as possible to avoid interference in communication. This setting was a realistic simulation of the experience that project stakeholders would encounter when working together at the distributed workshop venues.

For implementation of the workshop, a typical one-day job plan was adopted from Shen et al. (2004b), which consists of five main phases: information phase, function analysis phase, creativity phase, evaluation phase and development phase.

Each phase was allocated time in the agenda based on the activities involved in this phase. However, the actual time spent for each phase deviated from the agenda (Table 6.11) due to unforeseeable technical problems.

Table 6.11 Comparison of allocated time and actual time spent during the workshop

Phase	**Allocated (min)**	**Actual (min)**
Preparation	20	40
Information phase	120	135
Function analysis phase	75	75
Creativity phase	60	60
Evaluation phase	60	40
Development phase	25	25

A pre-workshop meeting was conducted virtually one week before the workshop. All participants joined the meeting and they were taught to use the VVMS and to solve common technical problems.

6.4.2 Implementation of the virtual VM workshop

Setup & test

Different from the traditional F2F VM workshops, the VT members joined the workshop complete virtually from geographically dispersed venues via ICT. Therefore, they needed some time to setup their hardware and software to access the virtual workshop room. During the process, some participants encountered technical problems with internet connections and audio/video settings. For the participants in the campus, the technician helped them to solve problems on site. And for the

participants remotely joining the workshop, the technician provided solutions via phone and emails.

Information phase

The aims of this phase are the confirmation of workshop objectives with participants, and clarification of the assumptions and review of the scope of VM studies for the Hotel ICON project. All the members of VT should ensure that they each fully understand the project background, objectives and constraints. In this phase key stakeholders delivered online presentations to clarify their requirements and responsibilities. To avoid the influence of echoes between participants' devices, the facilitator controlled the participants' audio switch and the sequence of presentation.

Function analysis phase

The VT was managed to identify, prioritise and classify the project's key functions in this phase. An elected secretary from the VT was responsible for recording the functions identified in discussion. Then these functions were put into an organised hierarchy, putting the basic functions on the left hand and secondary functions on the right hand to reflect a "How – Why" logic of project needs (Luo et al., 2011). The function hierarchy diagram was developed by the function tool of VVMS, Figure 6.3 shows an example which was generated in the experimental study.

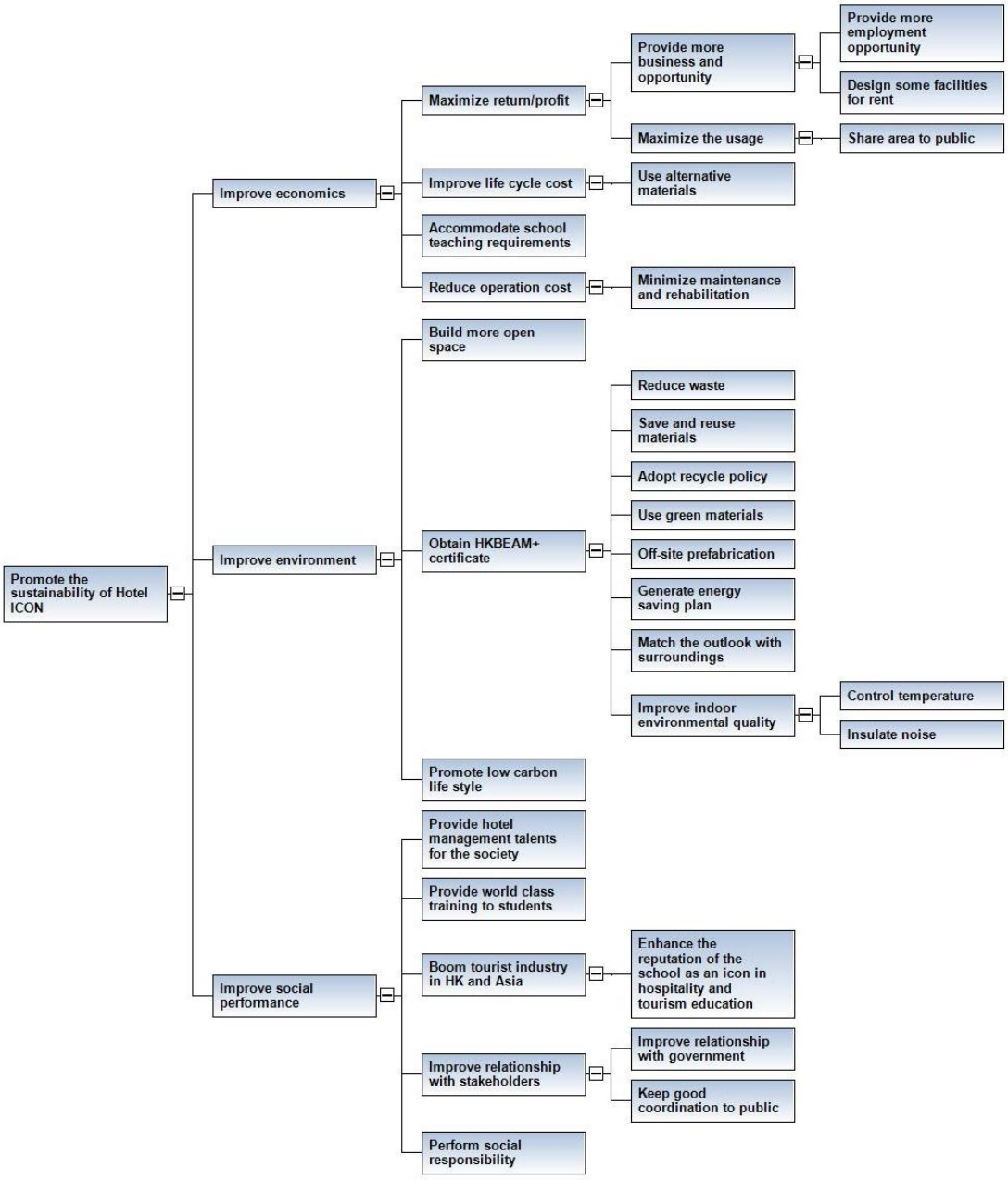

Figure 6.3 Function hierarchy in the virtual VM workshop

Creativity phase

The creativity phase was gone through in a systematic way with the participation of all VT members to compile an abundance of ideas regarding alternative ways to achieve the selected functions (Luo et al., 2011). The VT was divided into four groups

for better communication, and each of them consisting of 4-5 participants (Han et al., 2011). A creativity tool of VVMS was established to support the idea generation process which provided an independent virtual creativity room with idea generation pad and recordable text chat pad for each sub-group. The sub-groups generated ideas separately and then their outcomes were combined together for use in the next phase. During the process, participants within the same group can review ideas generated by each other but the action across groups was prohibited.

Evaluation phase

Two techniques were used in this phase: P category was used to select realistically possible ideas (P1 ideas) which have the value for development; and weighted evaluation technique (WET) was adopted to evaluate P1 ideas with key criteria (Shen and Chung, 2002). The evaluation tool of VVMS was very effective though the whole evaluation phase in collecting and calculating the scores from all participants. An important difference in setting from traditional F2F workshops is that each participant evaluated ideas in an independent page instead of group voting. Therefore, interference between team members and domination in evaluation were no longer considered as factors affecting the outcomes in virtual VM workshops (Shen et al., 2004b; Fan et al., 2008).

Development phase

In the development phase, the selected ideas were investigated in sufficient depth and developed into viable, efficient and cost-effective proposals and recommendations for implementation. Finally, the agreement of each stakeholder's responsibilities in the development of the project was developed by the whole VT together via the virtual discussion supported by the VVMS.

6.4.3 Data Collection method

Data collected in the workshop were in both quantitative and qualitative perspectives. Firstly, the VVMS system can automatically record meeting process and workshop outcomes. Secondly, facilitators objectively recorded and measured VT's participation and major events during the workshop by observation. Thirdly, an elected secretary from the VT recorded team performance during the workshop. After the workshop, the VT submitted a report which as part of the evaluation of their study. Finally, a questionnaire survey was conducted to collect participants' opinions on the workshop performance in each stage, their scores on overall satisfaction of the virtual VM workshop and the satisfaction of using the VVMS in each workshop stages. Most of the questions in the survey were "closed questions" including five levels of agreement. Two open questions were used to collect participants' open suggestions on the workshop implementation and the performance of the VVMS.

6.5 Summary

This chapter introduced two experimental studies conducted to evaluate the effect of using the VVMS on VVM workshops for major construction projects. Each experimental workshop involved a traditional F2F workshop session with a GDSS-supported team and a virtual workshop session with a VVMS-enabled VT. The results were collected in the form of workshop outcomes, observations, and questionnaire survey results, which were in line with the effectiveness, efficiency, and participant satisfaction factors, respectively, as well as the performance of the VVM workshops. The research findings from the workshop results will be discussed in depth in the next chapter.

Chapter 7: Research Findings and Discussion

7.1 Introduction

This chapter presents findings and discussion of this research. The results from the first experimental VVM workshop provided a revolutionary understanding of the implementation of VVM studies. Some major issues that influenced the performance of the VVM workshop are identified and discussed in this chapter. The second experimental workshop was conducted one year later with an improved workshop agenda and an enhanced virtual setting, which were improved based on the results of the first workshop. The results showed a positive conclusion that the use of VVMS can effectively support the implementation of VVM workshops and produce satisfactory outcomes.

7.2 Findings and discussion from the experimental studies

7.2.1 Experimental virtual VM workshop I

7.2.1.1 Questionnaire results

According to the questionnaire results, while the process of idea generation between the two Sessions was similar and both used the GDSS technique, the VVMS-enabled groups generated more unique ideas and high-quality ideas than the GDSS-supported groups in the VM workshops. However, there was also no significant difference in the ratings on Q16-Q18 between the two Sessions. It means that groups in both Sessions were satisfied with their performance in the idea generation while in case there is no

comparison between the two Sessions. While results from the questionnaire survey suggest that participants from the VVMS-enabled groups agreed with most of the statements, there were some significant differences between the two Sessions. The possible reasons for the results are discussed below.

7.2.1.2 The impact from GDSS in the two modes of workshops

There is evidence to suggest that using GDSS in a traditional VM workshop produces better results than when it is not used (Luo et al., 2010; Luo et al., 2011; Fan et al., 2008). The VVMS was developed based on the GDSS with the addition of a functional platform for virtual participation along with other virtual VM features. However, the added virtual features bring unstable variability and so the effect of VVMS cannot be expected to be any better than using GDSS in a traditional VM workshop. There is also no evidence to indicate that the groups in a VVMS-enabled virtual workshop perform and better or worse than groups in a GDSS-supported traditional workshop. Accordingly, an experiment was designed for this study to compare the outcomes of a one-day VVMS-enabled virtual workshop with those of a one-day GDSS-supported traditional workshop.

Participants in the VVMS-enabled workshop reviewed ideas between groups much more easily than the GDSS-supported workshop, and could see more ideas on one screen. This feature allows participants to review each other's' ideas and produce new

high quality ideas during the idea generation phase. The potential effect can help creative thinking and is in line with the result of Q18: “I managed to develop new ideas based on other participant ideas”. Besides, by reviewing others’ ideas, one can, to some extent, avoid generating the same ideas as others. Consistent with the results presented in Table 3, participants in the VVMS-enabled groups generated the same number of total ideas as the members of the GDSS-supported groups for the same four tasks, while also generating fewer repeated ideas, more unique ideas and more P1 ideas.

7.2.1.3 Environment of collaboration

In creativity phase, both Sessions generated ideas with same tasks, same duration and same facilitation. The idea generation functions of GDSS and VVMS are also similar. The only difference of workshop setting between the two Sessions was that whether allow communication between group members in creativity phase.

Some researchers found that in a VM workshop, communication between group members does not increase productivity during brainstorming sessions (Shen et al., 2004b; Shen et al., 2007; Shen and Chung, 2003; Fan et al., 2007; Fan et al., 2008; Fan and Shen, 2011). This counterintuitive finding was explained by Ziegler et al. (2000) who found that communication leads to consistent thinking that decreases the flexibility of idea generation. Therefore, groups in the VVMS-enabled virtual

workshop are expected to be more productive in idea generation than groups in the GDSS-supported traditional workshop.

The workshop results confirmed the speculation: communication not only affected the quantity but also quality of ideas in the creativity phase. Communication can potentially distract participants during the idea generation process. Although everyone had an equal opportunity to express his/her ideas in both Sessions, the VVMS was not particularly conducive to communication among members in Session B. By observation, when a discussion occurred in a GDSS-supported group, an idea may have been developed by multiple individuals together. This means communication is unavoidable happened among group members. In F2F workshops, people performed a trend to work cooperatively in idea generation process, but there is no discernible difference on outcomes between F2F mode workshops and computer-mediated communication mode workshops (Fjermestad, 2004). This suggests that communication among group members is not necessarily favourable to generating more unique ideas. In this research, because the groups in both Sessions used the same timetable in Creativity phase, the GDSS-supported groups have to manage more time to continue their creative thinking from interruption caused by communication than the VVMS-supported groups. This is an evidence of that communication affected productivities compared with non-communication groups in idea generation process.

In addition, pressures of the organizational structure of the GDSS-supported groups may have limited the creation of high quality ideas. The age distribution of participants in this experimental workshop ranged from 30 years old to more than 50 years old. The older participants had richer industrial experience and tended to be higher level professionals than the younger ones (the statistical results are shown in Table 6.4). Based on observations during the Session A workshop, the younger participants performed more actively at the beginning, but when the workshop was in the creativity and evaluation phase, the older participants gradually came to seize the initiative in all four groups. Although relatively junior members of the group appeared to respect the older more experience members, they also appeared to be pressurised by the situation. However, this was less apparent in the VVMS-enabled workshop due to the indirect video connection. Hence the GDSS-supported groups performed worse than the VVMS-enabled groups in generating ideas for the tasks.

7.2.1.4 Anonymity in creativity

The dual anonymity policy of the VVMS during the idea generation phase and the idea evaluation phase is another important reason which leads the results. In the GDSS-supported workshop, idea generation was totally anonymous for every participant and facilitator in order to alleviate concerns over receiving negative assessments from others during the idea evaluation process (Er and Ng, 1995). However, this only happened in the F2F environment (Session A) because those in the

virtual environment (Session B) did not face each other in person, which may have eased such concerns. Also, participation during the idea generation phase for those in Session B may have been stimulated by the participants' option to use their real-name so that they could justify their participation and contribution through group interaction in a virtual environment rather than through F2F meetings. However, in the idea evaluation phase, anonymous evaluation and voting processes effectively avoid negative emotions of participants that may from unfavourable evaluations and comments on ideas. The dual anonymity policy is one of the benefits of a VVMS-enabled virtual workshop.

The success of the VVMS-enabled workshop was dependent on the network environment of participants. However, each participant's network connection speed and stability was out of the workshop organizers' control. Limited by bandwidth, participants had varying degrees of network delay during the online workshops. In this experiment, most participants' average network delay was very slight and did not significantly affect the normal experience of the VVMS-enabled workshop. However, according to observations, some participants' network delay was very serious and unstable during the workshop. In severe cases there was sometimes a pause. In addition, the participants had no control over lags in the network.

7.2.1.5 Impact of network to VVMS-supported workshop

Because every move of a virtual VM workshop is based on the internet, severe delays and pauses will lead to participants not being able to follow the facilitation and temporarily losing their online video rights, audio rights and input rights. They cannot be helped under such circumstances due to the facilitator also relies on the network connection.

This was the most serious problem encountered in Session B, but its impact could not have been predicted before implementation of the VVMS-enabled virtual workshop. Therefore, it was not unexpected that the overall satisfaction of participants with poor network condition would be low. The statistical results of Q1~Q3 were consistent with the analysis, the standard deviations of Session B was extremely different from Session A for Q1~Q3 with values over 1.000 in these three questions.

7.2.1.6 Time arrangement in the workshops

According to the statistical analysis of survey results, the statement "My team managed to complete the task on time" in each phase was the most controversial question in the questionnaire. The problem was from three aspects: agenda design, time control, and network delay. First, because of the experiment requirements, only one agenda was designed for both Sessions. For various reasons the VVMS-enabled groups took longer to finish each phase compared to the GDSS-supported groups and

as Session A members could not wait to synchronize with Session B, the agenda ended up being biased towards the GDSS-supported groups' time table. Second, the facilitators had not received sufficient training in facilitating a virtual VM workshop. Hence, the facilitation of time control did not match the pace of Session B. When a task finished, some VVMS-enabled participants suggested the there was insufficient time to finish the task. In line with the questionnaire results, they felt neutral about the statement in the function analysis and evaluation phases. Third, participants finished the tasks at a different time in Session B because of the time delay. Hence, participants who completed a task earlier had to wait for those who were slower. However, as they could not as easily arrive at a mutual understanding as those in the F2F meetings of the GDSS-supported workshop, the feeling of being delayed was much more apparent amongst groups in the VVMS-enabled virtual workshop.

The above reasons more or less affected the experience of participants in the VVMS-enabled groups, reducing their overall satisfaction with the virtual VM workshop.

7.2.2 Experimental virtual VM workshop II

7.2.2.1 Quantitative results

When major functions of Hotel ICON project are identified, the function hierarchy model is used to display the hierarchical relationship of functions in a tree diagram

which is followed by how-why logic horizontally (as shown in Figure 6.3). This model identifies the higher order functions for selecting right solutions to ensure sustainability for the university as future owner of the completed project.

The basic function of the project is “Promote the sustainability of Hotel ICON” which must be attained to meet the customer’s needs. Supporting functions are any characteristics of a product which are not essential to the customers for the desired application of the item and that do not contribute directly to the accomplishment of a basic function.

The function priority matric (Table 7.1) was constructed from responses gleaned from each function, as to whether that function is technical or strategic and whether it constitutes a need or a want (Kelly et al., 2008).

During the function analysis phase, the VT was managed to analyse the identified functions by creating FAST diagram (Function Analysis System Technique). Various functions such as the basic functions, supporting functions, dependent and independent functions were sorted and listed out for onward analysis. The minor critical path for linking function as well as the unwanted functions was also taken in to account to allow the FAST diagram to be more specific. In consideration of the inexperience in drawing a FAST diagram of the VT and the limited workshop

Table 7.1 Project function priority matrix

Strategic needs	**Technical needs**
• Improve economics • Improve environment • Improve social performance	• Provide more business and opportunity • Maximize the usage • Use alternative materials • Minimize maintenance and rehabilitation • Reduce waste • Save and reuse materials • Adopt recycle policy • Use green materials • Off-site prefabrication • Generate energy saving plan • Match the outlook with surroundings • Improve indoor environmental quality • Enhance the reputation of the school as an icon in hospitality and tourism education • Improve relationship with government • Keep good coordination to public
Strategic wants	**Technical wants**
• Maximize return/profit • Improve life cycle cost • Reduce operation cost • Build more open space • Obtain HKBEAM+ certificate • Promote low carbon life style • Provide hotel management talents for the society • Provide world class training to students • Boom tourist industry in HK and Asia • Improve relationship with stakeholders • Perform social responsibility	• Provide more employment opportunity • Design some facilities for rent • Share area to public • Control temperature • Insulate noise

duration, only a part of the identified functions were developed into FAST diagram during the workshop to suggest how the acquisition of HK BEAM plus certificate would be accomplished by employing functional analysis technique, as shown in Figure 7.1 below:

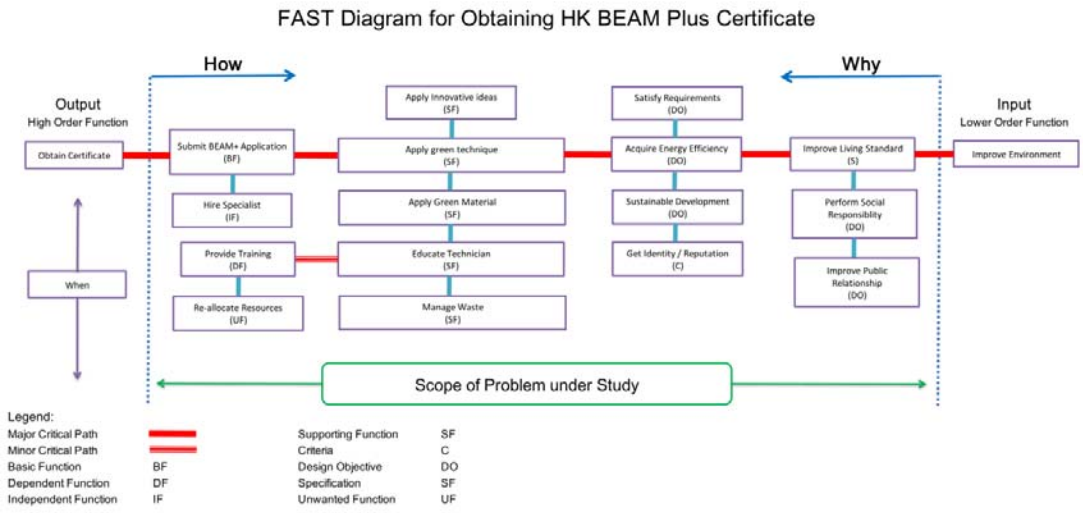

Figure 7.1 FAST diagram for Obtaining HK BEAM plus certificate

During the creativity phase, a brainstorming technique was used in idea generation to obtain more alternative ideas about each selected function to achieve project objectives. However, because of the time limitation, only four basic functions were selected from all identified functions for further investigation. All participants generated ideas in a creativity tool which is a component of the VVMS. This tool provides the support of grouping online idea generation via independent virtual room for each group. During the process, no judgment on the suggested ideas was emphasised by the facilitator to avoid negative impact on productivity of participant

who received critical comments. It is worth noticing that an anonymity policy was often adopted by the traditional GDSS in order to alleviate concerns over receiving negative assessments from others during the idea evaluation process (Er and Ng, 1995). However, the idea generation process is non-anonymity in VVMS supported virtual VM workshop because participants in the virtual environment did not face each other in person, which may have eased such concerns. Another important reason of adopting non-anonymity is that the VT members need to justify their participation and contribution by their identification such as specified ID with real name in the virtual environment.

Table 7.2 Productivity of idea generation

Functions	Duration (min.)	Total ideas	Total unique ideas	No. of P1 ideas
Obtain BEAM+ Certification	4	94	40	25
Create identity	4	123	31	16
Unsure Comfort	4	118	27	13
Enhance Appearance	4	113	25	12

Table 7.2 shows the final outcomes of creativity phase of the virtual VM workshop. The idea generation process produced (94+123+118+113) = 448 ideas of total, and eventually (40+31+27+25) = 123 unique ideas were validly consented by the facilitator and all participants together, and the VT performed a high efficiency in the process of getting consensus. In term of the efficiency rate of the idea generation, the

total generated ideas were compared against the total time spent for idea generation tasks. Because the workshop was overrun in the previous phases, the time left for the creativity phase and evaluation phase was very tight. Only four minutes were managed for generating ideas of each elected function in the workshop. It is found that the VT generated 28 ideas per minute during the idea generation process. Nevertheless, some ideas were inevitably duplicated or similar among the total generated ideas. After the consolidation work was finished by the facilitator and whole team together, the unique ideas were selected. The efficiency rate of unique ideas generation during the creativity phase was 7.68 per minute, which is largely reduced compared with the efficiency rate of total ideas generation. As can be seen, a large number of ideas were duplicated in this process. The problem is caused by the grouping setting, such that the isolation between groups meant that participants could not review others' ideas but focused on their independent performance.

The first step of the evaluation phase was putting all selected unique ideas into P categories, for reflecting the feasibility of the alternative ideas. P1 here refers to "Realistically possible", P2 refers to "Remotely possible" and P3 refers to "Fantasy" (Shen and Chung, 2003). Only P1 ideas will be evaluated by using the WET and to be developed in the action plan. The participants evaluated the feasibility of ideas via the evaluation tool of VVMS. Each of them voted in an independent web page without interference from others to exclude the impact of domination in the evaluation phase

(Fan et al., 2008).

Besides, in order to avoid missing answers in evaluation due to the large number of total voting items, all the items were compulsory and must be answered by the participants in the evaluation process. These answers were checked by the system automatically after submission, same setting adopting in the following evaluation steps.

The next step was the weighting for criteria. All participants managed to identify main criteria for selected functions (Table 7.3); however, taking into account the time consumed, only four criteria were marked for WET evaluation, which were time, cost, quality and safety.

Table 7.3 Identified evaluation criteria during the workshop

Item	Criteria
A	Time
B	Cost
C	Environmental
D	Safety
E	Maintain cost
F	Quality
G	Performance
H	Buildability

The final step of this phase was the WET evaluation. Based on the data from the

previous two steps, P1 ideas for each selected function were evaluated with a criterion. The process was repeated several times until all criteria were evaluated, and a total score for each P1 idea was calculated by the system automatically. All the alternative ideas were sorted in descending order by scoring in the system for easily searching the results. Figure 7.2 shows the evaluation results for the function of "Obtain BEAM+ Certification". Based on the results, the No. 3 idea of "Use natural light during daytime for some areas" received the highest score of 93 among all alternative ideas for the specific function, and No. 1 idea of "BEAM professional consultant" has also been recognised as one of the best solutions. As the results show, these top ranking ideas will be proposed in the workshop report as the high priority alternatives.

NO.	Idea		A	B	C	D	Total
3	use natural light during daytime for some areas	3.89/19	4.24/25	3.76/23	3.65/26		93
1	Beam Preofessional consultant	3.94/19	3.41/20	3.82/23	4.12/29		92
2	Keep waste Control management on Constrcution stage	3.61/18	3.24/19	3.76/23	3.71/26		86
4	use of Green / Recycle material such as eco paving (Construction Stage)	3.56/17	3.88/23	3.59/22	3.47/25		86

Figure 7.2 Evaluation results for the function of "Obtain BEAM+ Certification"

7.2.2.2 Qualitative results

Besides the quantitative outcomes and facilitator's observation, a questionnaire survey was conducted to collect participants' opinions on the virtual VM workshop implementation and performance of the VVMS during the workshop. The questionnaire has three parts: the first part is the background of respondents, including their qualifications, working experiences and the type of organisations in which they were employed; the second part is performance of the virtual VM workshop, including the overall performance and detailed statements in each phase; and the third part is performance of the VVMS used in the virtual VM workshop.

The total number of questionnaire received was 18. Despite the number being relatively small, all participants involved in the workshop filled out the questionnaire. In addition, these participants represented different disciplines in the workshop, such that the maximum number simulated the scenario of multi-stakeholders' participation in virtual VM workshop for real projects. Indeed, additional participants joining the virtual workshop will dramatically increase the difficulty in managing the VT under the virtual environment in current technology circumstance, in turn affecting the smooth implementation of the workshop and the final outcomes. Therefore, with the consideration of the participants' professional backgrounds, the results of questionnaire can be regarded as objective and effective.

In general, most participants were satisfied with the process and implementation of the virtual VM workshop. Table 7.4 shows five statements related to the overall performance of the workshop, all of them achieved the mean above 3.50 on a scale of 1 to 5. The pre-workshop are recognised by participants as an important procedure for preparing the virtual VM workshop. During the pre-workshop and introduction phase, sufficient background information and clear clients' requirement were delivered to participants that helped them towards a better understanding of workshop objectives. The effectiveness of communication between VT members were also confirmed by participants, VVMS successfully supported participation of the whole VT and accelerated the decision making process.

Table 7.4 Satisfaction to the overall workshop processes and implementation

Statements	Mean	Standard Deviation	Agree/Disagree with the given statement
Clear objectives of the VM workshop are provided.	4.33	0.471	Agree
My team members are able to actively interact with each other.	4.22	0.418	Agree
The workshop processes has accelerate the decision making process.	4.00	0.353	Agree
The used of VVMS supporting the communication and understanding among stakeholders.	3.67	0.353	Agree

Pre-workshop (briefing session) helped me to better participate in the VM workshop.	4.28	0.448	Agree

Table 7.5 listed six statements regarding to the effect of applying VVMS in virtual VM workshop. The participants positively appraised the features and main functions of VVMS, especially the online collaboration feature and online evaluation function. Their responses show that VVMS is an effective and efficient tool which can enable the virtual setting of VM workshops where participants are geographically dispersed.

Table 7.5 Satisfaction to the use of the VVMS in the workshop

Statements	Mean	Standard Deviation	Agree/Disagree with the given statement
I am satisfied with the performance of the VVMS.	4.11	0.340	Agree
I am satisfied with the features of the VVMS.	4.17	0.265	Agree
I managed to follow the instruction given by the facilitators in using VVMS in each phase of the workshop.	4.50	0.382	Agree
The VVMS successfully support the virtual VM workshop	4.00	0.118	Agree
The interface of VVMS is	4.17	0.735	Agree

user-friendly			
The VVMS provides a platform for efficient communication among stakeholders	4.11	0.340	Agree

Listed below are some of the representative feedbacks abstracted from the open questions in the questionnaire. These participants' opinions provide a basis for further improvement of both the framework of virtual VM workshop and the VVMS.

"By using the VVMS, I can communicate with my team mates across long distance." 12900681R

"During the VM workshop, I share my opinion freely with all participants, which encouraged creative thinking in idea generation and stimulated the productivity of the workshop." 12124615G

"The evaluation tool of VVMS is the feature I like most; it is much cost and time – effective." 11902013R

"Multi-points video conferencing helps implementation of the virtual VM workshop; it creates an atmosphere similar to F2F communication." 12010705G

“In the virtual VM workshop, we can choose everywhere we like for participation.” 12086813G

“The VVMS is good, we could avoid the many people only in one option because of the opinion told by the first people and it is convenient for people do not in HK.” 12133624G

7.3 Summary

This chapter summarized the research findings from the two experimental studies. Through the experimental workshops, the framework for VVM workshops was validated. The framework was found to aid the achievement of expected performance and outcomes. The quantitative and qualitative outcomes were collected through workshop records, observation, and a questionnaire survey. The findings indicated that participants in a VVMS-enabled virtual workshop can generate a larger quantity of unique and high-quality ideas than those in a GDSS-supported traditional workshop. In addition, the VVMS used for the virtual workshops received favorable comments from the participants. The discussion atmosphere was harmonious and positive, and creative thinking among the participants was stimulated by the system. However, the results indicated that the groups in virtual workshops could not finish tasks on time because managing each phase in virtual workshops required more time than traditional F2F workshops.

Chapter 8: Conclusions

8.1 Introduction

This chapter reviews the research aim and objectives. The conclusions of the entire research are then presented in terms of the three research objectives, and followed by a presentation of the study's contribution to knowledge and the description of research limitations. Finally, some suggestions are provided to improve further studies on the implementation of VVM studies.

8.2 Review of research objectives

The overall aim of this research is to improve the effectiveness and efficiency of VVM workshops with GDSS, which combines computing, communication, and decision support technologies to facilitate workshop participants in their search for value for money. The benefits of implementing VM in construction projects include, but are not limited to decreasing costs, increasing profits, improving performance, and improving quality. The complex nature of construction projects requires appropriate recognition and the management of multiple stakeholders to achieve the best outcome for the projects and to accommodate individual stakeholder values. Therefore, the effect of VM application in the construction industry is a significant concern. However, large-scale construction projects, particularly major infrastructure projects, can achieve better cost reduction rates by using VM than small-scale projects. Hence, VM studies have become a mandatory requirement for major construction projects in

some countries or local governments. For instance, the Hong Kong government requires construction projects with estimated costs exceeding 200 million HKD to conduct VM studies (LEUNG, 2009; WBTC, 2002).

Studies have proven the ability of GDSS to facilitate the interaction of workshop participants in the same location (Fan, 2009; Luo et al., 2011). However, efficiently and effectively managing multiple stakeholders who are geographically dispersed in a virtual workshop environment is both challenging and critical. The viability of using GDSS in such a situation needs to be investigated in greater depth, and a systematic and comprehensive experimental study on the effects of using GDSS on VVM workshops for major construction projects is deemed essential.

The above statements spawned the research question and generated the research objectives for this thesis. The research objectives for the current study are as follows:

1 To identify the essential features and functions required by a purposely-designed GDSS to support VVM workshops for major construction projects;

2 To validate and verify the extent to which a purposely-designed GDSS can support the completion of various tasks in a virtual workshop environment; and

3 To investigate and evaluate the extent to which the use of a purposely-designed GDSS affects the processes and outcomes of VVM workshops.

As mentioned in Chapter 1, five specific tasks were proposed to achieve the research objectives. These research tasks and how they have been completed are presented as follows:

(1) Establishment of a theoretical foundation for the investigation;

Through comprehensive literature review in Chapter 2 and 3, the features of VM and GDSS were identified and the proposed VVM workshop was introduced. Meanwhile, the review of current situation of implementing VM workshops in major construction projects revealed the need and importance of adopting VVM workshops in such projects.

(2) Identification of essential functions of GDSS for VVM workshops;

In chapter 3, the review of GDSS and virtual settings in VVM workshops were introduced. The research examined the development, taxonomy and components of GDSS, and investigated the application of GDSS in previous VM studies, thereby identified the general requirements of GDSS in VVM workshops and investigated the potential benefits that GDSS can provide in the VVM processes.

(3) Development of a prototype GDSS to support VVM workshops;

Through the research on Chapter 3 and 4, a conceptual framework which provides theoretical foundation to VVM study was established in line with the identified features of GDSS and virtual settings. Based on the framework, a web-based remote GDSS which is named the VVMS was developed as a tool to investigate the effect of using GDSS on VVM workshops for major construction projects (Chapter 5).

(4) Validation and verification of the proposed GDSS in VVM workshops; and

According to the outcomes of the experimental studies, the VVMS can successfully and effectively support the implementation of VVM workshops with satisfactory performance. The system validation was introduced in Chapter 6. It was concluded that:

- *The VVMS is a level 3 GDSS which enhanced the communication features in virtual setting of decision making;*
- *The use of VVMS achieved better performance in decision making process of VVM workshops;*
- *Pre-workshop meetings are necessary in VVM workshops for training the participants;*
- *Particular dual-anonymity policies are adopted in the system for different phases of VVM workshops;*
- *Specific facilitation skills for virtual settings are required in facilitating virtual*

teams;

- *The group size of virtual team in VVM studies is appropriately supported by the VVMS.*

(5) Evaluation of the effect of using GDSS on VVM workshops for major construction projects.

In order to achieve the objective, two rounds of comparative experimental studies between VVMS-enabled VVM workshops and GDSS-supported traditional VM workshops were employed during this study. The workshop outcomes, research findings and in-depth discussions were presented in Chapter 7.

8.3 Summary of findings

8.3.1 Conclusions from literature review and the conceptual framework

The literature review reveals the major features of the construction industry, such as large-scale investment, long-term project cycle, high complexity of management, uniqueness, and vulnerability to the risk of project delays and budget overruns, thereby reducing the value of the project. The use of VM studies in major construction projects presents the potential benefits to overcome these problems by clarifying major stakeholders' needs, and to gain a better understanding among them in the briefing stage in a construction project. However, the problem in implementing VM in major construction projects is also obvious as indicated in the dispersed nature

of participants due to long-term workshop durations. Therefore, there is an increasing need to conduct VM workshops virtually with geographically dispersed participants.

Although previous studies have proven the effectiveness of using GDSS in traditional VM workshops (i.e. Fan and Shen, 2011; Luo et al., 2011; Fan et al., 2012), the efficiency and effectiveness of managing multiple stakeholders, who are geographically dispersed, in a virtual workshop environment have not been tested. Hence, the present study investigated whether the GDSS can reduce process losses and increase process gain in a virtual workshop environment while ensuring active participation and quality of decision making.

The review of GDSS provided a comprehensive understanding of GDSS composition, taxonomy, and GDSS features. Furthermore, the overview of virtual collaborative environments clarified the differences between traditional F2F workshops and virtual workshops. The effects of a virtual setting and the characteristics of VT have been reviewed, which provided a basis to combine VM studies and remote GDSS in a virtual context.

Based on the above issues, a new job plan was developed for VVM workshops, which included specific procedures for implementing VVM studies. A conceptual framework based on the characteristics of VVM and the new job plan was proposed for four

levels, namely, process, implementation, communication, and collaboration. Each level has several sub-components that reflected requirements or key functions of VVM workshops. This framework emphasized that the VVM studies could be described from two perspectives of management and technology, which reflected the virtual features and the concerns.

8.3.2 Conclusions from system development

Existing GDSSs for VM studies were designed to support VM workshops, where participants were in the same location, and were supplementary to F2F discussions that occurred during the workshops. Based on the review of the taxonomy of GDSS, these systems were level 2 GDSSs with functions that stimulated the decision making process. The lack of communication features, particularly of communication control, was the major difference between levels 3 and 2 GDSSs. To achieve an enhanced quality of communication among VT members for VVM workshops, a level 3 remote GDSS named the Virtual Value Management System (VVMS) was developed for the current study. Departing from the traditional client/server structure, the VVMS is a completely web-based system that liberates users from the "bondage" of client software and a complex installation process. The VVMS consists of three modules. The first is a web-conferencing platform that provides audio and video connection to participants. The second and third modules comprise a creativity tool for idea generation and an evaluation tool for selecting alternatives, respectively. The VVMS

can support up to 25 video access points simultaneously, such that all participants can see one other on one screen through a video wall. This feature reduced the sense of isolation that participants might feel.

The main benefits of VVMS can be considered from two aspects. First, VVMS provided a platform for the virtual participation, communication, and collaboration in VVM workshops of participants. Second, VVMS improved the efficiency of the decision-making process by using computer-based functions. The VVMS satisfied the requirements in each phase of the VVM workshop, and provided an internet-based virtual communication and collaboration environment. Hence, the most highlighted virtual feature is that the system can be used anywhere through a computer with internet access. This feature freed the participants from the burden of a limited location and extended the workshop to a wider geographical scope.

8.3.3 Conclusions from experimental studies

8.3.3.1 Experimental Study I

The first experimental workshop was a comparative study of a GDSS-supported traditional VM workshop and a VVMS-enabled VVM workshop. The quantitative and qualitative outcomes were collected through workshop records, observation, and a questionnaire survey. The findings concluded that the VVM workshop could be successfully implemented through the support of the VVMS. The results indicated

that participants in a VVMS-enabled virtual workshop could generate a larger quantity of unique and high-quality ideas than participants in a GDSS-supported traditional workshop. The different collaboration environments and different anonymity policies in creativity of the two workshops were the two main reasons for the difference. However, the GDSS-supported workshop had an advantage in terms of participant satisfaction with the VM processes. The unstable network connection of some of the participants during the VVM workshop affected the group performance of session B. Moreover, the groups in the virtual session could not finish tasks on time because they needed more time to manage each workshop phase compared with the traditional groups.

The workshop outcomes and statistic results indicated that VVM workshops could be successfully implemented through the support of the VVMS. Although the experience of participants in the virtual environment has become closer to F2F environments because of the advancement of technology, the academe maintains a conservative attitude on the effectiveness and efficiency of virtual workshops. Some researchers even claimed no significant difference between F2F communication and computer-based communication (i.e. Fjermestad, 2004; Han et al., 2011).

Meanwhile, the performance of virtual workshops was restricted by multiple factors, such as organization, facilitation, technology, and implementation. Therefore, flexible

settings, such as dual-anonymous strategy, home participation, and virtual facilitation, which can only be applied in virtual circumstance, can be expected to produce positive effects on the outcomes of VVM workshops (Ebrahim et al., 2010).

8.3.3.2 Experimental Study II

The experimental workshop validated that the VVM workshop framework can be applied to the implementation of VVM workshops with the achievement of expected performance and outcomes. The participants involved in this workshop showed great interest and enthusiasm in this kind of online collaboration, although most of them were first-timers in attending the VVM workshop. However, the non-experience of some participants in VVM workshops and virtual settings caused problems during the workshop. Initially, the ICT used in the virtual workshop was seen as a double-edged sword and was considered as both power and obstacle (Han et al., 2011). Much time was wasted in preparing the devices of the participants and solving their technical problems, even though most of the participants had attended the pre-workshop session. Second, the facilitators had to control the audio switches manually to ensure better aural communication quality. These problems dispersed the attention of facilitators and, to some extent, affected the performance of the workshop.

Successful VM studies in the construction industry should clarify the client's objectives, improve communication with stakeholders, and stimulate creativity

through the interaction of the VM participants (Lin and Shen, 2006). In the current study, the VVMS used for the virtual workshop received favorable feedback from the participants. The discussion atmosphere was harmonious and positive, and the system stimulated creative thinking. The participants provided many insightful ideas, such as "provide a waterfall with LED on the external wall feature" for the fourth selected function in the idea generation process. However, some participants complained about the critical comments they received from fellow participants during the idea generation process, despite the facilitator emphasizing that there should be no judgment during this process. This result revealed that the discipline of participants is a challenge to VT management (Fisher and Fisher, 2000). In addition, the number of participants in the VVM workshops should be considered carefully. If the number is over 20, the complexity of managing a large VT will grow exponentially. A feasible suggestion is to let stakeholders located in the same venue join the VVM workshop together by using one computer instead of participating individually.

8.4 Original contribution to knowledge

The current research contributed to knowledge in three aspects:

(1) The research developed a new conceptual framework for VVM studies. The study successfully integrated knowledge from two areas, namely, VM and virtual collaboration environment. The framework provided an overlooking view to the VVM studies in terms of four perspectives, which are process, implementation,

communication, and collaboration. This study also established a new job plan that guided participants in effective and efficient participation in the VM process under a virtual context.

(2) The research leads to new knowledge of using a web-based remote GDSS to support VVM studies. The system, which was named VVMS, was designed to provide support to the full process of VVM workshops with both GDSS and virtual features. By adopting the VVMS, the study achieved the implementation of the real essence of VVM practices although the participants were geographically dispersed. The system architecture provided pioneering solutions to possible problems that may be encountered in both VM studies and virtual collaborative environments.

(3) This study analyzed the effect of using the proposed GDSS on VVM workshops for major construction projects. This research explored the application of VVMS in the newly expanded field of VVM workshops. To measure the performance of VVM workshops, a validation framework was developed with three specific measurements, namely, effectiveness, efficiency, and participant satisfaction. Positive results were achieved during the research, which showed that participants in VVMS-enabled VVM workshops performed more actively and were more productive than participants in GDSS-supported traditional VM workshops.

Participant satisfaction on the overall process and the implementation of the VVM workshops remained at the same level in both cases. However, the VT took a significantly longer time in finishing each task in the VVM workshops than in traditional F2F workshops. Specific results and a detailed discussion of the findings were reported in the conclusion.

8.5 Limitations of the study

The study had several limitations. First, group size limited the research to some extent. This circumstance was partly due to limited funds and the fact that the general network could not accommodate more than 20 virtual workshop participants with tolerable stability. Furthermore, some researchers had indicated that when the number of invited participants exceeded 15, team management became more complex and the process of arranging workshops required more time and resources (Benbasat and Lim, 1993; Shen and Chung, 2002). On the contrary, the participation of more experts and several rounds of experiments could improve the validity and reliability of the research results.

Second, the functions of the systems used and the general network condition limited the performance of the workshops. The experiment process was affected dramatically by serious network delays. We therefore suggest that VVMS-enabled groups use a separate timetable from GDSS-supported groups for each phase of the VM workshop,

and that facilitators should allocate more time for the function analysis and evaluation phases for the VVMS-enabled groups. In addition, a more mature GDSS in better network condition may receive improved outcomes.

Third, the lack of training of facilitators on virtual facilitation skills is a challenged in the VVM studies. In F2F workshops, facilitators introduced interactive activities, such as paired self-introduction and team ice-breaking games, to help ease feelings of nervousness or tension among participants. However, such activities were difficult to implement in a virtual workshop. Moreover, the lack of knowledge in existing literature about virtual facilitation skills limited the activities. Facilitators should therefore adjust their facilitation styles to a VVM workshop environment. New online activities and facilitation skills must be developed for VVM workshops, especially in ensuring participation and controlling the quality of workshop results when serious network delays/pauses occur.

8.6 Suggestions for the future research

Some suggestions on future research are listed as follows:

(1) First, the GDSS for VVM studies should be improved further. The use of GDSS significantly affected the performance of VVM workshops. Therefore, a more powerful GDSS will improve workshop outcomes and increase participant satisfaction.

(2) Second, future studies should investigate how the "virtual" aspect of a VVM workshop could receive maximum outcomes and participant satisfaction. The VVM workshops cannot completely replace traditional F2F workshops under current general network conditions. A possible compromise would be to use the VVMS in VM workshops to allow the virtual participation of those who are unable to attend the workshop in person. This adjustment should still result in an enhanced workshop experience for participants and better workshop outcomes.

(3) Third, virtual facilitation skills should be improved in future VVM studies. Facilitators should learn how to ensure participation despite the lack of direct interaction among participants, such as eye contact and body language, as well as the lack of real-time feedback from participants. In addition, the development of simple, fast, and easy virtual ice-breaking activities could be another important future research direction, which will contribute not only to virtual facilitation for VVM studies, but also to other research areas.

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Appendix

QUESTIONNAIRE SURVEY ON THE PERFORMANCE OF VM WORKSHOP

The objective of this survey is to measure the performance of the VM workshop. All collected information will be kept CONFIDENTIAL. Thank you very much in advance for your help in completing this questionnaire!

PART A: BACKGROUND OF THE RESPONDENT

Instruction: Please indicate your answer by tick the appropriate box.

1. What type of organisation you are currently employed?

☐ Government Department/Agency ☐ Developer ☐ Contractor
☐ Consultant ☐ Academic Institution ☐ Others: _____

2. What is your academic qualification(s)?

☐ Certificate ☐ Diploma / Advance Diploma ☐ Bachelor Degree ☐ Master Degree
☐ Doctor of Philosophy (PhD) ☐ Professional Certificate

3. How long is your relevant experience in relation to construction industry?

☐ More than 20 years ☐ 16 - 20 years ☐ 11 - 15 years ☐ 5 - 10 years ☐ Less than 5 years

4. To what extent do you agree with the following statements?

*(5 = **SA**: Strongly Agree 4 =**A**: Agree 3 = **N**: Neutral 2 = **D**: Disagree 1 = **SD**: Strongly Disagree)*

	SA	A	N	D	SD
Overall					
My knowledge in computer technology can support my participation in the whole process of the virtual VM workshop	5	4	3	2	1
My typing speed **did not** affected my participation in communication and creativity phase of the virtual VM workshop	5	4	3	2	1

PART B: PERFORMANCE OF THE VM WORKSHOP

Instruction: Please indicate your answer by circling the appropriate numbers. The meanings of the acronyms are given under the tables.

5. To what extent do you agree with the following statements about the performance of the VM workshop?

*(5 = **SA**: Strongly Agree 4 =**A**: Agree 3 = **N**: Neutral 2 = **D**: Disagree 1 = **SD**: Strongly Disagree)*

	SA	A	N	D	SD
Overall					
My team members are able to actively interact with each other.	5	4	3	2	1
Clear objectives of the VM workshop are provided.	5	4	3	2	1
The workshop processes has accelerate the decision making process.	5	4	3	2	1
The tools used in workshop support the communication and understanding among the stakeholders.	5	4	3	2	1
Pre-workshop (briefing session) helped me to better participate in the VM workshop.	5	4	3	2	1
Information Phase					
My team managed to acquire background information.	5	4	3	2	1
My team managed to clarify the client's objectives.	5	4	3	2	1
My team managed to identify the project/users' requirements.	5	4	3	2	1
My team managed to complete the task on time.	5	4	3	2	1
I am satisfied with the techniques used in this phase.	5	4	3	2	1
Function Analysis Phase					
My team managed to identify the primary functions.	5	4	3	2	1
My team managed to develop the FAST diagram.	5	4	3	2	1
My team managed to prioritise the functions.	5	4	3	2	1
My team managed to complete the task on time.	5	4	3	2	1
I am satisfied with the techniques used in this phase.	5	4	3	2	1
Creativity Phase					
My team managed to generate ideas to achieve the identified functions.	5	4	3	2	1
I managed to avoid criticism to other participant ideas.	5	4	3	2	1
I managed to develop new ideas based on other participant ideas.	5	4	3	2	1
I am satisfied with the efficiency rate of idea generation (total ideas/hour).	5	4	3	2	1
My team managed to complete the task on time.	5	4	3	2	1
I am satisfied with the techniques used in this phase.	5	4	3	2	1
Evaluation Phase					
I managed to express my opinions/views without pressure.	5	4	3	2	1
My team was not dominated by any of the team members.	5	4	3	2	1
My team managed to rate the evaluation criteria effectively.	5	4	3	2	1
My team managed to evaluate the ideas for the development effectively.	5	4	3	2	1
My team managed to evaluate the ideas for the development efficiently.	5	4	3	2	1
My team managed to complete the task on time.	5	4	3	2	1

I am satisfied with the techniques used in this phase.	5	4	3	2	1

6. To what extent do you agree with the following statements about the system used in VM workshop?

*(5 = **SA**: Strongly Agree 4 =**A**: Agree 3 = **N**: Neutral 2 = **D**: Disagree 1 = **SD**: Strongly Disagree)*

	SA	A	N	D	SD
Workshop Stage					
Information Phase					
The system can support the key stakeholder presentation.	5	4	3	2	1
The system can improve the information exchange process.	5	4	3	2	1
Function Analysis Phase					
The system can support the function analysis phase.	5	4	3	2	1
The system can simplify the function analysis process.	5	4	3	2	1
The system can enhance the function analysis process.	5	4	3	2	1
Creativity Phase					
The system can support the creativity phase.	5	4	3	2	1
The system can enhance active participation in idea generation.	5	4	3	2	1
The system can encourage creative thinking.	5	4	3	2	1
The system can provide equal opportunities to participants in idea generation.	5	4	3	2	1
Evaluation Phase					
The system can support the evaluation phase.	5	4	3	2	1
The system can increase the efficiency of the evaluation phase.	5	4	3	2	1
Independent voting can prevent domination/interference in evaluation phase.	5	4	3	2	1
The system can accelerate the decision making process of evaluation	5	4	3	2	1
Post-Workshop Stage					
If the data/results of the workshop can be recorded by the system it will ease my work in the post-workshop stage.	5	4	3	2	1
General Issue					
The system successfully support the virtual VM workshop.	5	4	3	2	1
The system provides a platform for efficient communication among stakeholders.	5	4	3	2	1
The interface of the system is user-friendly.	5	4	3	2	1
Requirement of participants' network environment is a limitation for virtual VM workshop	5	4	3	2	1
Overall Satisfaction					
I am satisfied with the performance of the system during the VM workshop.	5	4	3	2	1
I am satisfied with the features of the system.	5	4	3	2	1
I could follow the facilitator instructions in each phase of the VM workshop via the system.	5	4	3	2	1

PART C: VIRTUAL VALUE MANAGEMENT SYSTEM

7. To what extent do you agree that the followings are critical of conducting a virtual VM workshop?

*(4 = **SA**: Strongly Agree 3 = **A**: Agree 2= **D**: Disagree 1 = **SD**: Strongly Disagree)*

	SA	A	D	SD
Pre-workshop (briefing session)	4	3	2	1
Trust between participants	4	3	2	1
Clear communication rules	4	3	2	1
Clear project's objective	4	3	2	1
Facilitator's experience in VM workshop	4	3	2	1
Facilitator's experience in virtual workshop	4	3	2	1
Virtual facilitation skills	4	3	2	1
Process control by facilitator	4	3	2	1
Participant's experience in VM workshop	4	3	2	1
Participant's experience in virtual workshop	4	3	2	1
Participant's disciplines during virtual workshop	4	3	2	1
Participant's network quality	4	3	2	1
Participant's computer skill	4	3	2	1
Participant's familiarity of the systems used in virtual workshop	4	3	2	1
Multimedia and technical support	4	3	2	1
Hardware requirements to participant	4	3	2	1
Software requirements to participant	4	3	2	1
Others 1. _____	4	3	2	1
Others 2. _____	4	3	2	1

8. What are the things you like the most about the online system features?

_____

_____

_____

9. Which tools and their designated functions should be improved of the online system?

_____

_____

_____

PART D: PERSONAL PARTICULARS

Name of Respondent: _____ Student No.: _____

Thank you very much for completing this questionnaire!

- THE END -