THE EFFECT OF USING GROUP DECISION SUPPORT SYSTEMS ON THE PROCESSES AND OUTCOMES OF VALUE MANAGEMENT STUDIES

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The Effect of Using Group Decision Support Systems on the Processes and Outcomes of Value Management Studies

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DECLARATION

I hereby declare that this thesis is my own work and that, to the best of my knowledge and belief, it reproduces no material previously published or written nor material that has been accepted for the award of any other degree or diploma, except where due acknowledgement has been made in the text.

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Abstract

As a result of factors such as technological development, uncertain economic conditions, social pressures, and fierce competition, clients in the construction industry are placing increasing demands upon the industry in terms of value for money. As a useful tool that can help the industry meet these challenges, value management (VM) has been widely used in many developed countries for several decades. However, reluctance to use VM often stems from the time that an expensive team has to invest in undertaking the VM process. If a way could be found to make the process more efficient and effective, then the cost of undertaking VM would decrease. Moreover, VM faces more difficulties when employers and employees, and superiors and subordinates are in the same team, due to member dominance and conformance pressure. It is proposed that group decision support systems (GDSS) may be used to make the VM process more efficient and effective by utilising modern technological developments to increase process gains and reduce process losses.

The main objectives of this research are (1) to investigate the extent to which the use of GDSS can improve effectiveness and efficiency in the processes and outcomes of VM studies in construction projects; and (2) to identify critical success factors for the integration of GDSS with activities in the VM process, in order to help ensure effective and efficient communication and decision-making in VM studies. These objectives have been achieved mainly through a systematic approach using purpose-designed experimental studies conducted in Hong Kong. The results of these studies have been analysed using statistical methods to reveal the detailed effect of using GDSS on VM studies. The results have shown that GDSS is a promising technology to improve the efficiency and effectiveness of current VM studies. The way of using GDSS in VM studies also provides a useful reference for both researchers and practitioners to design

and apply GDSS in the VM area. In order to further investigate the effect of using GDSS in real-life VM studies, an action research study has been conducted and the results are positive. Finally, four underlying critical success factors for using GDSS in VM studies have been identified through a questionnaire survey. They are: VM team's computer proficiency, system capabilities, workshop duration and number of participants, environmental setting.

This systemic investigation leads to new knowledge on the use of GDSS to support and improve VM studies in construction industry. These outcomes can have a profound impact on the way VM workshops should be conducted and on the use of GDSS to improve the effectiveness and efficiency of VM studies. They also provide possible solutions to the difficulties frequently encountered by users during VM studies. These outcomes are valuable to the construction industry in Hong Kong, where both the government and the industry have called for wider use of VM, and yet users have encountered more difficulties than their overseas counterparts due to large number of participants and short duration of the workshops.

Publications:

Refereed Journal Papers:

1. **Fan, S.C. and Shen, Q.P. (2006). "The effect of using group decision support systems on the processes and outcomes of value management studies."** *Value Engineering,* **25(9), 58-61.**

2. **Fan, S.C. and Shen, Q.P., Tang, R.J., and Lin, G.B. (2006). "The effect of using group decision support system in value management studies: an experimental study."** *International Journal of Construction Management,* **6(2), 49-62.**

3. **Fan, S.C., Shen, Q.P., and Lin, G.B. (2007). "Comparative study of idea generation between traditional value management workshops and GDSS-supported workshops."** *Journal of Construction Engineering & Management (ASCE),* **133(10), 816-825.**

4. **Fan, S.C., Shen, Q.P., and Kelly, J. (2008). "Using group decision support system to support value management workshops."** *Journal of Computing in Civil Engineering (ASCE),* **22(2), 100-113.**

Refereed Journal Papers Under Review:

5. **Fan, S.C., and Shen, Q.P. (2008). "Critical success factors for using GDSS in value management studies."** *Journal of Construction Engineering & Management (ASCE),* **under review.**

6. **Fan, S.C., and Shen, Q.P. (2008). "A study of the effect of using group decision support system in value management studies."** *Journal of Management in Engineering (ASCE),* **under review.**

Book Chapters:

7. **Shen, Q.P., and Fan, S.C. (2009) A group support system for collaborative working in a value management workshop environment. In SHEN, Q.P., Brandon, P., and Baldwin, A., ed.** *Collaborative Construction Information Management.* **Taylor & Francis. Ch. 18.**

Conference Papers:

8. **Fan, S.C. and Shen, Q.P. (2004). "A web-based group decision support system for value management studies in construction." IN:** *Proceedings of 2004 International Conference on Construction & Real Estate Management,* **6-7 Dec., Hong Kong, 113-117.**

9. **Lin, G.B., Shen, Q.P., and Fan, S.C. (2004). "A framework for performance measurement of value management studies in construction." IN:** *Proceedings of 2004 International Conference on Construction & Real Estate Management,* **6-7 Dec., Hong Kong, 307-311.**

10. **Fan, S.C., Shen, Q.P., Li, H., and Kelly, J. (2005). "The effect of using Group Decision Support Systems on the Processes and Outcomes of VM studies." IN:** *Proceedings of 2005 International Conference on Construction & Real Estate Management, Vols 1 – Challenge of innovation in construction and real estate,* **12-13 Dec., Penang, Malaysia, 722-726.**

11. **Shen, Q.P., and Fan, S.C. (2005). "A group decision support systems for Value Management studies." IN:** *Proceedings of 2nd International Conference on Value Engineering & Enterprise Technology Innovation,* **16-18 Oct., 19-28.**

12. **Fan, S.C., Shen, Q.P., and Lin, G.B. (2005). "Using group decision support systems to support value management studies." IN:** *Proceedings of China Institute of Professional Management in Construction of the Architectural Society of China Conference,* **12 Dec., Hong Kong, 96-103.**

13. **Lin, G.B., Shen, Q.P., and Fan, S.C. (2005). "Utilizing information technology to facilitate performance measurement in VM studies." IN:** *Proceedings of 2005 International Conference on Construction & Real Estate Management, Vols 1 – Challenge of innovation in construction and real estate,* **12-13 Dec., Penang, Malaysia, 516-520.**

14. **Shen, Q.P., Fan, S.C., Tang, R.J., and Lin, G.B. (2006). "A comparative study of Face-to-Face and GDSS-supported Brainstorming in Value Management Workshops." IN:** *Proceedings of 2006 International Conference on Construction & Real Estate Management, Vols 2 – Challenge of innovation in construction and real estate,* **5-6 Oct., Sheraton World Resort, Orlando, Florida, USA, 1192-1195.**

15. **Tang, R.J., Shen, Q.P., Fan, S.C., and Lin, G.B. (2006). "Using windows sharepoint service to support value management studies." IN:** *Proceedings of 2006 International Conference on Construction & Real Estate Management, Vols 1 – Challenge of innovation in construction and real estate,* **5-6 Oct., Sheraton World Resort, Orlando, Florida, USA, 728-732.**

16. **Fan, S.C. (2006). "Improving Value Management Workshops in Construction: A GDSS Approach." First runner-up in the Student Paper Competition organized by SAVE & IVM, IN:** *Proceedings of 2006 International VM*

Conference – Delivering Value Today and Tomorrow, **14-15 Sep., The Grand Hotel, Brighton, UK.**

17. **Fan, S.C., Shen, Q.P., Kelly, J. and Lin, G.B. (2007). "Comparing the performance of IVMS-supported value management workshops with traditional value management workshops." IN:** *Proceedings of 2007 International Conference on Construction & Real Estate Management, Vols 1 and 2 – Challenge of innovation in construction and real estate,* **21-22 Aug., Bristol, UK, 959-963.**

18. **Lin., G.B., Shen, Q.P., and Fan, S.C. (2007). "Comparing the Validating the Performance Measurement Framework for VM Studies in Construction." IN:** *Proceedings of 2007 International Conference on Construction & Real Estate Management, Vols 1 and 2 – Challenge of innovation in construction and real estate,* **21-22 Aug., Bristol, UK, 968-972.**

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List of Abbreviations

CSFs	Critical Success Factors
CVA	Competing Value Approach
EBS	Electronic Brainstorming
FAST	Function Analysis System Technique
GDSS	Group Decision Support System
GSS	Group Support System
IT	Information Technology
IVMS	Interactive Value Management System
SAVE	Society of American Value Engineers
VA	Value Analysis
VE	Value Engineering
VM	Value Management
VMCPs	Value Management Change Proposals
W.E.T	Weighted Evaluation Technique

Chapter 1: Introduction

1.1 Introduction

This chapter provides an overview of the thesis. It includes the research context, the research propositions, the research objectives, the scope of research and the research process. Following this, the structure of the thesis is outlined, which comprises nine chapters.

This research gives a background to the use of Value Management (VM) and the difficulties encountered by current practitioners. The focus of this thesis is to offer a solution to improve current value management studies by overcoming these difficulties. This has led to the investigation of the effect of using Group Decision Support System (GDSS) in the process and outcomes of value management studies. GDSS is introduced as the solution to these difficulties. A web-based GDSS prototype is developed during the research. Chapter two and three review the academic literature on value management and GDSS.

1.2 Research Context

Value Management is a structured and analytical process that seeks to achieve value for money by providing all the necessary functions at the lowest cost consistent with the required levels of quality and performance (AS/NZS 4183:1994). It enables organisations to adopt a consistent approach towards decision-making, taking into account the needs of the business, the environment within which it is operating, and the people involved (BS EN12973: 2000; Green, 2001). As an effective tool in meeting the increasing demands for value enhancement (McGeorge & Palmer, 1997; Barton, 2000), VM has been widely used in many countries in the last five decades. Several laws in US mandate VM use in the public sector. For example, the Defense Authorization Act (Public Law 104-106) states that each executive agency must establish and maintain cost-effective VM procedures and processes. Another example is the 1995 National Highway System Designation Act which requires states to carry out a VM analysis for all federal-aid highway projects with an estimated total cost of $25 million or more (SAVE International, 2008a).

There has been a surge of interest in VM in the construction industry in Hong Kong, especially since the Asian financial crisis in 1997 (Shen and Kwok, 1999). A number of government departments and private enterprises in Hong Kong have applied VM to ensure value for money for their projects during the project feasibility study stage. The technical circular issued by the Works Bureau (1998) demands that VM studies be carried out for major projects in public works programmes. These applications have been reviewed recently by the Environment, Transport and Works Bureau (ETWB, 2002), which has confirmed the benefits of VM studies and recommended a wider use of the VM methodology. This is in line with the recommendations of the Construction Industry Review Committee (2001): VM should be used more widely in local construction because it can help clients and project teams focus on the objectives and needs of the project and all stakeholders, both long-term and short-term.

As suggested by Nunamaker et al. (1997), many things can go wrong with teamwork. As a result, the group decision-making process can be very difficult and unproductive. A recent survey suggested that VM users in Hong Kong encounter problems including a lack of active participation and insufficient time and information in the decision analysis (Shen and Chung, 2000; Chung, 2002). These problems are associated with the large number of participants and the short duration of VM workshops in Hong Kong.

They have affected the performance of VM studies and there is strong demand for improvements to the practice in order to maximise the benefits of the studies.

GDSS, also known as Group Support Systems (GSS), is 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 (DeSanctis and Galluple, 1987). GDSS consists of hardware, software, people, and procedures to support groups of people, and engages them in common tasks through the interface of a shared environment (Aiken et al., 1995). It is a “silent partner” that improves the efficiency, reliability and quality of group decisions in meetings (Thierauf, 1989). It can provide technological efficiencies and interaction advantages, which can overcome some of the difficulties frequently encountered among large teams (Dennis, 1991). Many studies have demonstrated the effectiveness of GDSS in supporting the group decision-making process (e.g. Dennis et al., 1988; Chun and Park, 1998). Although the findings of these studies contain discrepancies due to variations in the experimental settings, the common findings of a number of field studies have provided evidence to support the effectiveness of GDSS in practice. These field studies have consistently shown positive results, and nearly all “real world” users are extremely satisfied with GDSS applications. Hence, as a branch of information technology, GDSS has the potential to promote active participation, encourage interaction, and facilitate decision analysis in VM workshops.

The primary purpose of GDSS is to reduce the “process losses” associated with member dominance, social pressure, inhibition of expression, and other difficulties commonly encountered in groups, and at the same time to increase the “process gains” such as supporting parallel idea generation and information processing, allowing rapid and easy access to external information, enabling users to interact simultaneously, and above all, the efficiency and quality of the resulting group decisions (DeSanctis & Galluple, 1987; Dennis et al., 1988; Nunamaker et al., 1997; Turban & Aronson, 2001). Because of its success in facilitating group decisions, GDSS is gaining acceptance in commercial sectors. It has been widely used by international corporations such as IBM, Motorola, Xerox and 3M, and government departments in various countries such as the US Navy and NASA. The potential limitations of using GDSS, such as the additional resources required for hardware and software facilities and the lack of body language and facial expressions that aid communication, etc., have also been identified and documented (e.g. Aiken et al., 1995; Pervan, 1998; Turban & Aronson, 2001).

1.3 Research Propositions and Objectives

The overall aim of this research is to investigate the effect of using GDSS on the processes and outcomes of value management studies. This research reviews value management and the problems encountered in current studies. Following this is a literature review of GDSS, which investigates whether the use of GDSS is appropriate for value management studies.

A research proposition that has emerged from a literature review on VM is:

1. VM users encounter the problems of a lack of active participation and insufficient time and information in decision analysis.

Another research proposition that has emerged from the literature review on GDSS is:

2. GDSS can reduce process losses and increase process gains during the group decision-making process.

Hence, the main research proposition is:

- The use of GDSS can provide technological efficiencies and interaction advantage, which can overcome the difficulties encountered in current VM studies.

To confirm the research proposition, the main research objectives are:

- To investigate the extent to which the use of GDSS can improve effectiveness and efficiency in the processes and outcomes of VM studies in construction projects.

- To identify critical success factors (CSFs) for the integration of GDSS with activities in the VM process, in order to ensure effective and efficient communication and decision-making in VM studies.

In order to achieve the main objectives, six tasks need to be completed:

- To review the available literature on value management to enclose the problems/difficulties encountered by current users;

- To review the available literature on the application of GDSS to determine whether it is appropriate to use it in VM studies;

- To develop a GDSS prototype that can be used as a tool to investigate the effect of using GDSS in VM studies;

- To develop a generic model of how the GDSS prototype that is developed can be applied in a VM study;

- To determine the extent to which the use of GDSS can support VM studies;

- To identify the CSFs for the integration of GDSS with activities in VM process.

1.4 The Research Process

Value management is the main research area, and the research stems from a questionnaire survey by Shen and Chung (2000), which suggests that VM users in Hong Kong encounter problems, namely a lack of active participation and insufficient time and information in the decision analysis. This has affected the performance of VM studies and there is strong demand for improvements to the practice in order to maximise the benefits of the studies. The use of Group Decision Support Systems (GDSS) provides technological efficiencies and interaction advantages, which can overcome some of the difficulties frequently encountered among large teams (Dennis, 1991). Therefore, it is proposed that the use of GDSS in VM workshops can overcome the above problems and improve performance. A literature review on GDSS is undertaken to identify the appropriateness of using GDSS in VM workshops and also what types of GDSS is appropriate for VM workshops. Then a web-based GDSS prototype, named Interactive Value Management System (IVMS) is designed as a tool to investigate the effect of using GDSS in VM workshops. The research methods (and their purposes) used to meet the objectives are (1) four experimental studies to validate the GDSS prototype and to investigate the effect of using GDSS in VM studies by comparing VM workshops that had GDSS support with traditional VM workshops; (2) action research in the form of a VM workshop with CEDD (Civil Engineering and Development Department) to further validate the GDSS prototype and investigate the effects of GDSS use in a real-life study; and (3) a questionnaire survey to identify the critical success factors of using GDSS in VM studies.

The research outcomes are: (1) new knowledge of the impact of using GDSS on the overall outcomes of VM studies; (2) a web-based GDSS prototype; (3) a framework on how the GDSS can offer support during each stage of VM studies; and (4) identification of the critical success factors of using GDSS in VM studies.

1.5 Thesis Structure

The structure actually aims to reflect the research process. Chapter 1 briefly introduces this research through a description of the research context, the research propositions and objectives and the research process.

Chapter 2 reviews the value management literature, provides a background of the history of VM, and also introduces the job plan of VM. The common benefits and current problems of VM studies are outlined, and previous information technology applications in VM studies are reviewed.

Chapter 3 presents a comprehensive literature review on GDSS. The background of GDSS is introduced, followed by the key features of GDSS. Previous empirical research studies on GDSS are discussed to provide a basic understanding on the effect of using GDSS.

Chapter 4 introduces the model building process, and mainly discusses the considerations taken into account during the development of the GDSS prototype. The purpose and development environment of the GDSS prototype, Interactive Value Management System (IVMS), are also described.

Chapter 5 explains the research methodology adapted for this thesis and why particular research methods were chosen. The research methods used are (1) four experimental studies to validate the GDSS prototype and to investigate the effect of using GDSS in VM studies by comparing VM workshops that had GDSS support with traditional VM workshops; (2) action research in the form of a VM workshop with CEDD (Civil

Engineering and Development Department) to further validate the GDSS prototype and investigate the effects of GDSS use in a real-life study; and (3) a questionnaire survey to identify the critical success factors of using GDSS in VM studies.

Chapter 6 introduces the framework on how to integrate IVMS with value management workshops. The supports that IVMS can provide during each stage of VM workshops are illustrated in details.

Chapter 7 introduces the research methods conducted to validate the system developed during this research and to test the hypotheses, including experimental studies, a questionnaire survey and an action research. There are three types of experimental studies: a comparative study of idea generation, a validation study of using IVMS in the full process of VM workshops, and a comparative study of using IVMS in the full process of VM workshops. The action research is used to further validate the effect of using GDSS in a real-life VM study.

Chapter 8 presents the research findings, which include the quantitative data on the extent to which GDSS can enhance the performance of VM studies, as found in the three types of experimental studies and the action research. Four critical success factors have also been identified through a questionnaire survey.

Chapter 9 summarizes the thesis and highlights the research conclusions. The contributions of the research are explained as well as the limitations. The recommendations for further researches are also suggested.

1.6 Summary

This chapter provides an introduction to this study, in which the research context, research propositions and objectives, and the research process are discussed. Finally, the structure of this thesis is presented. A review of Value Management is presented in the next chapter.

Chapter 2: A Review of Value Management

2.1 Introduction

The major purpose of this research is to investigate the extent to which the use of GDSS can improve effectiveness and efficiency in the processes and outcomes of VM studies in construction projects. Hence, it is necessary to gain insight from previous studies that have been conducted in the field of VM studies. This section, Literature Review – Value Management, concentrates on five major areas: (1) the background and history of VM, (2) definition of VM, (3) job plan of VM, (4) benefits of VM, (5) problems encountered in current VM studies, and (6) IT applications in VM.

2.2 The Background of VM

Value management (VM) was first developed by Lawrence Miles of the General Electrical Company (GEC) in 1947. At that time, the manufacturing industry in the United States was running at a maximum capacity, which resulted in shortages of materials. Miles, who was in charge of purchasing the materials for GEC, had to find alternatives. He developed a system of techniques called value analysis (the origin of VM), to achieve the necessary functions of a project at a lower cost by using various substitutes.

In 1954 the US Department of Defence's Bureau of Ships became the first US government organisation to implement a formal programme of value analysis. However, they used the term "value engineering (VE)". In 1959 the Society of American Value Engineering was established and, from that time, VE came into common use as the preferred term in North America. The involvement of the government played an important role to the initial development of VE in the USA, because of a necessary demand for an auditable structure. VE spread to many US federal, state and local government agencies following the introduction of the cost reduction programme of Secretary McNamara in 1964.

VE was first applied to buildings by Dell'Isola in 1963, when he introduced VE to the Navy's Facilities Engineering Command. A VE incentive clause was added to the contract, which aimed to encourage contractors to suggest alternatives to improve the design by sharing the savings. This method then spread quickly in the construction industry and become a mandatory requirement in many public projects in USA. Over the past decades, VE has spread throughout the world and is used widely in the manufacturing and construction sectors in many countries, such as the USA, the UK, Australia, Korea, India, Saudi Arabia, Japan and China. Today, a number of terms, such as value management (VM), value engineering (VE) and value analysis (VA), are used synonymously in VM studies. The term 'Value management' was first used by the General Services Administration in 1974 to reflect the fact that value techniques were not confined to technical issues but had evolved to include a focus on management activities and company policy (Macedo et al., 1978). 'Value Management' or 'the Value Methodology' are generally accepted internationally as descriptions of the entire service. The differences and relationships between VA, VE and VM will be discussed in the following part. However, in this thesis, value management (VM) is used instead of VA/VE.

With respect to the development of value management, it is interesting to note Kelly, et al.'s observation (2004): "Over the whole period value management has continuously improved, unlike other management fads that emerge, are applied with gusto and then die to be replaced by another" (Kelly, et al., 2004).

2.3 Definition of VM

2.3.1 What is VM?

VM is a creative, organised approach whose objective is to optimise the cost and/or the performance of a facility or system. There are a number of definitions of VM, as follows:

"Value analysis is a problem-solving system implemented by the use of a specific set of technologies, a body of knowledge, and a group of learned skills. It is an organised creative approach that has for its purpose the efficient identification of unnecessary cost, i.e. cost that provides neither quality nor use nor life nor appearance nor customer features." (Miles, 1972)

"Value engineering is a creative, organised approach whose objective is to optimize cost and/or performance of a facility or system." (Dell'Isola, 1982)

"Value Engineering (synonymous with terms Value Management and Value Analysis) is a function-oriented, systematic team approach to provide value in a product, system, or service. Often, this improvement is focused on cost reduction; however, other improvements such as customer perceived quality and performance are also paramount in the value equation." (SAVE International, 1998)

"VA is a management technique which analyses, by means of a systematic approach, how to reduce cost whilst taking into account customer requirements; it not only assesses the degree of innovation desired or allowed for in the product or service, but also covers the implementation and follow-up of solutions proposed and therefore strengthens companies' innovative capacity and competitiveness." (Commission of the European Community, 1991)

“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 is a service which maximizes the functional value of a project by managing its evolution and development from concept to completion, through the comparison and audit of all decisions against a value system determined by the client or customer.” (Kelly and Male, 1993)

“VM is a systematic, multi-disciplinary effort directed toward analyzing the functions of projects for the purposes of achieving the best value at the lowest overall life cycle project cost.” (Norton and McElligott, 1995)

Of all the definitions, the latter three are the most well-known and widely accepted. Woodhead and Downs (2001) state that each definition of value management does not capture its complete meaning; together they provide a tapestry that gives us a richer understanding. Kelly et al. (2004) have presented several important considerations that should be paid attention to in the definition of VM. First, VM is a process more than a method/technique. There are a series of steps which comprise a number of techniques. Second, VM is used to make choices on which components best fit in with the value system of a client so that an appropriate decision can be made on the relative balance between, for example, capital expenditure and operational expenditure. This means that it is not just about making choices on capital cost but about cost in use, which may include thinking about maintenance costs, operating costs and disposal costs. It should be noticed that cost cutting is only one of a potential number of value strategies that is available as part of a value study. Third, it is important to make explicit these choices. VM aims to clearly bring out choices involving both the subjective and objective components of value. Fourth, functional benefits are also mentioned. This draws out the economic, social and psychological dimensions of value and raises the question about who decides on the benefits and how. Finally, VM is team based because of the involvement of resolving different and potential competing and conflicting value systems coming together to address a particular value problem.

VM is still one of today's most misunderstood management concepts (Fong, 1999). Practitioners and researchers are easily confused by the jargon associated with it. A general definition of VM should be used in both academia and industry.

2.3.2 VA, VE and VM

There is often confusion over the exact meaning of VM, and how it is distinct from VE and VA. The distinctions are often very loose. These three terms are still largely used interchangeably in the literature. In fact, VE is the term favoured historically by the Society of American Value Engineering (SAVE) in USA. Since SAVE has considerable influence internationally in construction, the term is in common use around the globe. SAVE was renamed SAVE International in 1977 and a new term "Value Methodology" is now used instead of VE. This new term is used as a collective term, which includes the processes known as value analysis, value engineering, value management, value control, value improvement and value assurance. In the Australian/New Zealand Standard, VM is synonymous with VE and VA and can be applied any time during a project life cycle. However, there is a commonly accepted distinction between them in construction in the UK. This thesis will follow the UK approach.

Value analysis (VA) is a philosophy implemented by the use of a specific set of techniques, a body of knowledge, and a group of learned skills. It usually refers to the application to an existing project, product or service to achieve value improvement. It is an organised creative approach, whose purpose is the efficient identification of unnecessary cost. In other words, it is the cost that provides neither quality nor use nor life nor appearance nor customer features (Miles, 1961).

VE is the process by which the functional benefits of a project are made explicit and by which the consistency of the project's functional benefits with a value system determined by the client is appraised. It is usually applied in the design and construction stages to achieve value improvement. On the other hand, it is the process of making explicit the functional benefits a client requires from the whole or parts of a project at an appropriate time during design and construction (Kelly, et al., 2004). VE aims to achieve the special function at a cost as low as possible. The objects already exist and are concrete. The aim of VE studies is to tackle technical problems at a tactical level and solve the question "How to do it?".

VM aims to evaluate and implement the value system of the client while the objectives are not yet settled and are abstract. The VM studies are about making decisions at a strategic level and solving the question "what to do?".

VE and VA are viewed as component parts of VM studies in many circumstances, for VM is used as the total process of enhancing value for a client from a project from the phases of concept through to operation and use.

However, there are some other terms in use, which have also been adopted as sub-processes within VM, and the list is shown as follows:

- Value Planning (VP) is applied during the concept phase of a project.

- Value Reviewing (VR) is applied at any point in the project life cycle to record the effectiveness of the value process which relates to the overall sequence of actions that lead to value improvements.

2.4 Principles of VM

As shown in Fig.2.1, five principles essential to the success and advancement of VM methodology have been identified. They are: job plan, functional approach, function cost analysis, team approach, and environment for creative thinking.

The functional approach is an essential element of the VM methodology with a relatively long evolutionary development history (Gregory, 1984). It consists of a group of techniques that differentiate it from traditional cost reduction and cost planning efforts. The objective is to forget the product as it exists and concentrate only on its necessary functions required by the clients. This approach leads to a systematic identification and clear definition of the client's requirements, an improved functional understanding of the design problem, and an effective accomplishment of those functions.

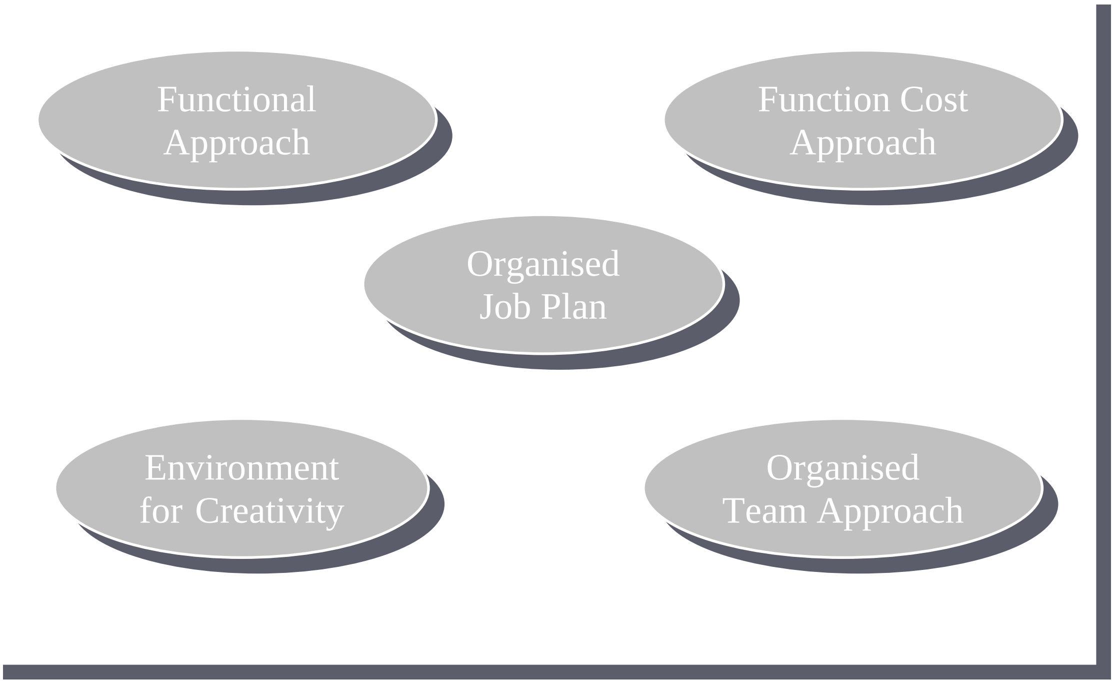


Fig. 2.1 Principles of Value Management Methodology (Shen, 2005)

The function cost approach aims to develop a better understanding of the product, project or process through the analysis of the relationship between function and cost. It makes it possible for costs per function to be established, giving a true picture of the product. Normally, a monetary parameter is used to estimate the cost of functions.

VM studies organise all relevant disciplines together as a team to explore the overall optimisation of the system, instead of seeking sub-optimisation within each individual domain. Hence, it is important to know the team characteristics and how to facilitate the VM team in the VM studies.

The environment for creativity is also important for VM studies. Since the number of good suggestions remains fairly constant as a proportion of wild suggestions, the number of good suggestions will increase in with the overall number of suggestions (Kelly and Male, 1993). It is thus good to keep a good environment for creativity in order to increase the quantity of ideas/suggestions. It is suggested that a multi-disciplinary group can work out 65% to 93% more ideas than that from an individual working alone. Hence, better ideas can therefore be derived from the large number of ideas generated.

The VM job plan is the key element of VM studies and it is discussed in detail in the next part.

2.5 Job Plan of VM

The VM job plan is a sequential approach to implementing the core elements of a value management study and contains systematic procedures for accomplishing all the necessary tasks associated with a VM study. It outlines specific steps to effectively analyse a product or service and develops the maximum number of alternatives to achieve the product's or service's required functions (SAVE, 1998). Dell'Isaola (1997) suggested that the job plan is an organised problem-solving approach, which distinguishes VM from other cost-cutting exercises. Kelly and Male (1993) also suggest that the use of a structured system method is one of the characteristics that distinguishes VM from other cost reduction exercises. There is a variety of VM job plans, such as Charette, SAVE 40-hour plan, VM audit, Contractor's Change Proposal, Truncated workshop, and Concurrent Study. Based on these job plans, various VM studies can also be categorised into different groups (Kelly and Male, 1991). The first two job plans will be introduced in detail, because they are widely used in VM studies, especially the SAVE 40-hour approach, which is the most widely accepted formal approach in the construction industry.

2.5.1 The Charette Job Plan

This method seeks to rationalise the client's brief through the identification of the function of key elements and the spaces specified. This analysis is conducted at a meeting involving the client's staff and the design team with the main purpose of assuring that the designers fully understand the client's requirements. The main advantages of this job plan, as outlined by Kelly and Male (1991), are that it is considered by many clients to be an inexpensive and effective method of briefing the design team and clarifying their own requirements, taking less than two days compared with the five days required by the 40-hour job plan. Furthermore, as the Charette is usually carried out in the very early design stages, it can play a major role in project cost control and value enhancement.

2.5.2 The 40-Hour Job Plan

According to the Value Methodology Standard (SAVE, 1998), the SAVE 40-hour plan comprises three major phases: pre-study stage, value study stage and post-study stage.

2.5.2.1 Pre-study Stage

The pre-study stage aims to provide an opportunity for all parties to understand project issues and constraints, and therefore to give and receive information before VM workshops. The preparation tasks involve six areas including:

- Collecting user/customer attitudes
- Completing the data file
- Determining evaluation factors
- Defining the scope of the study

- Building data models

- Determining team composition.

2.5.2.2 Value Study Stage

The value study is the core element of the job plan and it is composed of six phases: Information, Function Analysis (Analysis), Creativity, Evaluation, Development and Presentation.

Information Phase

The objective of the information phase is to complete the value study data package in order to produce an information base in VM studies. It also confirms the objectives, clarifies the assumptions and reviews the scope of the studies. The main tasks in this phase include: collecting historical cost data; identifying client's needs, wants and requirements; clarifying project givens and assumptions; obtaining design standards as well as specifications; having a thorough understanding of the project. This phase ensures that all members of the team fully understand the background, constraints, and limitations of the study so as to broaden their perspectives beyond their particular area of expertise. The client needs to give the team a brief on the objectives of the project, the project status and the client's major concerns. This phase will answer the following questions: 'What is it?' 'What does it do?' 'What does it cost?'

Function Analysis Phase

Function definition and analysis is the heart of VM studies. It is the primary activity that separates VM from all other "improvement" practices. The aim of this phase is to find the areas that have the greatest potential for savings or further improvement. This phase will be performed with the following steps:

- Identify and define functions of products and projects using active verbs and measurable nouns;
- Classify functions as basic functions or secondary functions;
- Develop function models by the use of Function Hierarchy or Function Analysis System Technique (FAST);
- Assign cost and/or other measurement criteria to functions;
- Establish worth of functions by assigning the previously established attitudes to functions;
- Compare cost to worth of functions to establish the best opportunities for improvement;
- Assess functions to select for further analysis;
- Key questions to be settled in this phase are “What does it do?” and “What does it cost?”

Creativity Phase

The objective of this phase is to develop a large quantity of ideas for performing each function selected for study. This is a creative type of effort, totally unconstrained by habit, tradition, negative attitudes, assumed restrictions, and specific criteria. Various creative techniques, such as brainstorming, the Delphi technique and lateral thinking, have been applied in this phase in order to facilitate the generation of as many ideas as possible by team members. Judgement or discussions are not allowed during this activity to maintain the free flow of ideas. The motto of this phase is “Every idea is a good idea”. The ideas generated will be evaluated in the next phase. “What else will do the job?” is answered in this phase.

Evaluation Phase

The objectives of the evaluation phase are to synthesize ideas and concepts generated in the creative phase and to select feasible ideas for development into specific value improvements. The collected ideas are examined according to both economic and non-economic factors, which are defined during the pre-study or evaluation phases, in order to highlight the best ideas for further study (Norton and Mc’Elligott, 1995). Various models and techniques, such as cost models, energy models, LCC models and the weighted evaluation technique may be used in this phase. In this phase, the question: “What does each alternative cost and how does it perform?” will be answered.

Development Phase

The objective of the development phase is to select and prepare the “best” alternative(s) for improving value. It investigates the selected ideas in sufficient depth and develops them into written recommendations for implementation. The data package prepared by the champion of each of the alternatives should provide as much technical, cost, and schedule information as is practical so that the designer and project sponsor(s) may make an initial assessment concerning their feasibility for implementation.

Presentation Phase

This phase aims to obtain concurrence and a commitment from the designers, project sponsors, and related stakeholders in order to proceed with the implementation of the recommendations. The recommendations are summarized in a final proposal and presented to all decision-making bodies and related interested parties for approval. The proposal usually includes a statement of follow-up procedures which are necessary to ensure the implementation.

2.5.2.3 Post-study Stage

The objective of the post-study stage is to assure the proper implementation of the approved value management change proposals (VMCPs). Assignments are carried out to track the progress and collect feedback on the proposal.

2.6 Benefits and Critiques of VM

In the USA, VM is widely used in many areas, such as construction, manufacturing, transportation, environment and even health care and so on. By applying VM to construction projects, highway and transportation department, US$ 1 billion were saved in 2000 (SAVE International, 2008b).

The primary objective of VM is to achieve better value and improved return on investment. Generally, this purpose can be achieved through:

- Cost and time savings;
- Consideration of options;
- Expenditure decisions;
- Minimizing wastage;
- Forecasting risks;
- Concentrating expenditure on adding value;

- Staging and phasing.

Much literature has discussed the benefits of VM studies. Dell'Isola (1982) described the benefits of implementing the VM techniques to the design and construction of a building project, as summarized in Table 2.1.

Table 2.1 Benefits of VM in Construction Projects (Dell'Isola, 1982)

Areas	***Description***
Time	Early application of VM will save design time by clarifying scope, reducing false starts, and helping to prevent budget overruns and redesign.
Standardization and simplification	VM helps ensure that simplified and standardized alternatives are considered after an analysis of redundant and unnecessary functions. This reduces cost.
Isolating design deficiencies	A VM team can uncover the potential design deficiencies that occurred during the design process.
Help in solving problems	VM is one of the best methods for solving the problems of performance, reliability, unforeseen conditions etc.
Conducting special studies	Techniques such as cost control, life cycle costing and energy conservation can be enhanced by combining them with VM studies. VM provides a comprehensive umbrella to optimize all inputs.

Besides these, Norton and Elligott (1995) suggested that the team approach of VM improves the decision-making process and listed a number of benefits as follows:

- Provides a forum for all parties involved;
- Provides an authoritative review of the entire project;
- Takes into account life cycle costs;
- Crystallizes the project's brief;
- Identifies project constraints, problems that may have been neglected.

Fong (2003) pointed out the early application of VM will deliver the following benefits:

- Recognize the strengths, weaknesses, opportunities and threats created by the 'build' or 'no build' options;
- Encourage the client's early commitment to the project;
- Clarify the client's needs versus wants;
- Enable the client to understand the problems that he is attempting to solve;
- Formulate the real needs of the company;
- Improve the accountability, feasibility and thoroughness of the investigation as alternative options are considered and evaluated;
- Disseminate the briefing process of the problem to all concerned parties, to make sure that there is no misunderstanding or miscommunication;
- Discuss the problems thoroughly from all the participants' points of view;

- Safeguard the decision from any future auditing exercise, as evaluation of alternative options has been made.

Although VM has been applied in construction for nearly forty years and has obtained a high reputation, critiques on it seem never to cease. It is reported by US Navy that failed VM studies account for about more than 2% of the total VM cases. Although this is only a small proportion, it should not be ignored. Typical critiques of VM in the construction industry include (Liu, 2003):

- The time consumption and interruption to the flow of design work – The 40-hour workshop is regarded as a standard approach for implementing VM studies and is recommended by many VM organizations and societies. The main problem for implementing this method is time. It is usually difficult to assemble all the key stakeholders for so long period and retain their attention from other things throughout this period of five days. What is more, the design team usually needs considerable time to review VM proposals and to re-design during the post-workshop period. Kelly and Male (1993) have suggested that sometimes the time for these processes is not allowed in a crowded design schedule.

- Many researchers have advocated that VM should be implemented as early as possible to maximize its results (Green, 1994; Dell'Isola, 1997). However, the most common point for VM intervention in practice is 35% of the way through the total design of a construction project since any changes to the original design are more easily introduced, costing data is more readily available in the form of the cost estimate and savings can easily be identified (Kelly and Male, 1993). This time seems too late to exert VM's influence on project concept formulating and feasibility studying.

- The traditional VM practice (it is carried out at 35% of the way through the design stage by an external team) is essentially a design audit (Palmer et al., 1996). The adversarial attitudes of the original design team cannot be easily changed, for many designers will argue that the VM team could not be expected to fully understand the project in a short period of time in comparison to the existing design team.

- The design liability of VM proposals is a thorny issue in VM applications. Whether the VM team or original team take the design liability for any recommendations implemented is debatable, although the design team determines whether the proposal recommended by VM team is accepted or rejected (Kelly and Male, 1993).

- A number of influential VM researchers gave a strong emphasis to function analysis (Dell'Isola, 1982; Zimmerman and Hart, 1982). They considered that function analysis was an indispensable factor contributing to the success of VM studies and made VM different from traditional cost reduction methodologies, which is also supported by Kelly et al. (2004). However, there is not a clearly defined approach to functional analysis in practice in North American VM (Palmer, 1992). Recently, in the book "Value Management of Construction Projects", (Kelly, et al., 2004) the process of function analysis is described in detail. This problem is expected to be eliminated.

- Structuring the cost model is still a problem. According to many guidance notes, the total cost should be broken down by the functions. However, the method may cause confusion when a component provides more than one function. For example, the window of housing contributes both ventilation and lighting; how much cost will be assigned to lighting and ventilation?

2.7 VM in Hong Kong

VM was introduced to Hong Kong in 1988 and is gaining increasing acceptance, especially after the Asian financial crisis in 1997 (Shen and Kwok, 1999). In recent years, VM has been increasingly applied to public construction projects. They were initiated by the Architectural Services Department (ArchSD), one of Asia's largest multi-disciplinary professional offices in the public sector, which has played a leading role in promoting and using VM in Hong Kong. In 1998, the Works Bureau and the Planning, Environment & Lands Bureau jointly issued a technical circular which demands VM studies for major projects in subordinate departments (Works Bureau, 1998). The Construction Industry Review Committee (2001) also recommended that VM should be used more widely in local construction. Having been promoted by the government, many construction projects have applied VM to ensure value for money.

Although the 40-hour job plan (USA approach) is widely used in many VM studies worldwide, there are several major differences between Hong Kong approach and USA approach, including stage of application, focus of study, number of participants and duration.

Stage of application: VM is usually applied in sketch or detail design stages in USA compared to feasibility or concept design stages in Hong Kong.

Focus of study: because of the different stages of application, VM in Hong Kong usually focuses on the strategic issues, while VM in USA is used to tackle technical problems at a tactical level.

Number of participants: 5-8 participants comprise the VM team in USA while there are usually 15-30 members in Hong Kong. The reason is that the independent team is the common approach in USA. In Hong Kong, the VM is applied in the early stage of the project which leads to a large number of stakeholders involved, so the VM team is much larger than in USA.

Duration: the USA approach usually lasts 40 hours, while 8-24 hours in Hong Kong approach (Shen, 1997). The potential reasons are time and cost (Shen, 1997). In Hong Kong, the land price is very high and occupies the majority cost of the project, so the clients normally give the designers and other consulting firms very limited time to complete the design and other related work. Hence, it is difficult to assemble key project stakeholders for such a concentrated period of 40 hours. Since the consultancy fees in Hong Kong are high, a five-day VM workshop means that the client needs to pay relatively large amount of money. As a result, the majority of VM studies in Hong Kong last from one to two days.

The short duration and large VM teams of VM studies in Hong Kong seem to affect the VM team to complete necessary analyses, evaluation and development of alternative solutions. In order to identify the difficulties encountered during VM studies in Hong Kong, a recent survey has been conducted by Shen and Chung (2000).

2.8 Problems Encountered in the Current VM Studies

The recent survey, which was conducted by Shen and Chung (2000) in Hong Kong, has listed the frequency of difficulties encountered in VM studies as shown in Table 2.2.

Table 2.2 Problems of VM Implementation in Hong Kong's Construction Industry (Shen et al., 2004)

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

Lack of Information

These research findings show that lack of information is ranked as the most frequently encountered difficulty in VM studies. This is consistent with the work conducted by Park (1993), who suggested that insufficient information is a key problem in VM studies. The potential reasons are suggested as follows.

Project information is poorly coordinated in the pre-study stage. It is necessary for stakeholders from various department or organizations invited to the VM workshop to learn project information prior to the studies. Hence, all project information should be gathered in the pre-study stage to produce a complete file. However, this process is not well coordinated in the construction industry. In Hong Kong, a one-day workshop is most popular in the construction industry instead of 40 hours, for the clients try to shorten the duration of VM studies to save costs. This results in situations in which participants can only receive the project information paper one day before the workshop. Consequently, they do not have sufficient time to study the paper and prepare the relevant materials and hence function analysis cannot be started quickly at the beginning of the workshops.

It is difficult to retrieve project information in VM workshops. Participants also reported that the direction of creative thinking is unpredictable, and it is therefore difficult for them to ensure that all relevant project information is ready in workshops. Moreover, a conference room is often a semi-closed environment and the physical boundary may prohibit them from retrieving any new information during workshops. As a result, participants lack project information in VM studies. They often make assumptions and put "unanswerable questions" into an action plan. This will delay subsequent tasks and increase "uncertainty" in the evaluation phase.

Lack of Participation and Interaction

The VM process is centred upon a participatory workshop involving a multi-disciplinary, representative group of people working together to seek the best value solutions for a particular situation. Thus, the contributions and involvement of stakeholders are important to the success of VM studies (AS/NZS 4183:1994 and Reichling, 1995). However, a lack of participation and interaction were ranked as one of the most frequently encountered difficulties in the survey. Some potential reasons are given below.

National culture difference. Hofstede (1991) defined culture as "the collective programming of the mind that distinguishes the members of one category of people from those of another". Much of the research on culture in the literature is based upon the four dimensions defined by Hofstede: power distance, uncertainty avoidance, individualism, masculinity. By comparing countries with Western-English cultures (e.g. UK, USA) and countries with Eastern-English cultures (e.g. Hong Kong, Singapore), Hofstede concluded that Western-English cultures should be characterized by high individualism and relatively lower power distance. Status differentials are usually considered undesirable. Whereas, Eastern-English cultures are with lower individualism and relatively higher power distance. Both superiors and subordinates expect power differences to be translated into visible status differentials. These characteristics of Hong Kong culture determines that it is more likely that people in Hong Kong are not willing to express their ideas in public, especially when their boss also attends the workshop. It is not unusual that some participants are reluctant to speak out in VM workshops because of shyness in public speaking.

Domination by a few individuals. Because of the short duration of VM workshop, any domination of the discussion would result in an uneven chance for each member to participate. If some members are active, they may dominate the discussion and prevent others from participating in the process.

Poor team spirit. Since a VM team usually is a temporary one, the members, coming from different disciplines and organizations, need time to develop good relationships. However, it is difficult to do this given the short duration of VM workshops. This may result in a lack of a sense of belonging and contribution to the studies.

Conformance pressure. The members of the VM team are from different hierarchical levels, including senior executives, middle managers, and works. Hence, senior members may, intentionally or unintentionally, exert pressure on junior members. The junior members may be afraid to criticize bad ideas from senior ones because of the traditional cultural and social status. As a result, some junior members become inactive and remain silent during the VM workshops. To overcome this problem, there are various methods applied to promote active participation in VM workshops, such as the "role-playing" method. However, this problem is believed to exist in current VM workshops and prohibits the members' participation and interaction to a large extent.

Difficulty in Conducting Evaluation and Analysis

The reasons for this problem are discussed as follows.

Insufficient time to complete analysis. It is suggested that the ideas produced in the creative phase require extensive consultation and in-depth investigation to analyse their feasibility and potential benefits, but the time is usually insufficient to complete the analysis in VM workshops. The analysis activities, such as backup calculation and cost analysis, are time-consuming and might take over half of the time of a VM workshop (Norton and McElligott, 1995). Moreover, the problem is believed to be more serious in Hong Kong than in America and Australia. Shen (1997) has suggested that the duration of VM workshops is very short and some sessions are used to educate participants who are unfamiliar with VM processes. Hence, it is difficult to complete all the necessary analysis within a VM workshop in Hong Kong's construction industry.

Insufficient information to support analysis. As discussed in the previous section, the lack of information still inhibits the process of analysis. Members can therefore conduct the evaluation and analysis processes efficiently in VM workshops. This may delay the progress of the evaluation and development phases in VM studies.

Many methods have been applied to eliminate or solve these difficulties. In recent years, the continuing improvement in the performance/price ratio of personal computing facilities has made information technology (IT) an effective tool for solving some efficiency-related difficulties (Shen, 1996). Hence, researchers have tried to apply IT in VM studies and have achieved good outcomes. In the following part, the application of IT in VM studies will be discussed.

2.9 Information Technology Applications in VM

Information technology (IT) can be a very useful tool in a VM specialists' toolbox and a number of successful applications have been reported (Murray, 1988; Paulson et al, 1989; Shen, 1993; Shen, 1996; Otero, 1997). Some examples of IT applications in VM studies are given below.

- A software package called Value Management Software Tools Set has been developed by the United Technologies Corporation in the US. The package can integrate data throughout VM studies and improve productivity through standardizing the methodology, computerizing the recurring tasks, and eliminating human errors in VM studies (Otero, 1997).

- In France, a specialized software package called Functional Performance Specification has been applied in VM studies (AFAV, 2000).

- In the United Kingdom, a knowledge-based system has been applied to support the decision-making process in VM studies (Shen, 1993).

- A research study has also been conducted on the use of an integrated computerized system in VM studies in Saudi Arabia (Assaf et al., 2000).

These packages, however, are specifically designed for particular organizations and they are limited to internal use only. In Hong Kong, it is observed that IT is underutilized in VM and none of the specialized software packages or advanced computer tools are being applied in practice.

GDSS, also known as Group Support Systems, is a computer technology which combines communication, computing, and decision support technologies to facilitate the formulation and solution of unstructured problems by a group of people (DeSanctis and Galluple, 1987). From the literature, the common findings of a number of field studies have proved the effectiveness of GDSS in practice. These field studies have consistently shown positive results, and nearly all "real world" users are extremely satisfied with GDSS applications. These findings demonstrate the effectiveness of GDSS in supporting the group decision-making process (e.g. Dennis et al., 1988; Chun and Park, 1998). Shen and Chung (2002) have also investigated the effect of using GDSS in VM studies and reported positive results.

2.10 Summary

Value management originated from US in the 1940s and was first applied in the construction industry during the early 1960s. At the beginning of this chapter, the definition and terminology associated with VM as well the differences and relationships between VA, VE and VM were discussed. Then the principles of VM were introduced and a typical job plan of VM workshops, especially the SAVE 40-hour job plan, was explained. It then proceeded to describe the common VM benefits and critiques. The

VM approach in Hong Kong was then reviewed and its problems were also presented. Finally, the existing applications of IT in VM studies were reviewed and discussed.

The Hong Kong approach is different from USA approach in four main aspects: stage of application, focus of study, number of participants, and duration. The application in the early stage of projects in Hong Kong determines that there are a large number of participants involved. The high land price and consultancy fee leads to short duration (usually one or two days) of VM studies. The short duration and large number of participants have affected the performance of VM studies in Hong Kong. The problems in current VM studies have been identified by Shen and Chung (2000) through a questionnaire survey. The problems are lack of information, lack of participation and interaction, and difficult in conducting evaluation and analysis. The possible reasons have also been discussed, for example, national culture difference and poor team spirit. In order to overcome the above problems, information technology is proposed by the author as a potential solution. GDSS is chosen as the technology in this research to improve the performance of current VM studies. A literature review on GDSS in details will be presented in the next chapter.

Chapter 3: A Review of GDSS

3.1 Introduction

In a typical construction project, a large number of participants tend to work separately on the design and production. This makes the process of design and construction fragmented. This fragmentation has led to well documented problems with communication and information processing and has contributed to the proliferation of adversarial relationships between the parties within a project. This fragmentation is also often seen as one of the major contributors to low productivity in construction (Nitithamyong and Skibniewski, 2004). The success of projects depends on collaboration between all the stakeholders. Information technology (IT) is now used more and more in the construction industry to improve the collaboration between stakeholders to reduce the problems generated by fragmentation.

In this part, a review of various literature that is pertinent to this research is presented. As one type of information technology, it is believed that GDSS may enable managers to deal with the increasing complexity of their jobs generated through the escalating amounts of information available in a group setting (Ackermann and Eden, 1994). Firstly, the background of GDSS is introduced. Then, the key features of GDSS are presented. Finally, previous empirical research is discussed. The phases covered in this chapter are: (1) the background of GDSS, (2) components of GDSS, (3) laboratory and field studies of GDSS, and (4) GDSS tools and characters.

3.2 The Background of GDSS

GDSS is a relatively new technology that emerged in the early 1980s. However, GDSS has been around for some time longer than this, especially in the US and UK, although it has rarely been defined as such. The first notions of what we now call GDSS were conceived in 1965 at the CASE Institute of Technology (Dennis et al., 1988). Strategic Choice (Friend and Hickling, 1987) and Soft Systems Methodology (Checkland, 1981) were developed in the UK for supporting the decision making processes of groups. In the US, Strategic Assumption Surfacing and Testing (SAST) was developed for similar purposes (Mason and Mitroff, 1981). These tools are all non-computer supported and rely instead on instruments such as large sheets of paper and coloured pens.

Computer supported GDSS has recently become an area of great interest and considerable money is being invested in its development. It is widely believed that computer support should be contained in a typical GDSS system. The earliest definition of GDSS given by Huber (1984) presents it as “a set of software, hardware and language components and procedures that support a group of people engaged in a decision related meeting”. The other most commonly cited definition is “GDSS, also known as Group Support Systems, is 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” (DeSanctis and Galluple, 1987). The researchers elaborated: “A GDSS aims to improve the process of group decision making by removing common communication barriers, providing techniques for structuring decision analysis, and systematically directing the pattern, timing or content of discussion”.

A special decision room emerged in the early 1980s to meet the need for a special meeting room. The technology in this kind of room would permit “each user seated at a workstation to interact with the set of requirements and the proposed design of the system” (Deninis et al., 1988). Today, GDSS is gaining acceptance as an effective tool for increasing the productivity of meetings in industry (Aiken et al., 1995; Gary, 1987). It has been widely used by international corporations, such as IBM, Motorola, Xerox, and by government departments in various countries, such as the US Navy and NASA (Flavin and Totton, 1996). Various GDSS systems have been developed, such as the Group Systems and CommandNet in University of Arizona, Cognito and Group Intelligence in GroupSystems Corporation and GroupSupport.com.

The term GSS (Group Support Systems) is also used in the current literature. GDSS is used throughout this thesis for consistency; however, the two terms should be regarded as interchangeable in meaning.

In order to give a more detailed picture of GDSS, an introduction to the components of GDSS is presented in the following section.

3.3 Components of GDSS

GDSS refers to the systems that provide computer-based aids and communication support for decision-making processes. A group decision support system is an interactive computer-based information system which combines the capabilities of communication technologies, database technologies, computer technologies, and decision making technologies to support the identification, analysis, formulation, evaluation, and solution of semi-structured or unstructured problems by a group in a user-friendly computing environment (Er and Ng, 1995). The components of GDSS include hardware, software, and people; but in addition, within the collaborative environment, communication and networking technologies are added for group participation from different sites. There are three fundamental types of components that compose GDSSs (Bidgoli, 1998):

- Software – the software part may consist of the following components: database and database management capabilities, user/system interface with multi-user access, specific applications to facilitate group decision-makers' activities, and modelling capabilities.

- Hardware – the hardware part may consist of the following components: I/O devices, PCs or workstations, individual monitors for each participant or a public screen for a group, and a network to link participants to each other.

- People – the people may include the decision-making participants and/or the facilitator. A facilitator is a person who directs the group through the planning process.

In order to test the effectiveness of GDSS, a variety of research studies have been done during the last several decades. A literature review has been conducted on these studies, as shown in the following section.

3.4 Laboratory and Field Studies of GDSS

As GDSS became an increasingly well established research topic, it moved into the realm of empirical research. There are two types of research: laboratory studies and field studies. In the mid 1980s, GDSS research was mainly centralized in university research laboratories. A common feature of laboratory research is its predominant use of student subjects. Although the limitation of using students as participants has long been recognized (Lorge et al., 1958), there was still a lot of research using students due to the difficulty of persuading real managers to participate in GDSS sessions. The key difference between the practice of laboratory and field researches is the extent of concern over the outcomes. Students who participate to solve trivial or contrived problems will not be very interested in the outcomes, whereas the businessmen, executives or other professionals who typically participate are very concerned about outcomes. Also, the outcomes (for example, decision quality) could be measured by checking how close a solution is to an “expert recommended solution”, this cannot be done in field studies where there is no such thing as a correct answer. Therefore, it is difficult to generalize results from laboratory experiments to field studies.

In the late 1980s, researchers began to realize that there was also a need to conduct field studies with ‘real people’. Compared to laboratory studies, field studies were slower to get going. Dennis et al. (1989) wrote that “not all field research is formally documented and submitted for publication”, from which it can be concluded that it is difficult to know precisely how much field research has been done.

The results from laboratories were inconsistent because of the different experimental settings and subjects adopted in studies. Nevertheless, the true effectiveness of GDSS in improving the group decision-making process has been assured by field studies. GDSS field studies have consistently shown positive results, and nearly all “real-word” participants are extremely satisfied with the application of GDSS in meetings (Dennis et al., 1988). It is concluded that GDSS is highly useful in improving the group decision-making process (Dennis et al., 1988; Chun and Park, 1998).

Since there are a variety of taxonomies of outcomes of GDSS research, including: Mennecke et al.’s (1992) group performance measurement through individual perceptions and group development; Pinsonneault and Kraemer’s (1990) task- or group-related outcomes; and Zigurs and Dickson’s (1990) distinction between performance and satisfaction outcomes. The latter taxonomy is the most representative one.

Following this taxonomy, the criteria used to assess the performance are as follows: decision quality, idea generation, and depth of analysis, participation and influence, conflict, and satisfaction outcomes (process satisfaction and outcome satisfaction). However, the laboratory studies and field studies are quite different and have a different nature; hence the same criteria could not be used to evaluate the two. Davison (1998) used the following criteria for field studies: decision quality, time and cost, participation and re-participation, and the satisfaction outcomes instead the ones presented above.

Two important observations about the outcomes have been done by Davison (1998). Firstly, as mentioned above, there is a prevailing inconsistency of results in laboratory experiment research. Jessup et al. (1990) comment that "unfortunately, empirical investigations thus far provide confusing results". There are many explanations for this inconsistency, for example, the lack of theory driven methodological research (Rao and Jarvenpaa, 1991), the prevalent use of students as subjects, the preference for using small sized groups, and the fact that these groups are formed for the sole purpose of the task studied (Pinsonneault and Kraemer, 1990), and even experimental design itself (Galliers and Land, 1987). A second observation is made by Pervan (1994) who notes that there has been insufficient replication of experimental conditions to make anything more than the most tentative of generalizations about GDSS performance.

3.4.1 Laboratory Studies

3.4.1.1 Decision Quality

There are two ways to measure the decision quality in laboratory studies. The first is to construct a task that has a known correct answer. The other is to employ expert as judges. Pervan (1994) used the first method in eleven of thirty lab studies and employed the second in another ten out of thirty studies. In only five out of sixteen studies did

GDSS-supported groups outperform unsupported groups (in the other fourteen studies, no comparison was made). In ten studies there was no difference, while in one, the unsupported groups outperformed the GDSS-supported groups. Zigurs et al. (1988) also commented that GDSS did not result in higher quality decisions. Dennis et al. (1991) made a summary of this kind of research and found that only four out of 25 studies have shown that GDSS-supported groups increased the effectiveness and three were without difference (in the other eighteen studies, no comparisons were made).

3.4.1.2 Depth of Analysis

As one of the most representative characteristics of a GDSS system, anonymity is important to the depth of analysis. In a related study, Connolly et al. (1990) found that anonymous groups generated more high quality ideas when subjected to a negative evaluation tone. It is also pointed out by Ocker et al. (1996) that distributed anonymous groups generated more creative and unique ideas in a software requirements development task. The expression of individual opinions was encouraged by the distributed and anonymous nature of the communication medium, resulting in a much wider range of ideas than was the case in face-to-face groups (Davison, 1998). Hence, deeper and broader analysis could be achieved.

3.4.1.3 Idea Generation

In GDSS empirical research, the quantity of unique or critical ideas generated by group members has been usually used to measure the performance of ideas, since it is more difficult to make a standard rule to tell what kinds of ideas are better than others. On the contrary, it is easy to count the number of unique or critical ideas. Much research has been conducted to compare the traditional face-to-face brainstorming methods and electronic brainstorming (EBS) approaches, such as studies by Diehl and Stroebe

(1991), Paulus et al (1997), Stroebe and Diehl (1994). Many studies have indicated that electronic approaches surpass the unsupported face-to-face brainstorming methods (Gallupe et al., 1990, 1991, 1992; Connolly et al., 1990; Dennis and Valacich, 1993).

Compared with nominal approach, empirical research in both group psychology and social psychology has consistently shown that people generate fewer and lower quality ideas in face-to-face brainstorming than in nominal brainstorming (Diehl and Stroebe 1987; Mullen et al, 1991; Paulus et al, 1995; Stroebe and Diehl, 1994; Sutton and Hargadon, 1996). However, there are mixed ideas on the question of whether nominal or EBS technology is more effective (Cooper et al., 1990; Dennis and Valacich, 1993; Gallupe et al., 1991; Pinsonneault and Kraemer, 1990; Valacich et al., 1994). According to the summary of past studies, EBS groups were never found to generate more unique ideas than nominal brainstorming groups for groups consisting of less than nine members (Cooper et al.,1990; Dennis and Valacich, 1993; Valacich et al., 1994; Gallupe et al., 1990 and 1991). For very large groups, there is still no clear evidence supporting the superiority of electronic brainstorming to nominal brainstorming (Pinsonneault et al., 1999).

3.4.1.4 Participation and Influence

In the GDSS environment, users can generate ideas in parallel and enter them simultaneously into their computers. This kind of parallelism helps reduce production blocking since users no longer have to wait for other to express their ideas (Gallupe et al., 1991; Jessup et al., 1990). Furthermore, the whole environment is anonymous; each participant can read on his or her screen the ideas generated by others without knowing from whom they originate. This may alleviate the fear of being criticized. As a result, EBS is also thought to reduce evaluation apprehension losses (Connolly et al., 1990;

Gallupe et al., 1991; Gallupe et al., 1992). However, while some studies do support the notion that GDSS-supported groups will participate more equally (Lewis, 1982; Applegate et al., 1986; George et al., 1987; Zigurs et al., 1988), in others, no differences were found between GDSS-supported and unsupported groups (Beauclair, 1987; Gallupe et al., 1988; Jarvenpaa et al., 1988; Watson et al., 1988). Nonetheless, there are several studies that indicate that GDSS-supported groups experience a more even distribution of influence (Zigurs et al., 1988) and a reduction of dominance (Lewis, 1982).

3.4.1.5 Satisfaction Outcomes

Jessup and Tansik (1991), and Cass et al. (1991) found that with GDSS support, face-to-face groups experience higher levels of satisfaction than dispersed groups. This can be attributed to the fact that in a face-to-face setting, the medium of communication is richer than in a dispersed situation, where visual and verbal interaction are impossible (Smith and Vanacek, 1989) unless video and audio conferencing tools are available.

For groups without GDSS support, a general observation has been made that as group size increases, group member satisfaction decreases (Mullen et al., 1989). This decrease may be attributed to the loss of individual recognition in the 'crowd' (Diener, 1980) and to the subjective discomfort associated with being surrounded by many people (Knowles, 1980). A number of studies have found that when GSS support is present, group size increases lead to satisfaction level increases (Gallupe et al., 1992), but these results are not entirely consistent, as Valacich (1989) found larger groups to be no more satisfied than smaller groups.

3.4.2 Field Studies

3.4.2.1 Decision Quality

Field studies indicate greater promise for GDSS. Nine of ten field studies indicated that effectiveness was improved (Dennis et al., 1991). However, it is arguable that there is no correct answer, or should not be a correct answer, in a field setting, and so decision quality is not a directly measurable variable (Davison, 1998). The nature of the problems in field studies does not always lend itself to easy judgement in the same way as the sometimes simplistic and contrived problems found in laboratory researches. Still, though, it may be possible for experts to judge the decision quality. Pervan's meta-analysis of the GDSS literature (1994) indicates that GDSS supported groups achieved significantly better solutions than unsupported groups.

3.4.2.2 Time and Cost

In field studies, since all the participants are ‘real people’, time and cost will be of great concern. In contrast, in laboratory studies time seems not to be so important as the participants are all students and their time is part of their normal study. Hence, it is more appropriate to look at time and cost together in the field studies. An almost unequivocal finding from field studies is that GDSS-supported groups are more efficient than unsupported groups (Adelman, 1984; Nunamaker et al., 1988).

3.4.2.3 Satisfaction

Satisfaction is a frequently measured variable in field studies and is often used as a justification for GDSS or an illustration of the benefits arising from GDSS use (Davison, 1998). Nunamaker et al. (1989) reported that their users at IBM were strongly satisfied with the computer-aided and group problem-solving processes. However, it is difficult to measure the level of satisfaction when the participants are not satisfied with the use of the GDSS.

The research literature indicates that both process and outcome satisfaction are higher in GDSS-supported groups than unsupported groups (Pervan, 1994). The data is typically collected from post-session questionnaires, but unstructured interviews are also employed.

3.5 GDSS Tools and Characters

In this section, the typical characteristics and general components of a GDSS system are discussed. A group decision support system is defined as an interactive computer-based information system which combines the capabilities of communication technologies (LAN, WAN, telecommunication), database technologies (relational, hierarchical, and network models), computer technologies (mainframe computer, minicomputer, microcomputer, personal computer, VLSI system, supercomputer), and decision technologies (linear programming, integer programming, goal programming, compromise programming, multi-objective linear programming, sequential optimization, dynamic compromise programming, AHP, Electre, multi-attribute utility theory, Q-analysis, risk analysis, simulation, forecasting, statistical analysis, decision tree, etc.) to support the identification, analysis, formulation, evaluation, and solution of semi-structured or unstructured problems by a group (Er and Ng, 1995). It is clear that a group decision support system is more than just a communication system; it involves decision modelling as well. Decision modelling, of course, requires utilizations of a model base and a database for alternative assumptions and choice analyses.

One of the key factors in GDSS, apart from decision modelling, is to facilitate the exchange of information, ideas, opinions, and options leading to decision making during group deliberations. Another common aspect of GDSS is the anonymity of participants. According to the above definition and these two important factors, a list of the components of GDSS software is shown as follows:

- Electronic brainstorming:
  - ✧ Simultaneous and anonymous generation of ideas
  - ✧ Ideas can be sorted by keywords.
- Group outliner:
  - ✧ Creation of a multilevel list of topics in a tree or outline structure
  - ✧ Comments can be attached at each level of the outline
  - ✧ Participants can view others comments.
- Topic commentator:
  - ✧ Allows participants to comment on a list of topics.
- Whiteboard:
  - ✧ Group-enabled drawing and annotation tool.
- Categorizer:
  - ✧ Categories of ideas are created
  - ✧ Ideas can be placed into the desired category.
- Vote:

- Develop consensus through group evaluation of issues
- Results are tabulated electronically and displayed on the screen on individual workstations
- Methods:
  - Rank order
  - Multiple selection
  - 4-point or 5-point agree/disagree
  - Yes/no; true/false.

- Alternative analysis:
  - Weight or rate a list of alternatives against a list of criteria
  - Results can be displayed on the screen.
- Survey:
  - Creation, administration and analysis of a questionnaire distributed to participants.
- Activity modeller:
  - Business process modelling tool.
- Briefcase:
  - Tool to improve individual productivity

- Provides access to commonly used applications such as word processing, e-mail.

- Personal Log:
  - Tool to improve individual productivity
  - Allows participants to make notes during a meeting.

3.6 Summary

In this chapter, a variety of GDSS research studies have been reviewed. First, the background and components of GDSS were introduced. Then the outcomes from both laboratory and field studies were summarized. Based on the review of the laboratory and field studies, it can be concluded that GDSS has the potential to improve the performance of group decision making both in the processes and outcomes. Various indicators to judge whether the GDSS is effective provide good reference on how to measure the performance of GDSS use in value management studies. Finally, the review of GDSS tools and characteristics provides useful information on how to design a GDSS prototype to support value management studies. This literature review is of great importance to the research as a whole in that it sets the scene for the research methodology, models and instrument that follow in the subsequent chapters. The next chapter discusses the major considerations during the development of the GDSS prototype, Interactive Value Management System (IVMS).

Chapter 4: Model Building

4.1 Introduction

A variety of GDSS packages have been built by different university research teams and other organizations since the 1980s, and many GDSS packages such as GroupSystems and Decision Explorer are available on the market. However, they typically offer a small set of tools such as electronic brainstorming and idea evaluation or voting to support discussion and decision. In order to overcome the problems listed above to make the VM process more efficient and effective, more specific functions are required, such as idea generation, function analysis, and decision matrices. With the recent development of Web technology, it is possible for Internet applications to address problems in various areas. For example, Palaneeswaran and Kumaraswamy (2005) presented a Web-based client advisory decision support system for design builder prequalification; Lee et al. (2006) introduced a Web-based system dynamics model for error and change management on construction design and construction projects; and Xie and Yapa (2006) developed a Web-based system for large-scale environmental hydraulics problems. A Web-based numerical model system has many advantages over a desktop model system, including easier access to distributed data and to the model system, efficient upgrades, improved compatibility, better user-developer communications, improved maintenance of security and the integrity of the model, and limited access to protected data (Xie and Yapa 2006). Hence, during this research, the author integrated Web technology and GDSS to build a Web-based GDSS prototype named IVMS to meet the needs of VM studies.

4.2 Consideration of GDSS Prototype Development

The following section aims to find the circumstances in which GDSS use in VM workshops can achieve the best performance. According to the situation, there are many factors that may influence the effect of GDSS use. Dennis and Wixom (2002) have summarized five key factors from the literature, four of which were drawn from Dennis et al. (1992) and one from Fjermestad and Hiltz (1999). These are: (1) the group task, (2) the GDSS tool, (3) the composition of the group, (4) the size of the group and (5) the effect of facilitation on the group process. In order to investigate whether GDSS use is appropriate and under what circumstances GDSS use may improve the performance of VM workshops, these five factors need to be analyzed according to the characteristics of VM.

Task: McGrath (1984) has divided tasks into four categories, two of which have been commonly used in GDSS research: generation tasks and decision-making tasks. Dennis and Wixom (2002) have suggested the difference between the two. The main objective of generation tasks is that participants work together to generate a number of ideas. Generation tasks are additive tasks, in that the outputs of individual participants are combined to form the team output. Participants do not need to select among ideas nor come to a consensus on a shared understanding. Decision-making tasks, in contrast, require participants to develop a shared understanding of criteria and alternatives and reach a consensus on which alternative is best. There are different primary measures of performance between idea generation and decision-making tasks. Idea generation mainly focuses on the number of ideas produced per particular time period, whereas decision-making primarily focuses on decision quality and time. Satisfaction with the process and outcome is considered in both of them. A VM workshop involves a very systematic process which is known as the job plan (Norton and McElligott, 1995).

According the Value Methodology Standard (SAVE International, 1998), one of the key stages of the job plan is to generate many alternatives for accomplishing the basic functions required by clients and then evaluate and select the best ones. Hence, a VM study is a decision-making task rather than a generation task. As mentioned earlier, decision quality, time and satisfaction with process and outcomes should be measured during this study in order to investigate the effectiveness of GDSS. Fjermestad and Hiltz (1999) compared idea generation and decision-making tasks and found that there were a greater proportion of positive effects to negative effects for idea generation across a wide array of outcome variables. Shaw (1998) also compared GDSS groups performing idea generation and decision-making tasks and found that the group performing idea generation tasks was satisfied. This is in consistent with Dennis and Wixom (2002). Since a VM study is a decision-making task, it may not be appropriate to use GDSS in VM studies from the aspect of "Task". However, one of the key stages in a VM workshop is the "Creativity" phase, which aims to generate as many alternatives as possible. This stage can be regarded as a generation task, and its performance can be improved by the use of GDSS. It is commonly believed that the more alternatives generated, the more quality ones can be obtained. The generation of quality alternatives is one of the main objectives of a VM workshop. Hence, the performance of the whole VM workshop partly depends on the quality of the "Creativity" phase, and therefore, better performance of VM workshops could be achieved by using GDSS in this key "Creativity" phase.

GDSS tool: Any application of information technology to support the work of groups may be considered a GDSS (McCartt and Rohrbaugh, 1989). There are a variety of GDSS tools that differ in many ways. DeSanctis and Gallupe (1987) have suggested three distinct levels of group intervention with GDSS. Level 1 GDSS attempts to provide technical features to remove communication barriers. Such features as automated input of anonymous ideas and concerns, electronic voting, and a large viewing screen can be found in most “electronic board rooms” or “computer-supported conference rooms” (McCartt and Rohrbaugh, 1989). Level 2 GDSSs provide decision modelling and group decision techniques aimed at reducing uncertainty and “noise” that occurs in the group’s decision process. Except for the same level 1 capabilities, these level 2 tools include decision-analytic aids and ways to organize and analyze information, such as by the use of multi-criteria decision models, voting and modelling. Level 3 GDSSs are characterized by some form of computer-mediated communication with electronic enforcement of a variety of possible rules that substantially alter the pattern, timing, or content of the interaction process of the group. Level 3 GDSSs include, for example, so-called “computerized conference” or “decision network” system designs (McCartt and Rohrbaugh, 1989). Fjermestad and Hiltz (1999) compared the use of level 1 and level 2 tools and found that use of level 2 tools led to a greater proportion of positive effects across a wide array of outcome variables. Shaw (1998) has similar findings. A meta-analysis study also suggests that decision quality is higher when using level 2 tools (Dennis and Wixom, 2002). Therefore, it is more appropriate to use level 2 GDSS tools than level 1 in VM workshops.

Composition of group: There are normally two working manners when teams use GDSS. Teams can work together virtually, using GDSS to work over the Internet in different places and at different times, or they can use GDSS in specially designed meeting rooms that enable members to work face-to-face (Dennis and Wixom, 2002). The main difference between the two is that virtual teams rely more on the electronic communication provided by GDSS and there is lack of concurrent feedback from the receiver to the sender. Although verbal communication is important for decision-making because group members must come to a shared understanding (Daft and Lengel, 1986), it is suggested that most shared understanding comes not from the verbal or typed components of communication, but rather from non-verbal messages such as facial expressions and voice (McCaskey, 1979; Penley et al., 1991). Reduction in concurrent feedback will reduce the accuracy of communication (Kraut et al., 1982) and increase the time taken to complete a task (Krauss and Weinheimer, 1966). Thus, the use of virtual team would be less effective and take more time for the reduction in concurrent feedback. Dennis and Wixom (2002) conducted a meta-analysis and found that decision quality is lower for virtual teams. Hence, teams that use GDSS in face-to-face-settings should experience higher decision quality and more efficiency during a VM workshop which is a decision-making process. It can be concluded that face-to-face teams are more appropriate than virtual teams in a GDSS-supported VM workshop.

Group size: Hunt (1992) stated that for optimum activity, group size should be between six and ten people. For larger groups, there is danger that the group will fragment and small cliques will form. Olaniran (1994) suggested that the maximum effective group size for groups without GDSS is believed to be five participants. However, the situation will change for teams using GDSS. Fjermestad and Hiltz (1999) concluded that larger groups outperformed smaller groups across a wide variety of factors in a GDSS environment. Dennis and Wixom (2002) also found, through a meta-analysis study, that larger teams using GDSS took less time and were more satisfied relative to their control groups than were smaller groups. In current VM workshops, the VM teams tend to be large (18-20) and are very rarely below ten (Kelly et al., 2004). The large team in VM workshops is an advantageous condition for GDSS use.

Facilitation: It is commonly believed that facilitation can improve outcomes in a GDSS environment (Mejias et al., 1997). There are two key dimensions: process facilitation and content facilitation (Massey and Clapper, 1995). Process facilitation attempts to help the group in structuring the process by which it uses the available GDSS tools. Content facilitation attempts to improve task performance directly by offering insights, interpretations, or opinions about the task and various decision alternatives available to the group. Dennis and Wixom (2002) found that process facilitation leads to higher decision quality and higher satisfaction with the process. In a GDSS-supported VM workshop, a GDSS facilitator is needed in order to facilitate the participants on the use of GDSS. The VM facilitator controls and leads the team through a process using analytical, arbitration, guiding and influencing skills to achieve the objectives (Kelly et al., 2004). From the above analysis, the GDSS facilitator should be a process facilitator, while the VM facilitator takes the role as a content facilitator. Another issue that should be considered is the quality of facilitator. A VM facilitator is supposed to be knowledgeable and skilled in the VM process. The GDSS facilitator should have a good understanding of the functions provided by the GDSS in order to apply it properly.

Finally, the above analysis can be summarized as follows:

- The decision quality, time, and satisfaction with process and outcomes should be measured in order to investigate the effect of using GDSS;
- According to the literature, better performance of VM workshops could be achieved by using GDSS in the “Creativity” Phase;
- A level 2 rather than a level 1 GDSS should be used to support the VM workshops;

- According to the literature, a face-to-face setting is more appropriate than a virtual environment when using GDSS in VM workshops;
- The group size of VM teams is appropriate for GDSS use;
- A GDSS process facilitator should be provided in a GDSS-supported VM workshop.

During this research, a web-based GDSS prototype named Interactive Value Management Studies (IVMS) has been designed, the details of which are introduced in the following sections.

4.3 Purpose of IVMS

IVMS aims to supply a useful toolbox that can support VM practitioners in overcoming the problems in traditional VM workshops. Another concern is to build a computerized project database that contains various types of projects, which can be used as references for similar projects. It should be stressed again that IVMS is designed not to replace traditional VM procedures but to act as a beneficial complement by providing technical features. The system can be used by a team whose members are geographically remote or integrated with the traditional face-to-face method to exploit the full benefits of both modes of communication.

4.4 Development Environment

Microsoft Windows Server 2003 is adopted as the operating system (OS), and Microsoft SQL server, which supports concurrent data access, is adopted as the database management system (DBMS). Microsoft Visual Studio.Net 2003 is used as the development environment of the application system. The system is coded mainly by using ASP.NET (Active Server Pages.NET), C#, and JavaScript.

IVMS is built based on the Windows SharePoint Services (WSS) designed by Microsoft, which serves as a platform for application development, typically to facilitate the development of Web-based programs for information sharing and document collaboration. The purpose of IVMS is to help increase individual and team productivity. Including such IT resources as team workspaces, e-mail, presence awareness, and Web-based conferencing, WSS enables users to locate distributed information quickly and efficiently, as well as connect to and work with others more productively. With the help of WSS, IVMS can be easily integrated with other useful software, including Microsoft Visio, Office, and Messenger. Based on the functions provided by WSS, IVMS integrates GDSS with the VM methodology to provide useful support to overcome problems in VM workshops.

Based on the characteristics of VM workshops and the features of GDSS, the system structure of IVMS is designed as shown in Fig. 4.1.

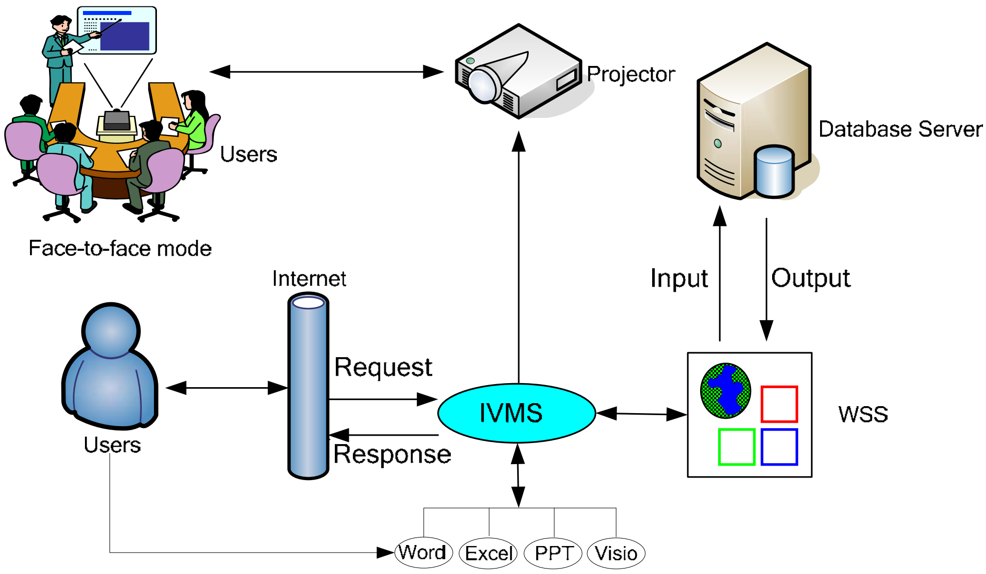


Fig. 4.1 System Architecture

4.5 Main Features

IVMS is a server-based application that supports multiplatforms including Windows 98, Windows 2000, and Windows XP. The software tools are installed and operated in an Internet server; no installation is required on users' computers. However, users also need to install some common software, such as Microsoft Office and Adobe Acrobat Reader, to view related documents stored in the system. It allows team members to have access to the system at any machine, anytime, and anywhere in the pre-workshop phase. The Web-based interface is designed to be user friendly, which makes self-learning easy and effective.

The main tools provided by IVMS include a document library, an online questionnaire survey, virtual meeting rooms and decision matrices, etc. Through these tools, IVMS aims to facilitate information management, improve communication, and assist decision analysis in the VM workshops. The following section illustrates how IVMS can contribute to VM workshops.

4.6 Summary

This chapter is a model building chapter, which mainly discusses the considerations taken into account during the development of the GDSS prototype. The major factors considered during the model building process include task, GDSS tool, group composition, group size, and facilitation. Based on the analysis of the above factors, a web-based GDSS prototype named IVMS has been developed. Its development environment and main features are also described during this chapter. A framework on how to integrate IVMS with VM workshops is illustrated in Chapter 6.

Chapter 5: Research Methodology

5.1 Introduction

This chapter introduces the main research methods adopted during this research, including experimental studies, questionnaire survey and action research. The research process is first outlined. Then the research strategy which examines different research methods and explains the reasons why the above three methods are selected and others are rejected is provided. Finally, the three research methods are introduced separately in details.

5.2 Research Propositions

The whole research process is shown in Fig. 5.1. This research stemmed from Shen and Chung's (2004) research, which investigated the problems in current VM studies. Literature reviews on VM, GDSS and team dynamics were conducted to form two research propositions:

a. Literature review on current VM studies

-> VM users in Hong Kong encounter the problems of lack of active participation and insufficient time and information in decision analysis.

b. Literature review on GDSS

-> GDSS can reduce process losses and increase process gains during the group decision-making process.

Based on the two research propositions, the main research hypothesis is:

The use of GDSS can provide technological efficiencies and interaction advantages, which can overcome the difficulties encountered in current VM studies.

To address the research propositions, the research methodology taken during this research has adopted three primary research methods as shown in Fig. 5.1:

- Four experimental studies to validate the GDSS prototype and to investigate the effect of using GDSS in VM studies. These studies compare VM workshops that had GDSS support with traditional VM workshops; a web-based GDSS prototype was developed as a tool.

- Action research in the form of a VM workshop with a local government department to further validate the GDSS prototype and investigate the effects of GDSS use in a real-life study;

- A questionnaire survey to identify critical success factors of using GDSS in VM studies.

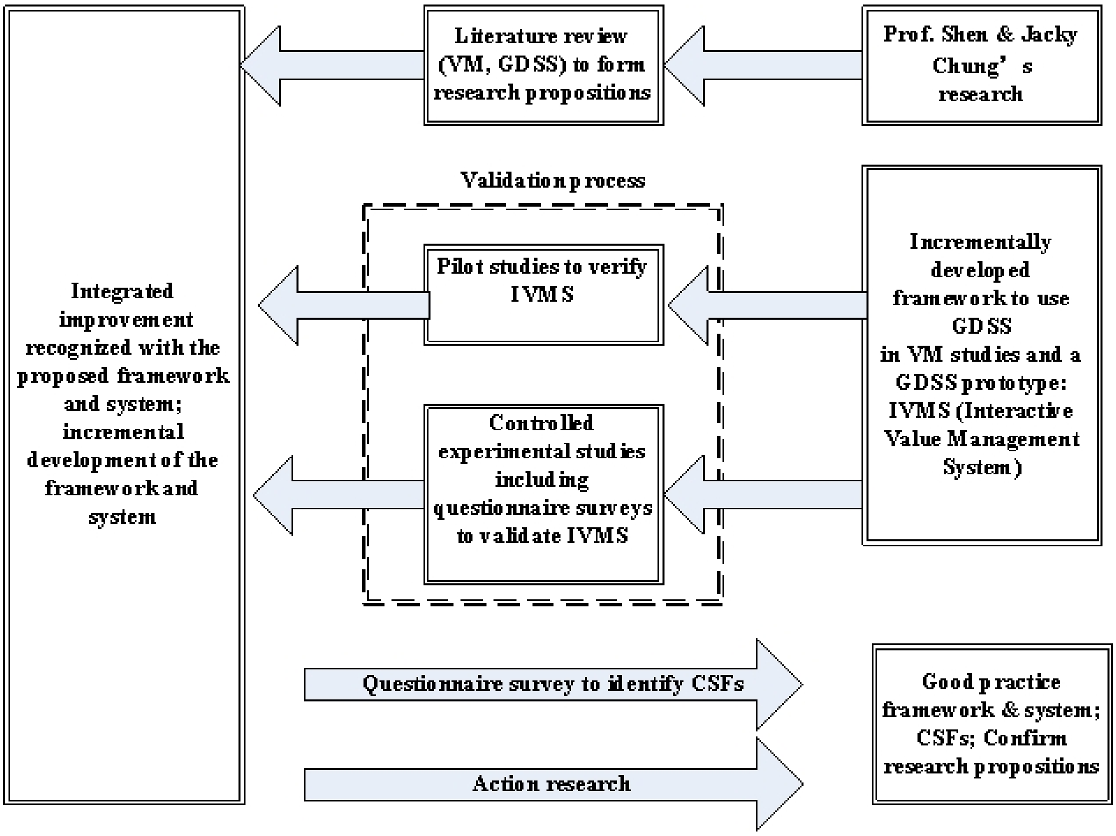


Fig. 5.1 Research Process

5.3 Research Strategy

The primary classification of research methods – quantitative and qualitative research – is used widely. Fellows and Liu (2003) describe the two methods as follows:

- Quantitative approaches tend to relate to positivism and seek to gather factual data and to study relationships between facts and how such facts and relationships accord with theories and the findings of any research executed previously.

- Qualitative approaches seek to gain insights and to understand people's perception of 'the world' – whether as individuals or groups.

Actually, the two approaches are not mutually exclusive. Triangulation which integrates the two techniques together can be very powerful in gaining insights and results that assist in making inferences and in drawing conclusions (Fellows and Liu 2003). The research undertaken in this study is more like a triangulation study.

It is necessary to conduct a review of other research methods before the main research approaches are chosen. Each commonly used research method, including its characteristics and applicability, is considered and listed as follows:

Case study: a case study is an empirical enquiry that investigates a contemporary phenomenon within its real-life context (Yin, 2003). It could have been adopted to examine the effect of using GDSS in VM studies. However, there is no case study information in this area, so this method was not employed.

Delphi technique: a technique to 'structure and facilitate group communication that focuses upon a complex problem so that, over a series of iterations, a group consensus can be achieved about some future direction' (Loo, 2002). This technique could have been used to determine the CSFs of using GDSS in VM workshops. However, it would likely have been a timely process and it would not be easy to find a group of experts that have GDSS experience. Instead, a questionnaire survey sent to the experiment participants was employed.

Experimental study: it is relatively easy to plan experiments which deal with measurable phenomena (Fellows and Liu, 2003). In this research, the effects of using GDSS in VM studies need to be measured. It is suitable to design experimental studies to measure the performance of VM studies with GDSS support.

Action research: the researcher becomes involved in a practical situation and observes that situation to learn lessons to improve practice (Waser and Johns, 2003). In this case, a GDSS prototype has been developed and validated during experimental studies, so an action research study could be used to further confirm the theory in a real VM study.

Questionnaire survey: a methodical technique that requires the systematic collection of data from populations or samples. This involves the researcher targeting a sample of persons who have been exposed to or experienced an event or process to question them in relation to these (Denzin and Lincoln, 1998). Hence, there are two areas that require a questionnaire survey. Firstly, during the experimental studies, a questionnaire survey is a useful complementary tool to collect data from participants. Secondly, a questionnaire survey is the most likely method to collect practitioners' views on the CSFs of using GDSS in VM studies. Hence, a questionnaire survey is designed to identify the CSFs during this research.

5.4 Experimental Studies

Hicks (1982) defines an experiment as a 'study in which certain independent variables are manipulated, their effect on one of more dependent variables is determined and the levels of these independent variables are assigned at random to the experimental units in the study'. The experimental style of research suited best to 'bounded' problems or issues in which the variables involved are known, or at least hypothesized with some confidence (Fellows and Liu, 2003). In the past two decades, past research has demonstrated that GDSS is successful in improving the efficiency, reliability, and quality of the group decision-making process (Dennis et al. 1990; Greenbery 1991; Nunamaker et al. 1996). Hence, it is reasonable for us to build the main hypothesis of this research: the use of GDSS can provide technological efficiencies and interaction advantages, which can overcome the difficulties encountered in current VM studies. It is also the main reason why experimental studies are chosen as the primary research style.

To conduct the experimental studies into the effect of using GDSS in VM studies, a GDSS system is needed. First, it is necessary to decide whether to develop a system or use a GDSS package available in the market, since there are many GDSS packages available for use. A variety of GDSS packages have been built by different university research teams and other organizations since the 1980s, and many GDSS packages such as GroupSystems and Decision Explorer are available on the market. However, they typically offer a small set of tools such as electronic brainstorming and idea evaluation or voting to support discussion and decision making. In order to overcome the problems listed above to make the VM process more efficient and effective, more specific functions are required, such as idea generation, function analysis, and decision matrices. With the recent development of Web technology, it is possible for Internet applications to address problems in various areas. For example, Palaneeswaran and Kumaraswamy (2005) presented a Web-based client advisory decision support system for design builder prequalification; Lee et al. (2006) introduced a Web-based system dynamics model for error and change management on construction design and construction projects; and Xie and Yapa (2006) developed a Web-based system for large-scale environmental hydraulics problems. A Web-based numerical model system has many advantages over a desktop model system, including easier access to distributed data and to the model system, efficient upgrades, improved compatibility, better user-developer communications, improved maintenance of security and the integrity of the model, and limiting access to protected data (Xie and Yapa 2006). Hence, the author integrated Web technology and GDSS to build a Web-based GDSS prototype named IVMS

(Interactive Value Management System) during this research to meet the needs of VM studies. Secondly, it is necessary to decide what type of GDSS should be developed at the beginning of the research. Five factors are considered, including the task, the GDSS tool, the composition of group, the group size, and method of facilitation. The details are introduced in Chapter 4.

5.4.1 Types of Experimental Studies Undertaken

Three types of experimental studies have been conducted: a comparative study of idea generation between traditional value management workshops and GDSS-supported workshops, a validation study of using GDSS in the full process of VM workshops, and a comparative study of traditional VM workshops and GDSS-supported workshops. The framework for the experimental studies is illustrated in Fig. 5.2. All of the experimental studies are designed following the main stages proposed by Fellow and Liu (2003), as shown in Table 5.1. Details of the studies are introduced in Chapter 7.

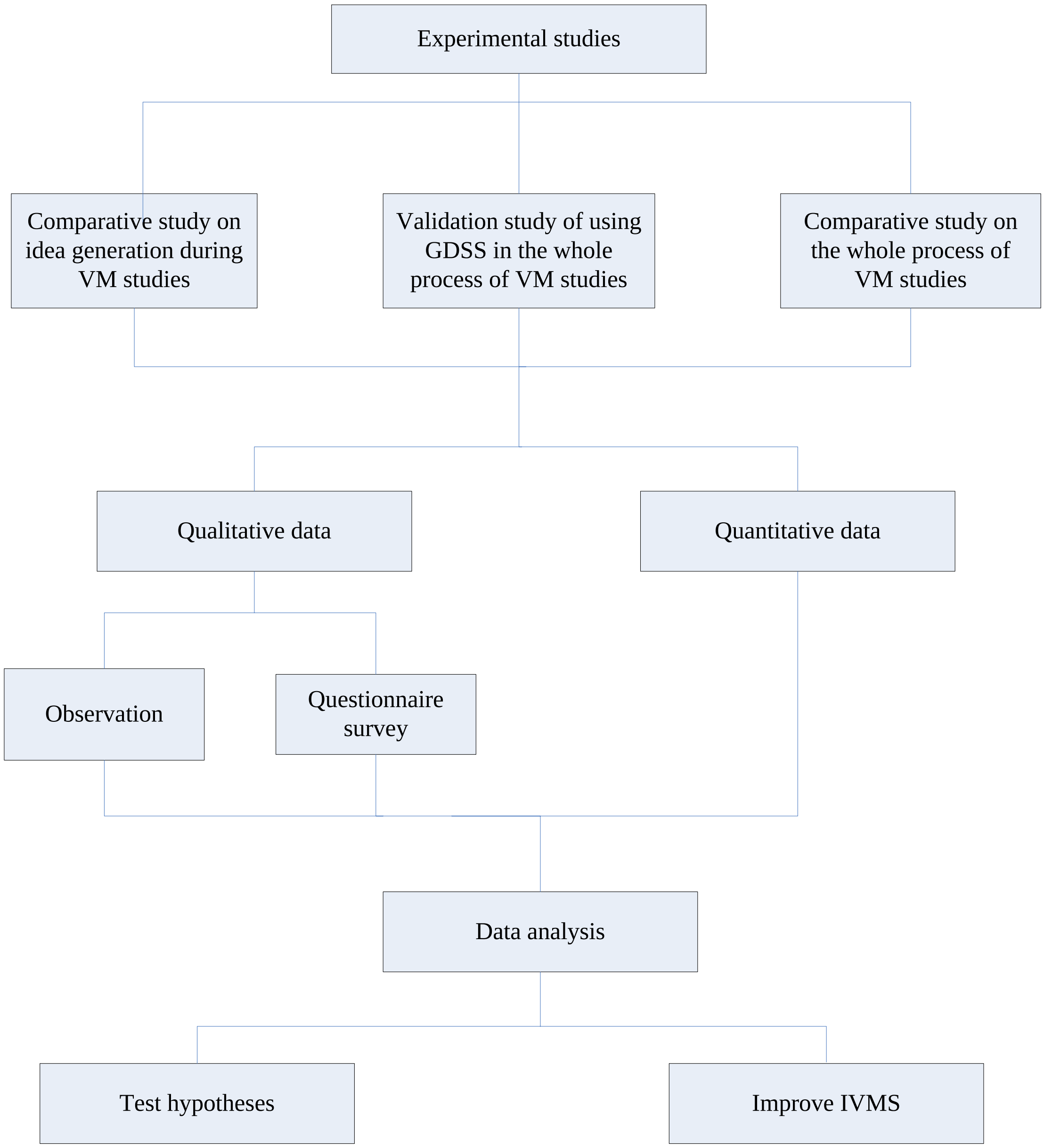


Fig. 5.2 Experimental Studies Undertaken

Table 5.1 Main Stages of Experimental Studies (Fellow and Liu 2003)

Experimental Design	
Main Stages	**Aims**
Aim	Test a theory, hypothesis or claim
Objectives	Determine what is to be tested and what limits to the scope of the experiment apply.
Identify variables	Determine the variables likely to be involved and their probable relationship – from theory and literature.
Hypothesis	State the hypothesis which is to be tested by the experiment
Design the experiments	Decide what is to be measured and how those measurements will be made. Consider confidence intervals for the results and practical aspects – time and costs of the tests.
Conduct the experiments	Maintain constant and known conditions for validity and consistency of results and collect data accurately
Data analysis	Use appropriate techniques to analyze the results of the experiment to test the hypothesis
Discuss	Consider the results in the context of the likely impact of experimental conditions and procedures as well as theory and literature derived knowledge
Conclude	Use the results of the analyses, the known experimental techniques and conditions, via statistical inference etc., and, in the light of other knowledge, to draw conclusions about the sample and population
Further research	Note further work which is advisable to test the hypothesis more thoroughly

5.5 Questionnaire Survey

A questionnaire survey is a methodical technique that requires the systematic collection of data from populations or samples, and involves the researchers targeting a sample of persons who have been exposed to or experienced an event or process to question them in relation to these (Denzin, 1998). The purpose of this questionnaire was to investigate the CSFs of using GDSS in VM workshops.

5.5.1 Research Framework

The specific research methodology of this research study follows the concept of Walker's (1997) model. Chan et al. (2004) also followed this model to explore critical success factors for partnering in construction projects. This model contains a literature review, face-to-face interviews, a pilot study, and a survey questionnaire (as shown in Fig. 5.3).

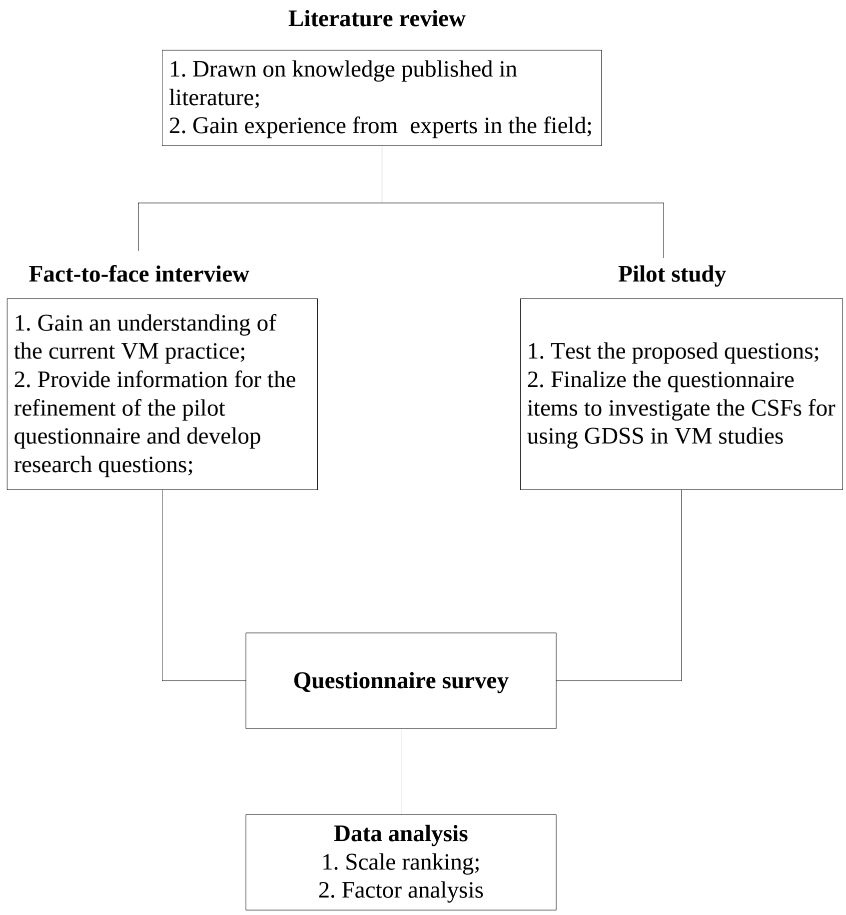


Fig. 5.3 Research framework [adapted from Walker (1997)]

As shown in Fig. 5.3, a literature review was conducted first to develop a research framework for the research study. The findings from the literature review also provided a basis for the following face-to-face interviews. A series of factors were also identified during the literature review, and then scrutinized and verified through eight face-to-face interviews with a number of selected practitioners and researchers with eminent experience in value management, including VM facilitators, consultants, and VM researchers in UK. The interviews were conducted in the interviewee's head offices, and lasted for one to one and a half hours. During the interview, the interviewees were also asked to review the pilot questionnaire and provide information for the refinement of the questionnaire. Before the questionnaires were sent out, a pilot study was conducted to ensure the survey questions were appropriate and clear to the target group. Finally, four perspectives were used to assess the factors, including participant perspective, facilitator perspective, technology perspective, and workshop perspective. As shown in Fig.5.4, there are 12 factors contained in the four perspectives.

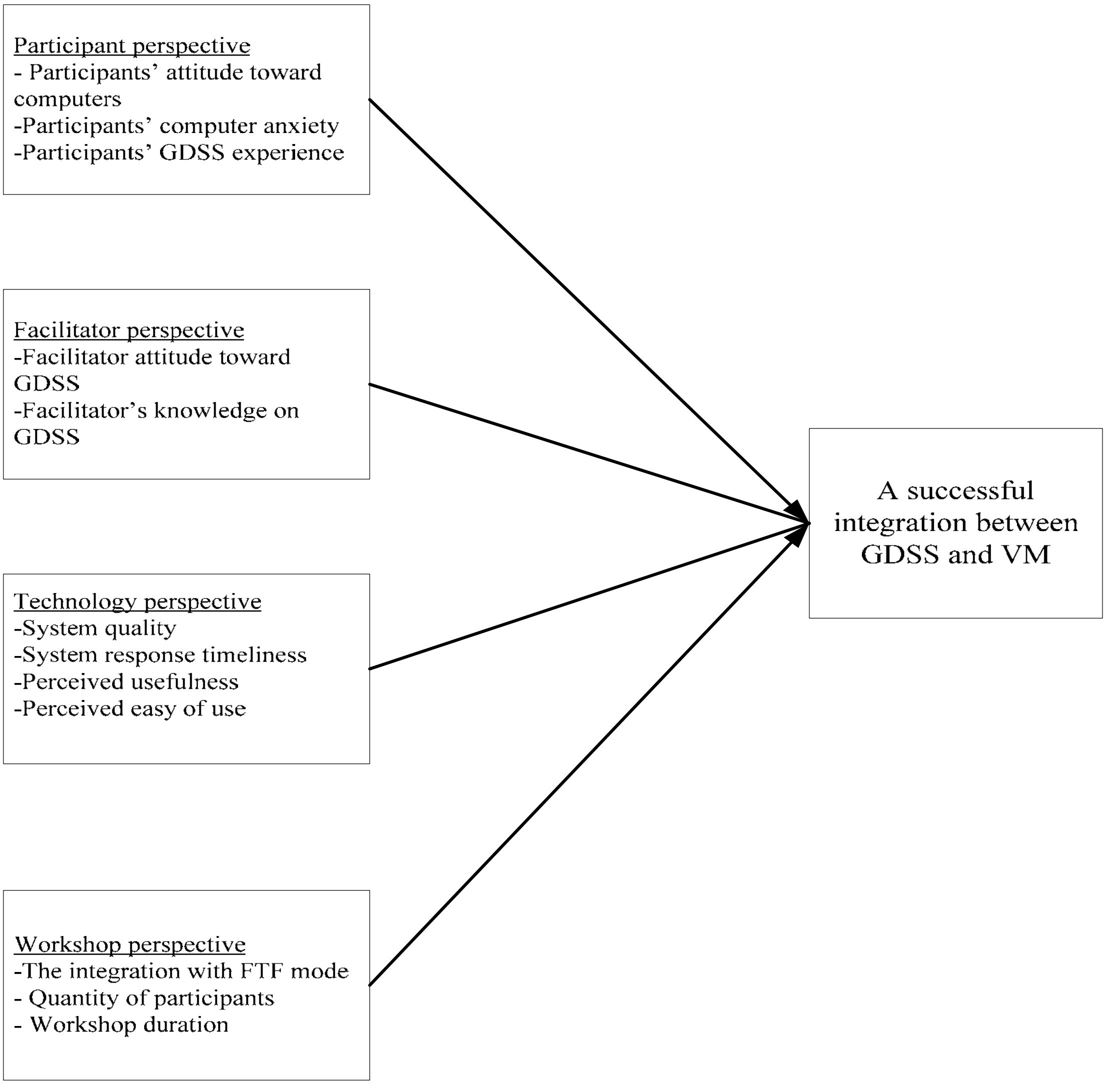


Fig. 5.4 Nominated Critical Success Factors for Using GDSS in VM Studies

5.5.2 Questionnaire Process

In order to make the results of the questionnaire survey more reliable, an experimental study, during which the GDSS prototype was used to conduct a VM workshop, was designed and conducted. A GDSS room was established to conduct GDSS-supported VM workshops during this study, as shown in Fig. 5.5. Each participant was provided a laptop, and a wireless network was set up. Each user could access the system on his/her laptop during the whole workshop. The projector and a large common viewing screen were also provided in the GDSS room, allowing the display of public notices or group information. The moveable seats and tables could be arranged in a U-shape or a semi-circle for different situations.

Fig. 5.5 A VM Study with GDSS Support

The participants were formed from 42 part-time postgraduate students enrolled in a value management course at the Hong Kong Polytechnic University. An integrated component of the course was a strategic simulation that required students to organize a VM workshop. All of the students have been working in the construction industry for several years. Their work experience enabled them to act and think in similar ways to real-life VM study participants during the experiment.

The task description was given to the participants three weeks before the VM workshop in order to help ensure the participants were fully prepared. The workshop was designed as a one and a half day VM workshop. During the whole process of the VM workshop, each session was observed unobtrusively by the author. The author recorded information relevant to the workshop performance, and also provided technical support to ensure the system worked normally during the workshop. After the experimental study, a questionnaire survey on CSFs was conducted. Some questions aimed to collect the background information of the participants, and the remaining questions in the questionnaire invited them to indicate the degree of each factor in relation to the success of using GDSS in VM workshops based on a six-point scaling, i.e., strongly agree = 6, generally agree = 5, slightly agree = 4, slightly disagree = 3, generally disagree = 2 and strongly disagree = 1. Thirty respondents returned their completed questionnaire, representing a response rate of 71.4%.

5.5.3 Research Sample and Questionnaire Distribution

The whole population should be the participants who have experience in the use of GDSS in VM workshops. Hence, the participants of the experimental studies planned and conducted during this research were chosen as the research sample. A web-page survey was employed as the method to distribute the questionnaires because it is fast and the responses can be preliminarily analyzed.

5.5.4 Likert Rating Scales

There are three rating scales adopted during this research: 4-point and 5-point scales were used during the questionnaire surveys in experimental studies, while a 6-point scale was adopted in the questionnaire survey to identify critical success factors. Usually a 5-point or 7-point scale is used. However, the problem is that respondents may be tempted to select the mid point (Fellows and Liu, 2003). Since the purpose of a rating scale is to allow respondents to express both the direction and strength of their opinion about a topic, a scale without a midpoint would be preferable for it could force the participants not to choose neutral answers (Garland, 1991). For this reason the 4-point scale was used in the first experimental study.

The reason why a 5-point scale was applied in other experimental studies is to keep consistency of the questionnaire survey format with another research study, which has collaborations with this research. Both research projects needed to conduct questionnaire surveys based on the same sample of subjects. The other research project used a 5-point scale, so the same 5-point format was adopted in this research to keep consistency.

Cox (1980) suggested that the magic number of seven plus or minus two appears to be a reasonable range for the optimal number of response alternatives. Dawes (2007) also argued that simulation studies and empirical studies have generally concurred that reliability and validity are improved by using 5- to 7- point scales rather than coarser ones (those with fewer scale points), but more finely graded scales do not improve reliability and validity further. Hence, a 6-point scale format was used to improve the reliability and validity and avoid the neutral answers in this research.

5.5.5 Questionnaire Analysis

Two statistical tools, scale ranking and factor analysis, were used to analyze the data from the survey questionnaire through SPSS (Statistical Package for the Social Sciences). The findings are listed and discussed in section 8.3 in Chapter 8.

5.6 Action Research

The action research is conducted as a necessary complement to the experimental studies. The purpose of the action research is to further validate the system developed during this research and to investigate the effect of using GDSS in a real-life VM study.

5.6.1 Definition of Action Research

Kurt Lewin, a professor at MIT, first coined the term "action research" in about 1944, and it appeared in his 1946 paper "Action Research and Minority Problems". In that paper, he described action research as "a comparative research on the conditions and effects of various forms of social action and research leading to social action" that uses "a spiral of steps, each of which is composed of a circle of planning, action, and fact-finding about the result of the action". Four idealized action research models based on outcome were classified by Lewin and his workers (Adelman, 1993):

- Experimental action research, a controlled study that has a scientific approach to social problems in order to discover the effectiveness of various interventions;
- Diagnostic action research, which aims to identify remedial measures and a plan of action for a specific problem;
- Empirical action research, in which data are accumulated from comparable research situations in order to identify generalizable principles;
- Participative action research, whereby community groups develop remedial action plans to solve local problem.

However, definitions vary widely between different research models. Action research involves active participation by the researcher in the process under study in order to identify, promote and evaluate problems and potential solutions (Fellows and Liu, 2003). Scott et al. (2002) defined action research as being dependent on the researcher becoming involved in a problem situation and using that situation as a research object about which lessons can be learned by conscious reflection. Waser and Johns (2003) highlighted that the researcher becomes involved in a practical situation and observes that situation to learn lessons to improve practice. Action research is an approach which is appropriate in any context when ‘specific knowledge is required for a specific problem in a specific situation, or when a new approach is to be grafted onto an existing system (Cohen and Manion, 1994). This is certainly the case for this research where the context, involving specific knowledge – GDSS knowledge – is to be applied to a specific situation – VM studies – to overcome a specific problem – the problems encountered in the VM studies. Hence, action research is an ideal research technique for this part of the PhD study.

5.6.2 Action Research Brief

The purpose of action research for this study is to validate the proposed GDSS prototype (IVMS) and further investigate the effect of using GDSS in a real-life VM study. Because the materials for this workshop are still confidential, the action research can only be introduced briefly. The client of this workshop was a local government department. The duration of the workshop was one day, and 37 participants took part in this workshop.

5.6.3 Action Research Participants

Action research is typically carried out by individuals who ‘own’ the research problem (Waser and Johns, 2003). Heale (2003) also pointed out that there is a lot of untapped knowledge that practitioners have access to, and that the only way of exploring this field is for the practitioners to conduct the research themselves as they have the knowledge and insight into the problems in their professional area. Heale (2003) states that action research is ideally suited to those working in practice as those outside the profession are unlikely to have the knowledge and skills or even the interest to initiate studies in research areas not entirely familiar to them. In this research, the participants are all stakeholders involved in a real public project, together with a VM facilitator.

5.6.4 Action Research Process

Fellow and Liu (2003) noted that action research is highly context dependent and so is neither standardised nor permanent as it is reliant on the project and the knowledge and subjectivity/perceptions of persons involved. They also cited that Liu (1997) states that action research is a shared process different from a hypothetical-deductive type of a research. In this research, the context is a VM workshop. During the workshop, the GDSS prototype (IVMS) was used to support the participants in achieving the workshop goals.

5.6.5 Requirements of Action Research

Action research is complex. The observer gets involved, which requires that the observer should provide a systematic perspective and keep relatively objective. The observer also has the main role of the interpretation of the process and products, during which observer bias may occur. This requires the observer only consider what is recorded during the workshop.

Henry (2000) states that there are three primary requirements:

1. "A trust-based relations…built up beforehand… accepted by all parties…"

It is really not easy to find a real-life VM workshop in which to use the GDSS. However, Prof. Shen (the supervisor of this PhD study) has a good, long relationship with the mentioned government department, and has successfully facilitated several VM workshops for them. After the validation study through the experimental studies, Prof.

Shen communicated with the government department about the benefits of the GDSS use, and finally all the parties were willing to use GDSS in this VM workshop.

2. The researcher will have fully accepted the firm's or institution's objectives for innovation or change by having negotiated the extent to which they will be involved and their freedom regards access to information and interpretation.

During this research, the author only observed the research and did not make any contributions to the workshop. The use of GDSS only provided support to the workshop and did not change the objectives of the workshop.

3. A research and innovation project will be jointly drawn up, which must be open ended with regard to the problems to be explored, but very precise in terms of methodology.

This study examined the research problems carefully, and various research tools, including observation during the workshops and field notes to record the workshop process prior to the formulation of a workshop report, have been used.

5.6.6 The Evaluation of Action Research Results

Green (1992) states that there is no way of determining if the success of a value management study has resulted in a better building design and therefore suggests that the only meaningful method of evaluation is to consult the workshop participants themselves. Following Green's idea, Hunter (2006) evaluated the action research results through the measurement of the participants' perceptions. This research followed Hunter's method and collected the comments of the workshop participants and the workshop facilitator to determine the participants' perception of using GDSS.

5.7 Summary

The three main research methods introduced in this chapter provide a logical route to determine whether the use of GDSS can improve the performance of VM workshops.

Four experimental studies are used to validate the GDSS prototype and to investigate the effect of using GDSS in VM studies. They compare VM workshops that have GDSS support with traditional VM workshops. A questionnaire survey is used to identify the critical success factors of using GDSS in VM studies. Action research in the form a VM workshop with a local government department is conducted to investigate the effect of using GDSS in a real-life study. The ultimate goal of this research is to apply GDSS in VM studies to improve the performance of VM; therefore positive results in a real-life study will be the real success.

The following chapters introduce each research method in details and present the research findings.

Chapter 6: Interactive Value Management System (IVMS)

6.1 Introduction

Although there are various application procedures at different stages of the project, all of them more or less follow the standard VM job plan. Male et al. (1998) gave a generic VM process in their benchmark study for value management. Fig. 6.1 illustrates the process and outlines the steps. The steps where IVMS can be used are marked with an asterisk (*) in this figure. The following part will illustrate the use of IVMS in VM workshops in detail according to this generic process.

This chapter introduces the framework which is proposed during this research on how to integrate IVMS with VM workshops. The introduction follows the sequence of the generic VM process. Each stage of the VM process is introduced with its main tasks and objectives, which is followed by a description of the supports provided for that stage by IVMS. The potential benefits of IVMS supports are also introduced and discussed.

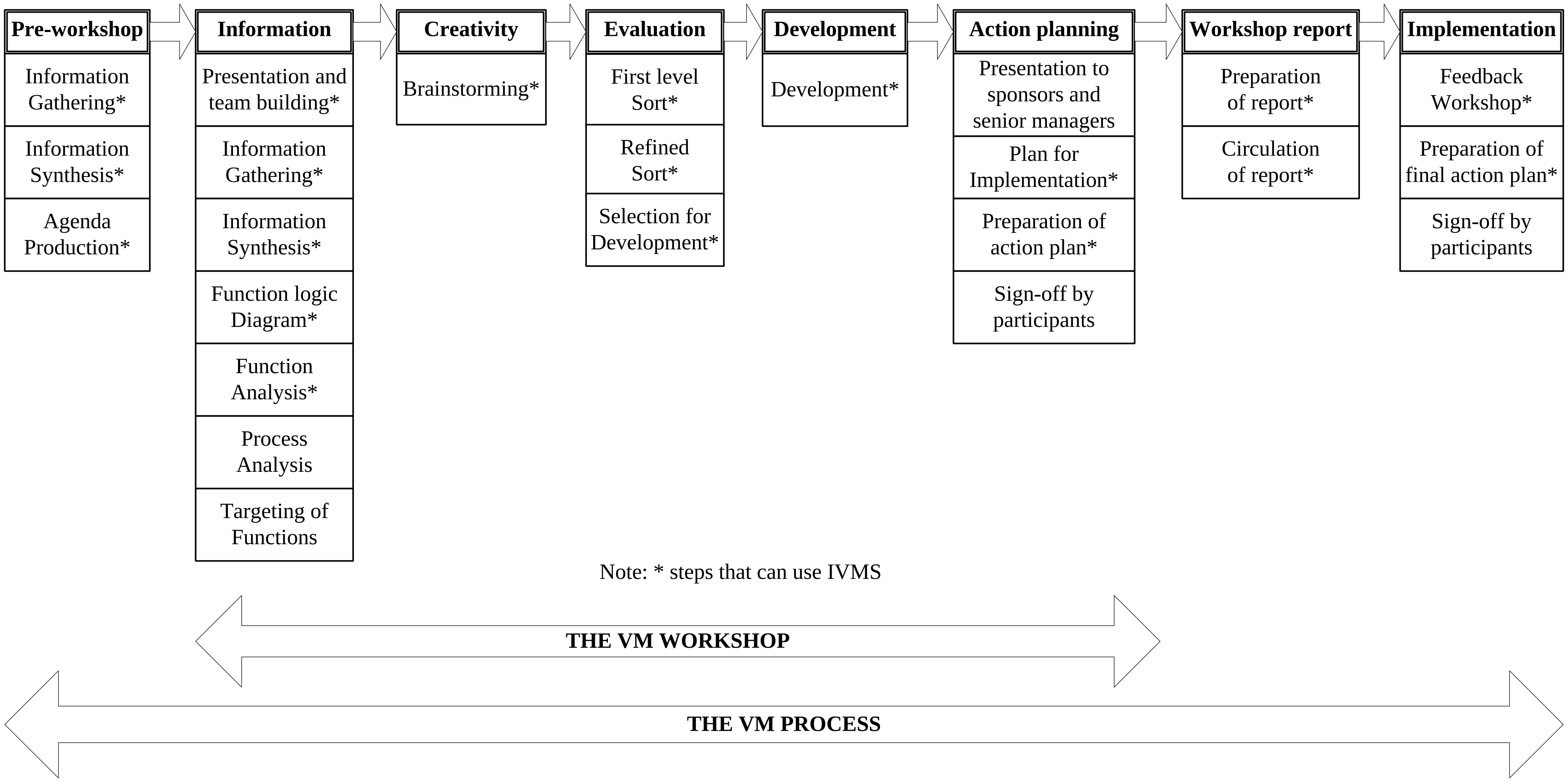


Fig. 6.1 The generic VM process (Adapted from Male et al. 1998)

6.2 Pre-workshop Stage

The pre-workshop stage provides an opportunity for all parties to understand project issues and constraints and therefore gives and receives information before VM workshops. The preparation tasks involve six areas comprising:

- Collecting user/customer attitudes;
- Completing the data file;
- Determining evaluation factors;
- Defining the scope of the study;
- Building data models; and
- Determining team composition (SAVE 1998).

As identified in Table 2.2, one of the main problems in VM workshops is poorly organized information and difficulty in retrieving project information in meetings, which is also mentioned by Park (1993). In order to overcome this problem, several tools that are provided are summarized in Table 6.1.

Table 6.1 Summary of Tools Provided in Pre-workshop Stage

Addressed Problems	*Tools Provided*	*Steps Involved*
Short duration; Poorly organized project information in the pre-workshop stage; Difficulty of retrieving project information in meetings.	Document library	Information gathering; Information synthesis.
	Discussion board	Information gathering
	Questionnaire survey	Information gathering
	Electronic agenda	Agenda production

A document library, as shown in Fig. 6.2, is provided for users to store and share project information. The main features are listed as follows:

- Version history. The document library can track document changes and maintain previous versions of documents so that if the team needs to revert to a previous version, this can be accomplished easily without having to restore a backup;

- Permission management. The document library offers a manageable set of permissions that control who can read, create, or modify documents. The facilitator can structure approval routing so that a change to a document will not be posted until it has been approved by a facilitator.

- Check-in/out mechanism. This allows users in the group to check a document in and out, thus guaranteeing that there is no chance of two users updating the document simultaneously.

- E-mail alert. A user can add an alert to a document such that an e-mail notification is automatically received when changes are made to the document. This improves the consistency of information and ensures that members can always receive the most up-to-date information throughout the workshop.

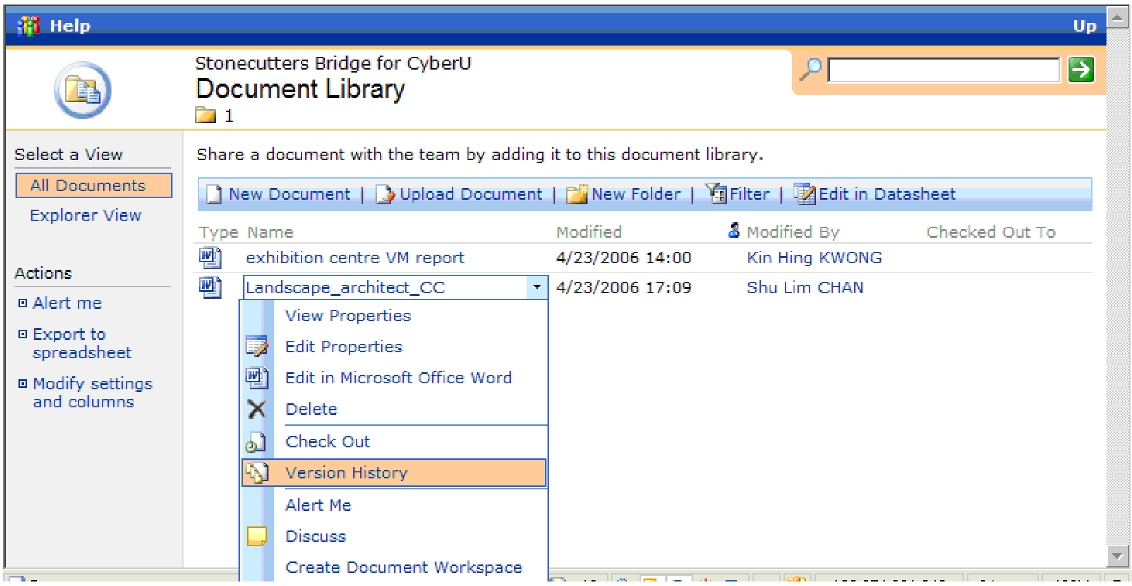


Fig. 6.2 Document Library

- Full-text search capability. All files of common types (including Microsoft Office and Adobe files, etc.) stored in the document library are indexed and can be searched in full-text pattern with the help of IFilter components. However, image files cannot be searched in full-text pattern. Users need to add detailed properties, such as a title and a brief, to make them easy to find.

- View selection. The system will automatically provide two views: an all documents view and an explorer view. Fig. 6.2 shows the view of 'All documents'. The 'Explorer View' is a feature of Windows SharePoint Services that allows you to access a document library as if you were manipulating a file system through a Windows Explorer window, providing you with the usual Windows features such as drag and drop. The users with authority can also create their own "ideal" view by clicking "Modify settings and columns".

A bulletin board is provided by the system for users to disseminate ideas, conduct discussions, and collect users' attitudes. One or more pre-meetings may be held in this phase to ensure that everyone involved in the project understands all the issues and constraints. Whenever the users have questions or fresh ideas, they can post their views on the bulletin board; others can read them and give replies or suggestions.

A questionnaire survey in this phase is usually used to collect the views of participants to give the facilitator an overview of strategic and tactical issues surrounding the project. The system provides an easy way to conduct an online questionnaire survey. The facilitator can make the participants answer different types of questions, including rating scale or multiple-choice types. If the respondents' names are designed to be visible when the survey is set up, the users can see how each team member responded. The system also provides a "graphical summary view" to display a compilation of responses.

An electronic agenda provides an outline of the workshop, including details of those who will lead the discussion on each subject and the time that is allotted. This ensures that the team members are prepared.

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

6.3 Information Phase

In this phase, information relating to the project under review needs to be collected together, e.g., costs, quantities, drawings, specifications, manufacturing methods, samples, and prototypes (Kelly et al., 2004). The objective is to identify, in clear unambiguous terms, the issues and functions of the whole or parts of the projects, as seen by the client organization (Male et al., 1998).This phase can be divided into two major parts: information sharing and function analysis.

6.3.1 Information Sharing

A VM workshop is commonly held in a conference room, a semi-closed environment with physical boundaries that may prohibit the users from retrieving any new information during workshops. A connection to the Internet breaks the physical boundaries of the conference room and allows members to access external information easily during the workshop. To enhance this Web-based feature of the system, a database including various websites is provided to facilitate users in their search for information. The participants can also add new useful website links to the database to enrich it.

The “document library” also plays an important role in the process of retrieving information, as all the information related to the VM workshops can be stored in the system before the workshop. Through the system, the files, especially those to be presented, can be shown on a large common viewing screen with the help of an LCD projector or “public” screen at each member’s terminal, which makes the process of reviewing data more efficient.

6.3.2 Function Analysis

The function analysis phase aims to clearly define the work involved and the requirements of the project (Assaf et al., 2000). The functional analysis system technique (FAST) developed by Charles W. Bytheway is a standard VM tool that facilitates function analysis. The technique begins with a brainstorming session, which aims to generate functions required by the product or service. All functions are expressed as an active verb plus a descriptive noun.

The functions generated are sorted by the VM team to create a diagram. Within the diagram, higher level functions appear on the left hand side and lower level functions appear on the right. In this way, the logical relationships between the functions of the product or service will be systematically demonstrated. At the end of this phase, the functions that need to be improved will be selected for further study in the next phases of the VM workshop.

The system provides support to the users in the brainstorming process of FAST. The Virtual Meeting Rooms provide support to users in the brainstorming session. According to the situation, the environment of these rooms can be switched between anonymous and nominal mode. In both modes, users can see all the functions that have been generated by others on their own computer, so users may spur each other on to generate functions. Furthermore, the functions are stored automatically in the system as they are generated. Compared to recording the generated functions on paper in the traditional way, this feature saves much time.

Following the generation of functions, the VM team is invited to order the functions by putting the highest-order need at the far left side and the lowest-order want at the far right. Some commonly used software, such as Microsoft Visio and Excel, can be used to integrate with the system to provide modelling tools. An LCD projector can be used to display the data analysis process. The tools provided by IVMS are summarized in Table 6.2.

Table 6.2 Summary of Tools Provided in Information Phase

Addressed Problems	***Tools Provided***	***Steps Involved***
Poorly organized project information in the pre-workshop stage; Difficulty of retrieving project information in meetings; Insufficient information to support analysis.	Document library	Presentation/Team building; Information gathering; Information synthesis.
	Links	Information gathering
Insufficient time to complete analysis.	Virtual meeting rooms	Function generation
	Integrated with other software	FAST

6.4 Creativity Phase

The main task of this session is to generate numerous alternatives for accomplishing the basic functions required by the clients by means of creativity-stimulating techniques such as brainstorming, synectics, morphological charts, and lateral thinking (Shen and Shen, 1999). Brainstorming is the most popular technique in the creativity phase. It requires that users consider a function and contribute any suggestion that may expand, clarify or answer that function. However, some participants are reluctant to speak out in this phase because they are shy of speaking in public or afraid of being criticized or sounding stupid (Camacho and Paulus, 1995; Diehl and Stroebe, 1987; Lamm and Trommsdorf, 1973; Mullen et al., 1991). Moreover, this process can be dominated by a few individuals, making the creativity process very unproductive.

In order to overcome these communication problems, the system provides virtual meeting rooms, which are like the “chat rooms” that are currently popular on the Internet. One of the basic rules of the brainstorming process is that the group should be relatively small (e.g., up to eight members) (Norton and McElligott, 1995). However, there can be 20 to 30 stakeholders in a VM workshop, in which case workshop members are nominated to five “rooms” in the system. Workshop members “go” to the assigned room, type their ideas, and submit them under the special functions that have been chosen in the “function analysis” phase. As shown in Fig. 6.3, functions are shown at the top of the interface to make it obvious to participants. The function can be changed by the facilitator. The left part shows the names of members in this room. Each member can read on his or her own screen the ideas generated by others.

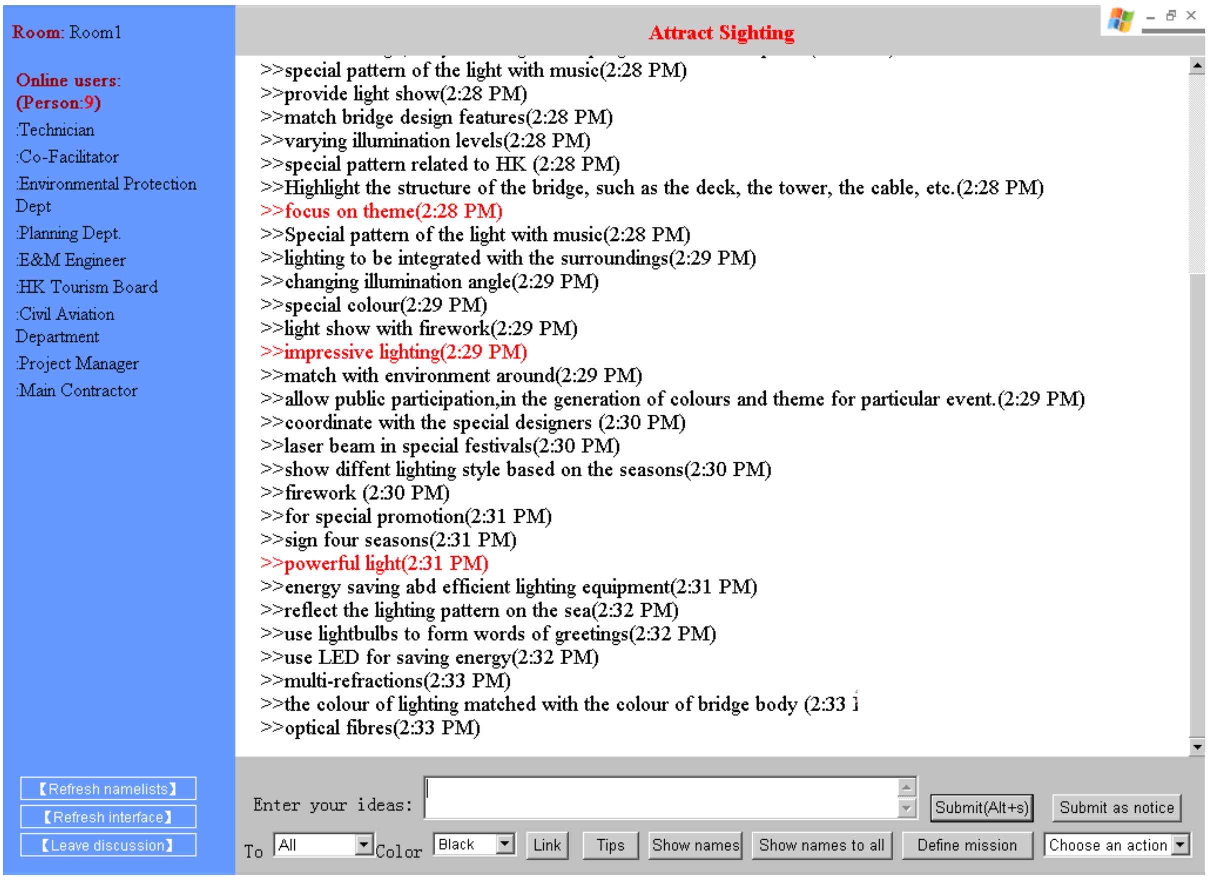


Fig. 6.3 A Typical Screen of the Virtual Meeting Room

The following section introduces the main features of these virtual rooms, which are designed to make the brainstorming session more effective and efficient.

6.4.1 Optional Environment: Anonymous or Nominal Mode

The environment can be set to be totally anonymous or nominal according to the need of the workshops. When the environment is anonymous, each user can read on his or her screen the ideas generated by other group members without knowing from whom they originate (as shown in Fig. 6.3). Users who fear receiving negative evaluations from others in the face-to-face session may appreciate the environment of anonymity in IVMS. This form of anonymity can reduce evaluation apprehension losses (Connolly et al., 1990; Gallupe et al., 1991; Gallupe et al., 1992). However, this does not mean that the nominal environment should not be used. While an anonymous environment encourages participants to express their ideas freely, it may also lead to laziness; some may work hard and some may free ride on the efforts of others. In a nominal environment, the users' names are displayed with the ideas they generated, giving them the stimulus to generate more ideas to prove themselves. Hence, the system provides the opportunity to choose the environment mode flexibly to exploit the full benefits.

6.4.2 Parallelism

Parallelism helps reduce production blocking since users no longer have to wait for others to express their ideas (Gallupe et al., 1991; Jessup et al., 1990). Users can express their ideas as soon as possible and then go on to generate other ideas.

6.4.3 Brainstorming Agent

It is found that there is more task-focused communication and less joking and laughing in GDSS-supported groups (Turoff and Hiltz, 1982), and people are more critical of each other's ideas when they communicate electronically (Siegel et al., 1986). DeSanctis and Gallupe (1987) suggested that features intended to address the social needs of groups should be included in GDSS systems. The IVMS provides an agent that can pop-up with different words and gestures corresponding to the situation. The agent can "monitor" the performance of both the whole group and individuals. The agent measures the performance of the whole group every five minutes based on several criteria, including the quantity of ideas generated by the group in the last five minutes, the corresponding idea generation rate, and what percentage of participants in the group generated ideas in the last five minutes. If the quantity, the idea rate or the percentage is over the number that has been previously set up, the situation will be judged as active. Then the pop-up agent will come out automatically to encourage the participants.

Actually, dozens of gestures and words for different situations have been designed. If the system "thinks" a certain situation is coming, it will choose the corresponding gestures and words randomly. Individual performance is also monitored by the agent according to the quantity of ideas she or he generated, the idea generation rate, and the duration in which he or she remains silent. For example, when an individual keeps silent or is active for a set period, the agent will appear to criticize or praise him or her. This mimics the traditional facilitator's duties in the VM workshop, which is to use facilitation skills to tap the group's reservoir of knowledge, experience, and creativity. The user who keeps silent may feel embarrassed when she or he is addressed by the facilitator directly. The system provides an alternative way to maintain active participation of all participants. When users are criticized by an animation agent, they may feel less embarrassed. In the validation studies that will be introduced in Chapter 7, this function is considered useful in enhancing the atmosphere of creativity by many participants.

6.4.4 Control Functions for the Facilitator

The control functions are the functions that only the facilitator can use in the VM workshops, including changing the environment mode, editing/deleting unnecessary ideas, posting VM notices, etc. This setting makes it convenient for the facilitator to control the whole process. For example, if someone in the group disrupts the brainstorming, the facilitator could put out some notice or criticize him or her secretly through the agent to make the workshop go smoothly. The facilitator in a traditional workshop can only encourage publicly, while IVMS allows anonymous encouragement.

6.4.5 Tips

This function is designed to inspire the users by providing some constructive suggestions; for example, “What if ice cream was hot or what if pigs could fly?” The aim is to provide “triggers” to make the participants think in a different way so that fresh ideas may come out. Hence, it should be considered useful even if only one tip gives the users some illumination.

6.4.6 Other Functions

Users can select different colours to display their ideas, which could make the ideas more attractive and easily distinguished from others. Internet links also can be posted during the brainstorming process.

Using the system, the participants can conduct the brainstorming to generate ideas or issues before the workshop, thus shortening the workshop's duration. Moreover, all the stakeholders can take part in the brainstorming by using IVMS, whereas only selected stakeholders can join the brainstorming in the traditional workshops. Table 6.3 provides a summary of this support.

Table 6.3 Summary of Tools Provided in Creativity Phase

Addressed Problems	***Tools Provided***	***Steps Involved***
Short duration; Shy about speaking in public; Dominated by a few individuals; Pressure to conform.	Virtual meeting rooms (anonymous environment, brainstorming agent, parallelism etc.)	Brainstorming

6.5 Evaluation Phase

According to the Value Methodology Standard (SAVE International, 1998), the main tasks in this phase include setting up a number of criteria and evaluating and selecting alternatives generated during the creativity phase. Various models and techniques, such as cost models, energy models, and the weighted evaluation technique (W.E.T.) are used during this phase. In addition, some form of weighted vote is also used (Kelly et al., 2004). This system provides an electronic weighted evaluation technique. A summary of this support is shown in Table 6.4.

Table 6.4 Summary of Tools Provided in Evaluation Phase

Addressed Problems	*Tools Provided*	*Steps Involved*
Insufficient time to complete analysis; Insufficient information to support analysis.	Idea categorization	First level sort
	List criteria; Assign weighting (Pair-wise comparison).	Refine level sort
	Electronic tools to score ideas	Selection for development

Weighted Evaluation Technique: The information flow of this technique provided by IVMS is shown in Fig.6.4.

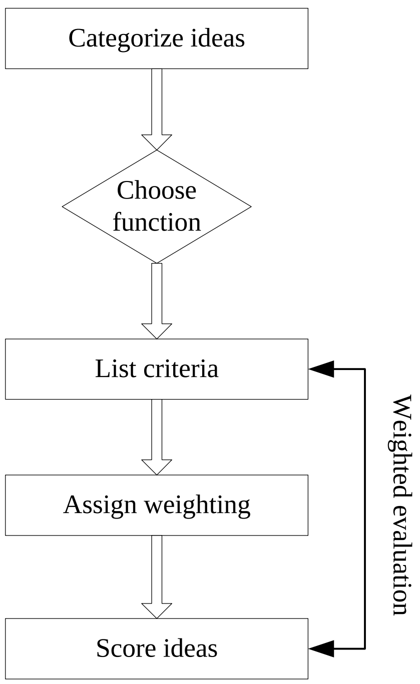


Fig. 6.4 Information Flow of W.E.T.

Idea categorization: Ideas generated in the "creativity" session will be automatically collected and listed corresponding to the functions. The facilitator can delete overlapping ideas and correct grammar or spelling mistakes. These ideas are then screened into categories P1, P2, and P3: P1 means "realistically possible"; P2 means "remotely possible"; and P3 means "fantasy," as shown in Fig. 6.5. Only the P1 ideas will be considered further in the subsequent phases.

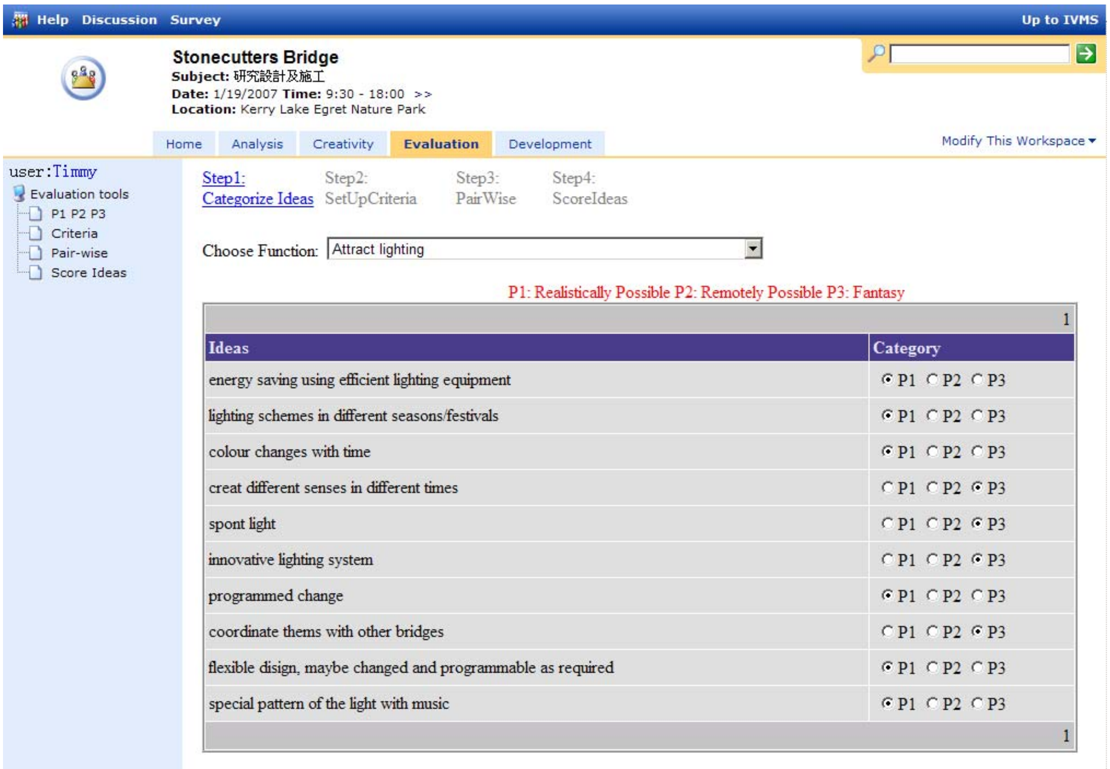


Fig. 6.5 Idea Categorization

Weighted evaluation: This step includes three tasks – listing criteria, assigning weighting, and scoring ideas – which are explained in the following three paragraphs.

List criteria: This part facilitates members in setting up a number of meaningful criteria against which the P1 ideas can be evaluated. It is important not to select criteria that are highly correlated with each other. Since one set of criteria may be used more than once, or may be very similar to another set, the system provides a function called "criteria database." When one set of criteria has been set up, the criteria can be saved as a template. If the users want to set up a similar set of criteria or use this set again, they can load the template.

Assign weighing: Since the criteria are not of the same importance, a relative importance weighting is assigned to each of the established criteria. The system provides an electronic team oriented pair-wise method to determine the weighting to be given to each criterion (See Fig. 6.6). The system assigns each criterion with a letter of the English alphabet, and the preferences are selected from a pop-up list with two parts of fixed entries. The first part is the letters of the two criteria that are being compared. For example, if criterion A and B are being compared, the entries of the first part will be fixed to A and B. The other part is four fixed entries: 1 means "Slight, no preference," 2 means "Minor preference," 3 means "Medium preference," and 4 means "Major preference." For example, if A is much more important than B, a score of 4 will be assigned to criteria A during the comparison, i.e., A/4. This is repeated for each pair of criteria. The system will automatically calculate the final scores as the sum of all the numbers in every score, $\sum Ax$. Fig. 6.6 is the "Scoring Matrix" screen. The process can be repeated to revise the results if necessary.

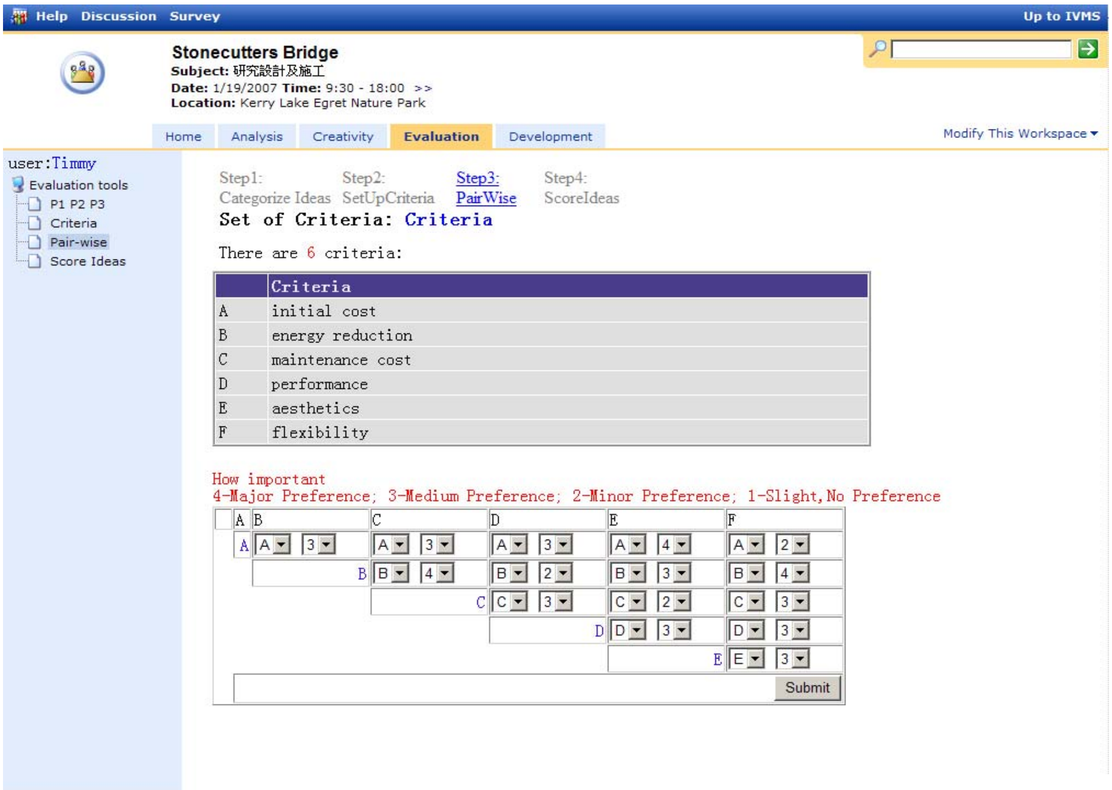


Fig. 6.6 Pair-wise Comparison

Score ideas: An interactive form is generated corresponding to the quantity of criteria and the P1 ideas from the previous phases. Participants need to score every idea under each criterion. Each score is multiplied by the criterion's weighting, and the subtotal will be automatically computerized as the final score of each idea. To focus the participants, only one criterion is displayed when scoring ideas; IVMS hides other criteria. Fig. 6.7 shows the screens of "score ideas" and the outcome. The process can be repeated to revise the outcomes, for example, when there is a divergence among the participants.

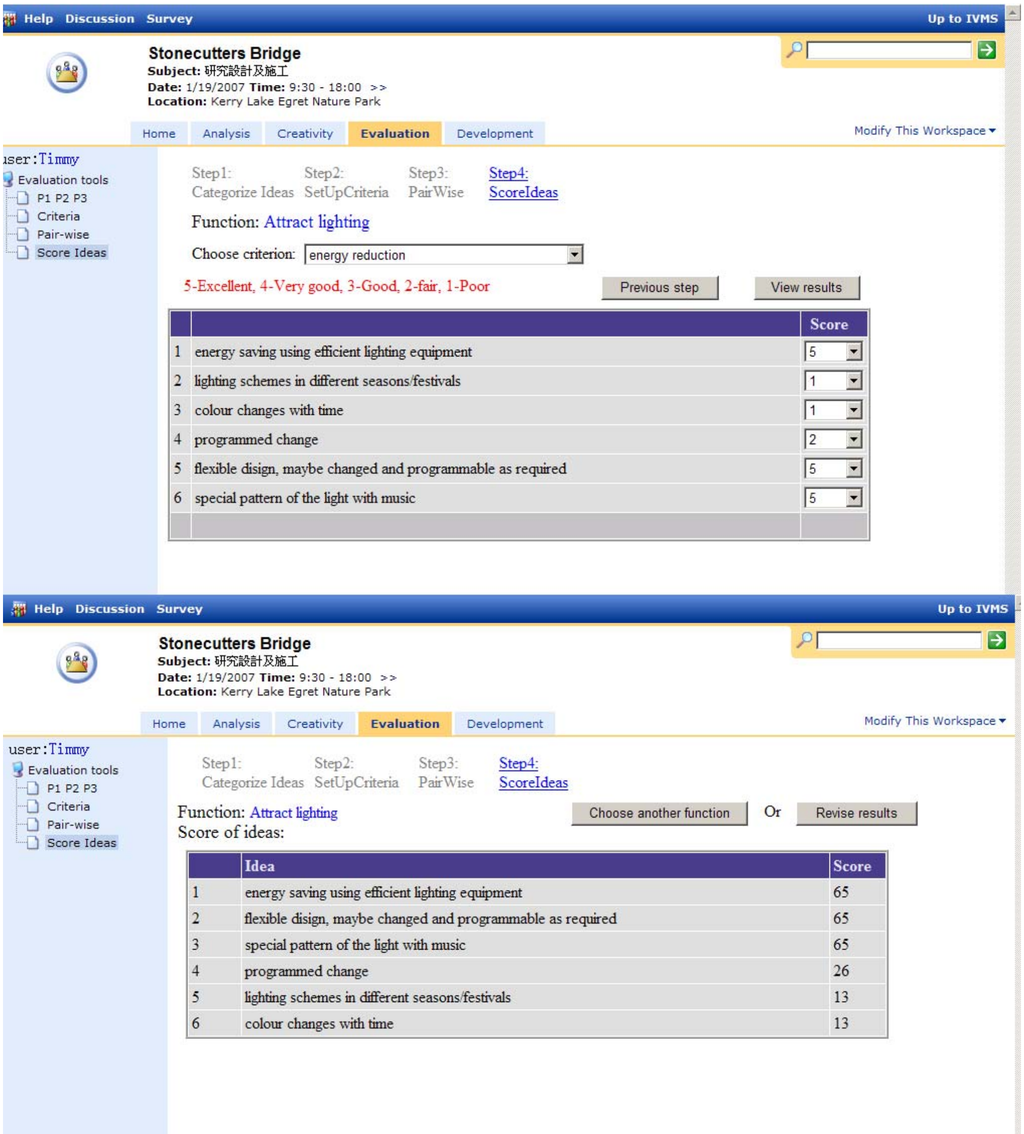


Fig. 6.7 Idea Evaluation

6.6 Development and Action Planning Phase

The development phase investigates selected alternatives in sufficient depth, such that they can be written into recommendations for implementation. This involves not only detailed technical and economic evaluation but also consideration of the applicability for implementation (Shen and Shen, 1999). There is wide scope for the use of life cycle cost models and computer aided calculations at this stage (Kelly et al., 2004). A whole life cycle cost toolkit has also been developed using VBA (Visual Basic for Application) for Microsoft Excel to support VM at this particular stage.

Action planning is to define and quantify results to prepare and present recommendations to the final decision makers. According to Fig. 6.1, this phase includes presentation to sponsors and senior managers, a plan for implementation, the preparation of the action plan, and signing-off by participants. The document library can be used to make the presentation process more flexible and effective. Users can upload the files to the document library, and then others can view them. In the case of a workshop where subgroups have been formed to develop ideas, this is more useful, for the reports of each group can be collected and shared quickly through the document library. “Action plan” is provided to facilitate the preparation of an action plan. It provides task management functionality including Gantt charts for visualization of task relationships and statuses. The function of e-mail notification is also integrated, which means a notification will be sent to the members when they are assigned a task. A summary of the support provided by IVMS in this phase is shown in Table 6.5.

Table 6.5 Summary of Tools Provided in Development and Action Planning Phase

Benefits	*Tools Provided*	*Steps Involved*
Simplify the process; Reduce human calculation errors.	Whole life cost toolkit	Development
Simplify the process of information exchange; Computerize the information gathering, and circulation processes.	Document library	Presentation to sponsors and senior managers
	Action plan	Plan for implementation; Action plan.

6.7 Workshop Report and Implementation Phase

A detailed report must be prepared as soon as possible after the workshop. The workshop report must then be circulated to the workshop participants to confirm their role in the implementation of the workshop proposals and any further development work necessary (Male et al., 1998). The system can automatically collect the main information of the workshop, such as the quantity of the ideas, the time of each phase of the workshop etc., which will be helpful to the preparation of the workshop report. The document library can also be used to circulate the report. The information collected could also be used to evaluate the process and outcomes of the workshop, and there is also a questionnaire at the end of the workshop to collect the users' attitudes towards the process and outcomes of the workshop. The information collected by the system and the questionnaire will produce a score for the workshop. Although this score cannot tell participants exactly whether this VM study is good or bad, it can give the users a general picture of workshop performance.

The objective of implementation is to assure the proper implementation of the approved value study change recommendations and collect feedback on the proposal. The system provides several efficient ways to collect feedback, such as a bulletin board, questionnaires and a notice board. Through these functions, users can conduct online discussions, post their ideas, and submit their feedback whenever they like through the Internet. Table 6.6 gives a summary of the tools that can be used in this phase.

Table 6.6 Summary of Tools Provided in Workshop Report and Implementation Phase

Benefits/Addressed Problems	*Tools Provided*	*Steps Involved*
Computerize and centralize the information gathering, distribution and circulation processes	Automatic workshop information collection	Preparation of report
Improve the efficiency of information sharing and enhance information circulation	Document library	Circulation of report
	Bulletin board; Questionnaire survey; Notice board.	Feedback workshop
	Action plan	Preparation of final action plan

As introduced previously, the author plans to build a computerized project database that can be used as a reference for similar projects. All the information involved during the whole VM process will be automatically stored in the database. The users can search related workshops by the title, date, the facilitator's name or keywords for reference.

6.8 Summary

This chapter introduce the framework on how to integrate the system with VM workshops. The supports provided by IVMS during each stage of VM workshops are illustrated in detail. This chapter also provides a picture of how the system is used during the experimental studies, which are introduced in the following chapter.

Chapter 7: System Validation

7.1 Introduction

This chapter introduces the experimental studies which have been conducted to validate the IVMS system. There are three types of experimental studies: comparative studies of idea generation, validation studies of using IVMS in the full process of VM workshops, and comparative studies of using IVMS in the full process of VM workshops. The validation framework on how to evaluate the performance of VM workshops is first described. Each experimental study is then introduced in details, which is followed by a description of the action research which aims to further investigate the effect of using GDSS in a real-life VM study.

7.2 Validation Framework

In building a computerized conferencing system, Hiltz and Turoff (1981) found that "Users cannot tell you what they need prior to using this technology." Consequently, users must have extended experience with GDSS before the effectiveness or ineffectiveness of systems design can be fully assessed (DeSanctis and Gallupe, 1987). Hence, in order to investigate the effectiveness and efficiency of the system, three types of experimental studies were designed and conducted. The design of these studies followed the analysis in Chapter 4 (Section 4.2) of the circumstances in which GDSS use in VM workshops can achieve the best performance. This analysis led to the following settings:

- A level 2 GDSS system, IVMS, is provided;
- Two facilitators (a GDSS process facilitator and a VM facilitator) are assigned for each experimental study;

- A face-to-face setting is arranged for each experimental study.

7.2.1 How to Evaluate the Performance

In order to investigate the effectiveness of GDSS, the major factors of performance should be defined. Researchers have different viewpoints on what is a performance factor or how they should be measured. Following the approach of Drazin and Van de Ven (1985), Benbasat and Lim (1993), and Dennis and Kinney (1998), Dennis and Wixom (2002) defined performance in terms of three major factors: (1) effectiveness as defined by decision quality or number of ideas generated; (2) efficiency as defined by the time to complete the task, and (3) participants' satisfaction with the process or outcomes. Likewise, after reviewing approximately 200 published papers on GDSS, Fjermestad and Hiltz (1999) found that among the outcome factors, group effectiveness and participants' satisfaction were the two factors most studied. Group effectiveness was measured in terms of decision quality, creativity and other related aspects while participants' satisfaction included process satisfaction, decision satisfaction and general satisfaction (Fjermestad and Hiltz, 1999; Paul, et al., 2004b). Although no single conception of performance is perfect, the above three factors comprising group effectiveness, group efficiency and participants' satisfaction can be considered as a reasonable set of factors to triangulate on the performance construction (Dennis and Wixom, 2002).

The above three factors (effectiveness, efficiency and participants' satisfaction) fall into outcomes, process, and participant's satisfaction respectively. While the outcomes can be measured by the quantity of ideas and the quality of decisions, and satisfaction can be measured through a questionnaire survey, evaluating the effectiveness of the decision process is problematic.

7.2.2 Evaluating the Performance of the Group Decision Process: the Competing Values Approach

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

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

Reagan and Rohrbaugh (1990) and McCartt and Rohrbaugh (1989) to judge the effectiveness of group interaction in decision making.

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

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

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

When the CVA framework was applied to the process of group decision making to assess the performance, four similar distinct perspectives were identified based on the above four models:

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

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

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

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

Fig.7.1 graphically depicts these four perspectives. Moreover, Quinn, Rohrbaugh, and McGrath (1985) proposed that each of these perspectives might depend on at least two dominant criteria (one oriented toward means, the other toward ends) by which group decision processes are evaluated. The proposed eight criteria were: 1) a goal-centered process; 2) the efficiency of decision; 3) an adaptable process; 4) legitimacy of decision; 5) a participatory process; 6) supportable of decision; 7) a data-based process; and 8) accountability of decision (McCartt and Rohrbaugh, 1989). This study adopted the above eight criteria to assess the effectiveness of the VM process.

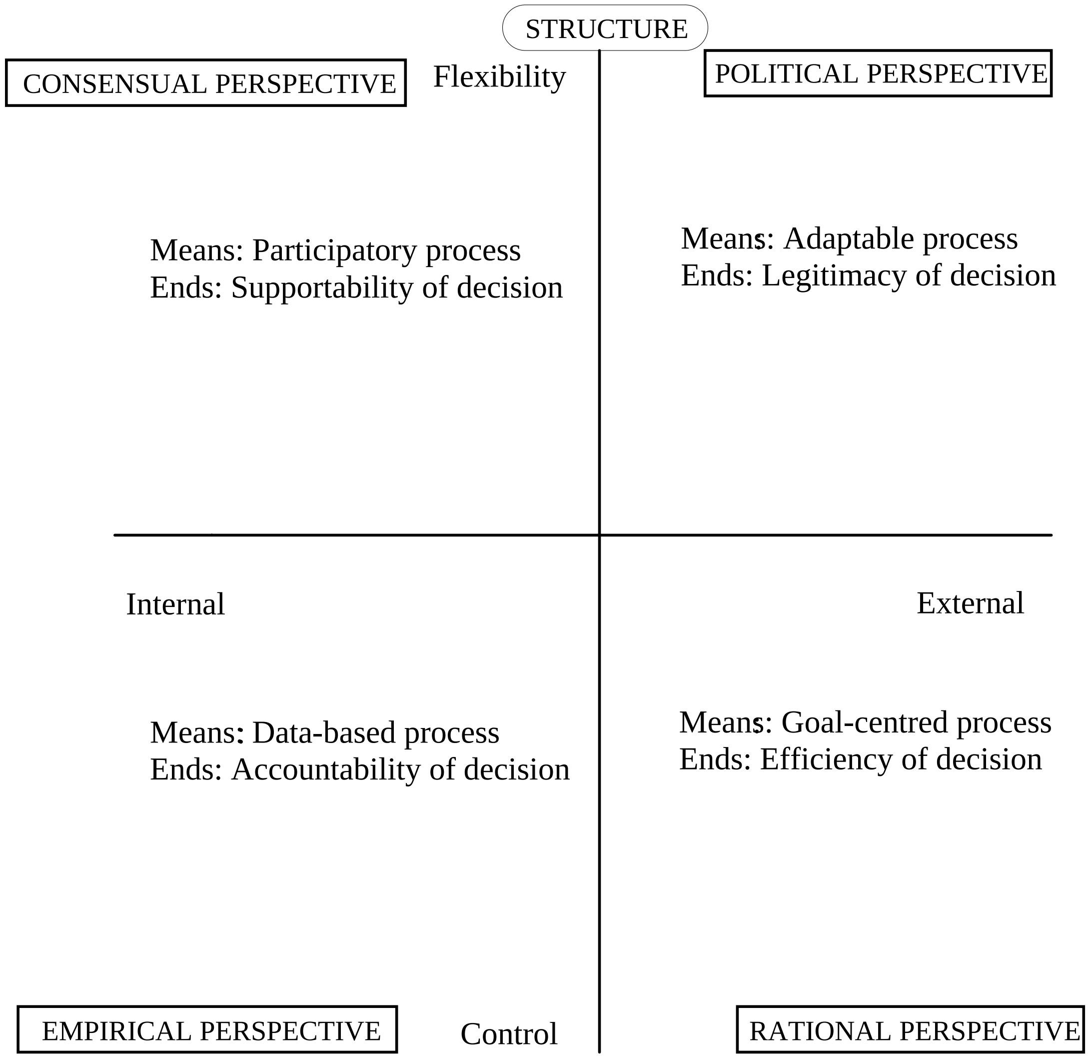


Fig. 7.1 The CVA Framework for Group Decision Processes (Adapted from McCartt and Rohrbaugh, 1989)

7.3 Experiment Studies

According to the survey, some VM users have encountered the problems of shyness about speaking in public, pressure to conform and domination by a few individuals in the idea generation phase of VM workshops in the construction industry (Shen and Chung, 2000). The same problems during the process of idea generation in meetings or workshops have also been indicated by other researchers (Diehl and Stroebe, 1987; Mullen et al., 1991). Since the idea generation phase aims to provide alternate solutions to the tasks of VM workshops, these problems can have a significant influence on the success of the VM workshops. There are four experimental studies, as shown in Figure 7.2. The first type of experimental study is to investigate the effect of using IVMS in the process of idea generation in VM workshops. Experimental study I and II are of this kind. Based on the experiences obtained from study I, several modifications were made for study II (as shown in 7.3.2) in an attempt to achieve more reliable results. Experimental study III is a validation study of using IVMS in the full process of VM workshops. Based on the results of study III, experiment study IV is a comparative study between a traditional VM workshop and a GDSS-supported workshop.

7.3.1 Experimental Study I: Comparison (a) of Idea Generation between Traditional and GDSS-supported VM Workshops

7.3.1.1 Review of Works in Idea Generation through Brainstorming

The most popular technique in the process of idea generation in VM workshops is called brainstorming. In traditional VM workshops, there are two commonly used methods: one is the face-to-face approach, and the other is the nominal approach. The main difference between the two methods is the level of interaction among participants. When the nominal approach is employed, participants generate ideas by working alone, without interacting with other participants. In contrast to this, participants can interact with others when using the face-to-face approach. Different to both of the above methods, the method employed in IVMS is electronic brainstorming, which is commonly used in a GDSS system. From the perspective of interaction, the electronic brainstorming is similar the face-to-face approach, for both approaches allow the interaction between participants. The advantages of electronic brainstorming over the face-to-face approach include anonymity and parallelism, which are introduced in details by Section 7.3.1.2.

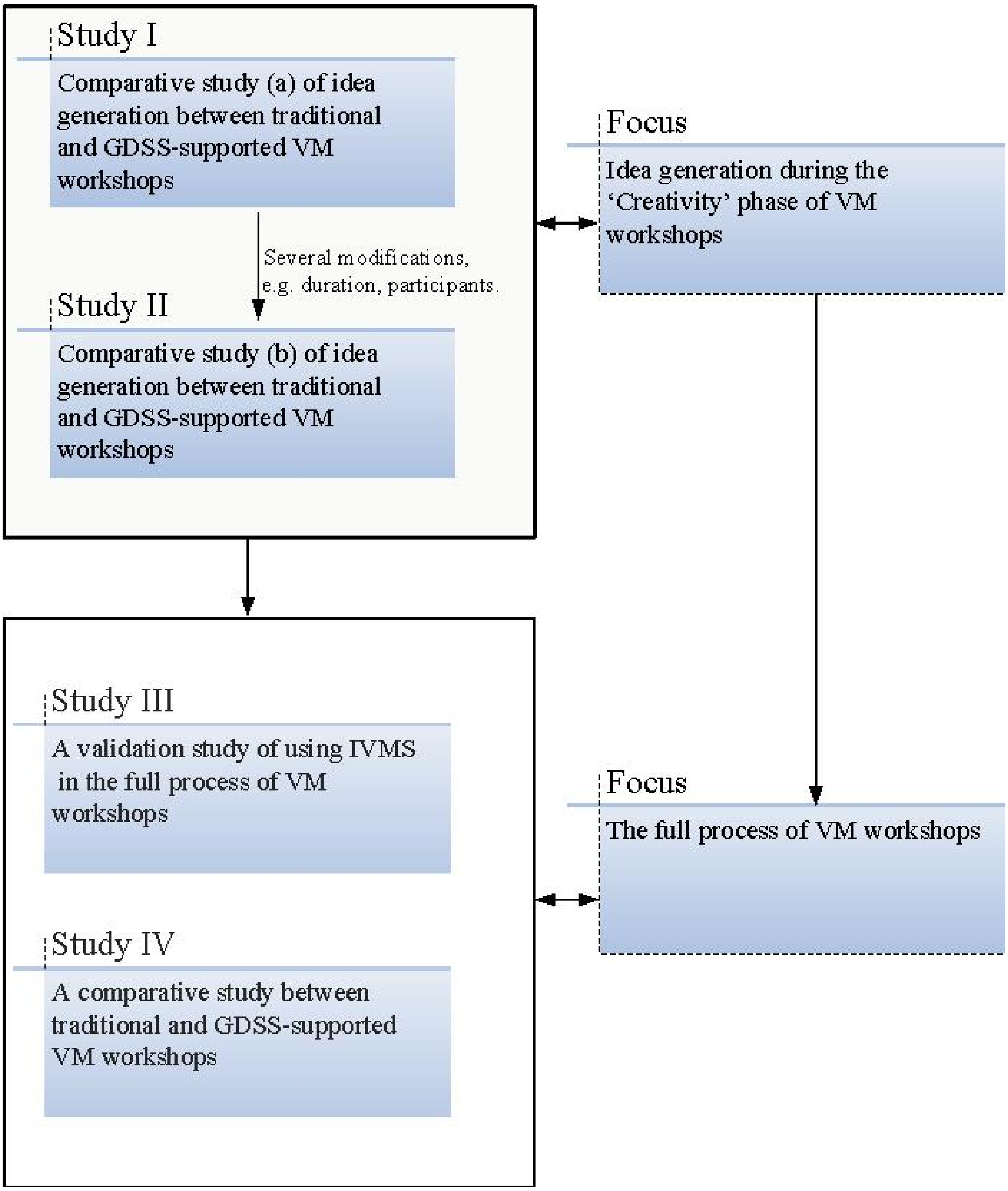


Fig. 7.2 Four Experimental Studies

There have been many studies in the area of social and group psychology that have compared these three brainstorming technologies, but this kind of study on VM workshops has not been conducted before. Past studies in social and group psychology show that there are three problems inherent to the traditional face-to-face brainstorming:

Evaluation apprehension: Participants sometimes do not like to express their ideas because they may feel shy or worry that they will be evaluated or judged by others (Camacho and Paulus, 1995; Diehl and Stroebe, 1987; Lamm and Trommsdorf, 1973; Mullen et al., 1991). This is also documented in a recent survey on VM workshops in Hong Kong (Shen and Chung, 2000).

Production blocking: The production of ideas may be blocked because only one person can express his ideas at a time, thereby limiting the opportunities of others to state their ideas (Diehl and Stroebe, 1991).

Free riding: Individuals intentionally limit their efforts and contributions by relying on other group members to accomplish the brainstorming task at hand (Diehl and Stroebe, 1987). This phenomenon is worse in groups when individuals perceive their efforts to be dispensable (Harkins and Pretty, 1982; Kerr and Bruun, 1983) or feel that the responsibility for generating ideas is diffused (Latane et al.1979; Williams et al. 1981).

There are two other problems suggested by Shen and Chung (2000):

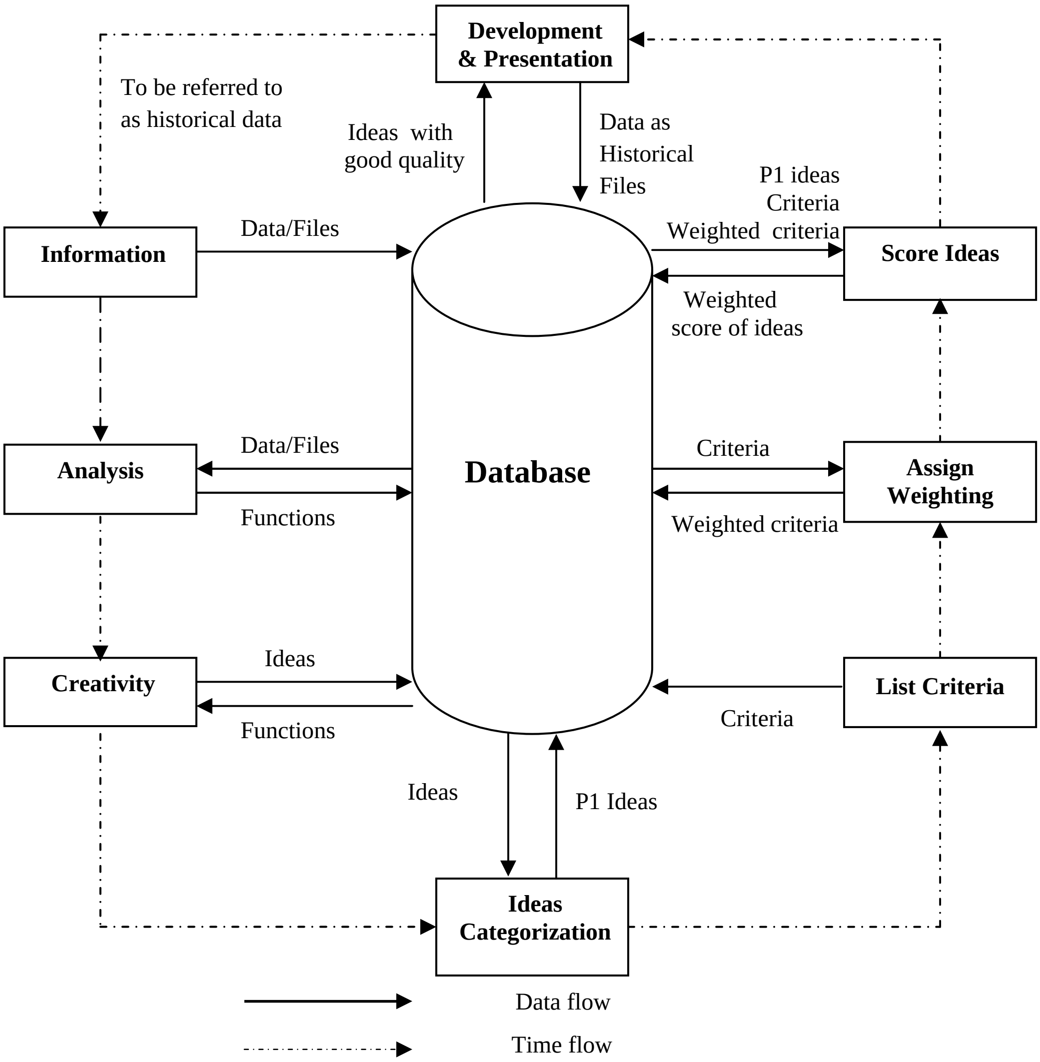
- Participants may feel under pressure to conform to others;
- The workshop may be dominated by a few individuals.

With regard to nominal technology, empirical research in both group psychology and social psychology has consistently shown that people generate fewer and lower quality ideas in face-to-face brainstorming than in nominal brainstorming (Diehl and Stroebe 1987; Mullen et al., 1991; Paulus et al., 1995; Sutton and Hargadon, 1996). However, on the question of whether nominal or EBS technology is better, the verdict is mixed (Dennis and Valacich, 1993; Gallupe et al., 1991; Pinsonneault and Kraemer, 1990; Valacich et al., 1994). According to a summary of past studies, EBS groups have never been found to generate more unique ideas than nominal brainstorming groups for groups consisting of fewer than nine members (Dennis and Valacich, 1993; Valacich et al., 1994; Gallupe et al., 1991). For very large groups, there is still no clear evidence supporting the superiority of EBS to nominal brainstorming (Pinsonneault et al., 1999).

7.3.1.2 Potential Benefits of IVMS in Brainstorming

IVMS is designed to support the whole process of a typical VM workshop in the construction industry, as shown in Fig. 7.3. It is a web-based system and can be used very easily. This system is installed and operated in a Web server; no installation is required on the users' computers. Users can access the system using any machine, at any time, anywhere, and at any phase of a VM workshop (pre-workshop, workshop, and post-workshop).

Since the "creativity" phase aims to provide alternate solutions to the tasks of VM workshops, its efficiency and effectiveness can have a significant influence on the success of VM workshops (Fan et al., 2007). The objective of this phase is to develop a large quantity of ideas for performing the functions selected for study (SAVE, 1998). The most popular method used in the "creativity" phase is brainstorming. In IVMS, a Virtual Meeting Room, which can be used in the "creativity" session, is developed by using the EBS method, which is just like a "chat room" that is now popular on the Internet. Users can generate ideas and enter them simultaneously into their computers. With such a step, IVMS is expected to help reduce the problems inherent in face-to-face brainstorming described earlier.



Notes: the VM workshop starts with the "Information" phase.

Fig. 7.3 Process of a Typical IVMS-supported VM Workshop

The main features include:

- **Anonymous environment.** In the anonymous environment, each user can read on his or her screen the ideas generated by other group members without knowing from whom they originate (as shown in Fig. 7.4). Users who fear receiving negative evaluations from others in the face-to-face session may not have this fear in the environment of anonymity in IVMS. This form of anonymity can reduce evaluation apprehension losses (Connolly et al., 1990, Gallupe et al., 1991, Gallupe et al., 1992).

- **Parallelism.** Parallelism helps to reduce production blocking since users do not have to wait for others to express their ideas (Gallupe et al., 1991; Jessup et al., 1990). Users can express their ideas immediately and then go on to generate other ideas.

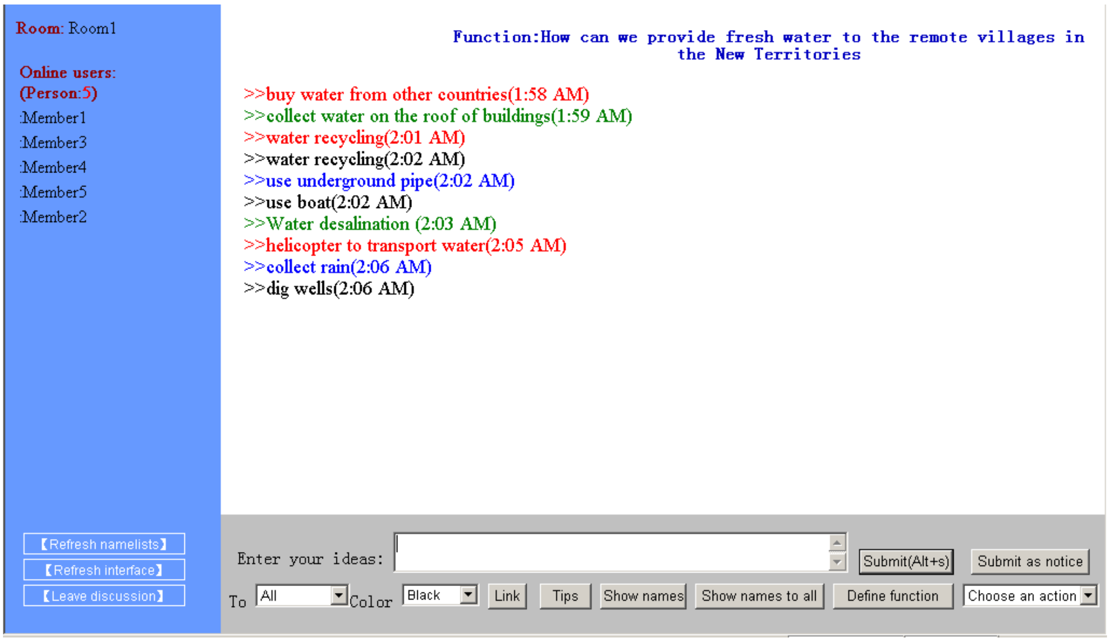


Fig. 7.4 Screen of Idea Generation in IVMS-supported Brainstorming

Hence, it can be expected that the use of IVMS will eliminate the problems and improve the performance of idea generation in VM workshops.

7.3.1.3 Experimental Hypotheses

According to the above analysis and literature review, groups using IVMS and the nominal approach would be expected to be more productive in generating ideas than groups using the traditional face-to-face approach (e.g. Connolly et al., 1990, Gallupe et al., 1991, Sutton and Hargadon, 1996). There is little evidence that could suggest that groups using IVMS are more productive than groups using the nominal approach.

However, the above results are all from studies in group and social psychology. They may not be applicable to VM workshops because very few such studies have thus far been conducted in the area of VM. The author therefore decided to carry out a laboratory experiment to compare IVMS with the other two traditional brainstorming methods. The primary hypotheses to be tested by this experiment were:

Hypothesis 1: A larger quantity of unique ideas will be generated by using IVMS than by using the traditional face-to-face approach in VM workshops.

Hypothesis 2: The quantity of unique ideas generated by using IVMS will not be larger than the one generated by using the traditional nominal approach.

In addition to the quantity, the author also aims to examine whether there are differences on the quality of ideas. Research has indicated that the number of good suggestions remains fairly constant as a proportion of wild suggestions. The more ideas, the larger the possibility that good suggestions will be obtained. In VM workshops, ideas will be categorized as P1, P2, or P3, where P1 refers to “realistically possible”, P2 refers to “remotely possible”, and P3 refers to “fantasy”. The quantity of P1 ideas represents the quality of ideas generated in the brainstorming session. Hence, two more hypotheses have been set up as follows:

Hypothesis 3: A larger quantity of unique P1 ideas will be generated using IVMS than by using the traditional face-to-face approach in VM workshops.

Hypothesis 4: The quantity of unique P1 ideas generated by using IVMS will not be larger than by using the traditional nominal approach.

7.3.1.4 Design of Experimental Study

The experiment was designed to test the hypotheses and the usefulness of IVMS. In order to provide comparative data, three scenarios were designed, namely: traditional face-to-face brainstorming, traditional nominal brainstorming, and IVMS-supported brainstorming. The main dependent variables were the number of ideas and the number of P1 (quality) ideas.

Six groups with five members in each group were formed by 30 undergraduate students from Department of Building and Real Estate, Hong Kong Polytechnic University. All of the students were enrolled in a VM course which has 42 contact hours including lectures and tutorial classes. Through this course, the students obtained a basic knowledge of VM and understood the process of VM workshops. The group size of five members was chosen to mirror the size of the discussion groups in a real-life VM workshop in Hong Kong. The groups comprised students from different grades so that the groups could be judged as ad hoc groups rather than established groups. These six groups were divided into two sessions, with each session involving three groups.

There is often a concern raised regarding the use of students as subjects in GDSS research. Fjermestad and Hiltz (1999) report that 94 percent of studies into GDSS involved students as subjects. The limitation of using students as participants has been recognized long before (Lorge et al., 1958), but there is still a lot of research using students because of the difficulty in persuading real managers to participate in GDSS sessions. However, Briggs et al. (1996) found no significant differences between executive business managers and graduate business students in evaluating technology. Also, Remus (1986) found no significant differences between line managers and MBA students with little business experience in production scheduling decisions. Furthermore, the participants in this experiment were all VM and construction students that were familiar with VM and the construction industry. Given these considerations, it is reasonable to use students as the subjects.

Each group carried out two tasks that were designed to be at a similar level of difficulty. Both tasks were extracted from real projects in Hong Kong. Task 1 is “How can we provide fresh water to the remote villages in the New Territories in Hong Kong?”(Detailed information of the villages was provided in the experiment); Task 2 is “How can we renovate the physical setting on the 5th floor to improve image of our department?” Both are typical brainstorming tasks and the participants were asked to generate solutions for them. Before the experiment, a pilot study was conducted to investigate whether they are at the same level of difficulty. Five students from the department were invited to generate ideas under the two tasks. In the post-session interview, they all agreed that both tasks were easy to understand and related to the students’ lives and studies. The interview also showed that it was not difficult for them to generate solutions for both tasks, but deep thinking was needed for good ideas. A statistical analysis, which showed that the two tasks were at the same level of difficulty, is described in the “Comparing IVMS-supported Brainstorming with Nominal Brainstorming” part (Section 7.3.1.7) of this chapter.

A facilitator with good knowledge of the system and VM workshops was involved to facilitate the experiment. The author assigned an observer to each group to record useful information such as the number of ideas generated by individuals in the face-to-face brainstorming process and the typing speed of participants in the IVMS-supported brainstorming process. The observer’s actions were designed not to influence the performance of the group members. A questionnaire was designed to collect information about the brainstorming experience of the participants, their work experience relevant to the experiment tasks, their comparative opinions between IVMS-supported brainstorming and other brainstorming methods, and their attitudes towards the design of IVMS.

In session A, three groups were assigned to carry out task 1 using nominal brainstorming, and then to carry out task 2 using face-to-face brainstorming. In session B, another three groups were assigned to conduct task 2 using face-to-face brainstorming first and then to conduct task 1 using IVMS-supported brainstorming. Due to the limitation of the number of experienced facilitators, the groups in the same session carried out the same task at the same time with one facilitator. Table 7.1 illustrates the framework for the proposed experiment.

Table 7.1 Framework for the Proposed Experiment

Session	Group	Tasks conducted
Session A	Group 1 Group 2 Group 3	All groups conducted task 1 through nominal brainstorming, followed by task 2 through face-to-face brainstorming.
Session B	Group 4 Group 5 Group 6	All groups conducted task 2 through face-to-face brainstorming, followed by task 1 through IVMS-supported brainstorming.

7.3.1.5 Variables and Measures

Independent Variables

Two brainstorming technologies were used in the present study: traditional brainstorming (including face-to-face brainstorming and nominal brainstorming) and IVMS-supported brainstorming. In the face-to-face brainstorming processes, the participants of one group sat in a circle and generated ideas orally. The ideas were recorded onto transparencies by one participant of the group, as happens in real-life VM workshops. After ideas were generated, the transparencies were collected by the facilitator, to conduct the evaluation. In the process with nominal brainstorming, the group members typed the ideas into the system without any interactivity. The ideas were collected by the system automatically. In the IVMS-supported brainstorming process, all of the activities were conducted through IVMS, and members of the group could interact with each other through the system.

The two tasks used in the experiment were not designed to determine whether there is any difference when brainstorming using different tasks but to prevent the same group from brainstorming on the same task. In order to reduce the influence of the tasks, these two tasks were designed to be at the same level of difficulty (details in Section 7.3.1.4). They were also used in the experiment by the groups in alternating order.

Dependent Variables

The main dependent variables were the number of unique ideas and number of unique P1 ideas generated by a participant. In the face-to-face brainstorming processes, all ideas were recorded by the recorders, while the observer recorded who generated the ideas and when the ideas were generated. In the IVMS-supported and nominal brainstorming processes, ideas were typed into the system by the participants and recorded by the system. A "P1 P2 P3" evaluation process was conducted after each generating process. Because the evaluation processes were carried out very briefly due to the time limitation, all of the ideas were re-evaluated by the author after the experiment using the same method. The number of P1 ideas generated represents the quality of ideas. In addition to the number of unique ideas and the number of unique P1 ideas, the information gathered from the questionnaire such as the participants' satisfactions with the process and outcomes were also analyzed.

7.3.1.6 Experimental Procedures

All experimental sessions took place in the Department of Building and Real Estate of the Hong Kong Polytechnic University. In all sessions, a name tag which was visible to everyone was placed on the table in front of each member. The three groups in session A gathered in the computer laboratory and conducted the nominal brainstorming. A five minute warm-up game was played before the brainstorming was conducted. The agenda was explained to the participants. The facilitator then explained the brainstorming rules to the participants: the more ideas the better, the wilder the ideas the better, do not criticize, and be as clear and concise as possible. At the end of the warm-up period, the facilitator introduced task 1. The participants then brainstormed on the task for 15 minutes. An evaluation of ideas was conducted after the brainstorming process. The groups moved to a meeting room after finishing the nominal brainstorming task and engaged in face-to-face brainstorming on task 2. The facilitator spent five minutes introducing the task, after which the groups began to generate ideas. After 15 minutes of idea generation, the ideas were evaluated by all of the participants together. The participants were asked to fill out the questionnaire after they finished both tasks.

The three groups of session B first gathered in the meeting room. A five minute warm-up game was also played before the brainstorming. The facilitator then explained the brainstorming rules and task 2, following by a 15 minute idea generation using the face-to-face approach. The ideas generated were evaluated at end of this session. They then moved to the computer laboratory and engaged in the IVMS-supported brainstorming. During the warm-up period, the facilitator introduced how to use the system and the participants then brainstormed for three minutes on a practice task with the system. The facilitator ensured that everyone had no problems in using the system. The participants then generated ideas on task 1 with IVMS support for 15 minutes. An evaluation of ideas with the support of IVMS was conducted after the idea generation. After completing both tasks, they filled out the questionnaire. The whole process was recorded on videotapes.

7.3.1.7 Experimental Results

Neither the number of unique ideas nor the number of unique P1 ideas was normally distributed. Therefore, nonparametric tests were used. Where this test indicated significant differences, the Mann-Whitney (MW) mean rank test was used to test the hypotheses.

Comparing IVMS-supported Brainstorming with Face-to-Face Brainstorming

First, a comparison was conducted between the results of session A's face-to-face brainstorming and the results of session B's IVMS-supported brainstorming. Since both of them had the same task, there was only one variable: the mode of brainstorming. Although there is another variable, 'participant', findings from the questionnaire survey (which is shown in next "Survey of Users' Feedback" section) suggested that the different participants in session A and session B could be regarded as the same. As shown in Table 6.2, the number of unique ideas per person generated through IVMS was larger than the number of unique ideas per person generated through the face-to-face approach (8.18>4.21). The statistical analysis also showed significance $p=0.005<0.05$. Therefore, hypothesis 1 was supported.

Table 7.2 Unique Ideas & P1 Ideas from the Face-to-Face and IVMS Approaches

	Unique ideas		*Unique P1 ideas*	
Brainstorming method ***(Number of participants)***	***Face-to-Face*** ***(15)***	***IVMS-supported*** ***(15)***	***Face-to-Face*** ***(15)***	***IVMS-supported*** ***(15)***
Mean	4.21	8.18	2.64	3.71
Standard deviation	2.89	4.10	2.62	2.47
Mann-Whitney (Mean rank)	11.04	20.09	13.29	18.24
Significance	p=0.005<0.05*		p=0.123>0.05	

Note: * is significant at the 0.05 level.

Table 7.2 also shows the number of unique P1 ideas obtained by the different brainstorming approaches. Participants using IVMS generated more unique P1 ideas than groups using the traditional method (3.71>2.64). However, there is no significant difference between the two sets of data, as the significance is p=0.123>0.05, which means that the number of unique P1 ideas generated through IVMS was not statistically larger than that through the face-to-face approach. Therefore, hypothesis 3 was not supported.

Comparing IVMS-supported Brainstorming with Nominal Brainstorming

As introduced previously, task 1 and task 2 were designed purposely to make them at the same level of difficulty to eliminate any influence caused by the change of tasks. In order to test whether the design is appropriate, the author conducted a comparison between session A's face-to-face brainstorming and session B's face-to-face brainstorming, which were conducted using different tasks. The "participant" was still a variable, but it could be disregarded as suggested by findings from the questionnaire survey (which is shown in next “Survey of Users’ Feedback” section). The results of the comparison are shown in Table 7.3.

Table 7.3 Comparison between Session A and Session B

	Face-to-Face (Session A) (Task 1) (Number of participants: 15)	**Face-to-Face (Session B) (Task 2) (Number of participants: 15)**	**Test statistics**
Unique ideas			
Mean	4.21	4.65	
Standard deviation	2.89	4.21	
Mann-Whitney (Mean rank)	16.14	15.88	p_1=0.936 >0.05
Unique P1 ideas			
Mean	2.64	3.06	
Standard deviation	2.62	3.03	
Mann-Whitney (Mean rank)	15.61	16.32	p_2=0.824 >0.05

Since p_1=0.936 >0.05 and p_2= 0.824>0.05, this suggests that the change of tasks did not increase or decrease the quantity of unique ideas or P1 ideas. Hence, in the following analysis, the effect of task changes will not be considered.

Table 6.4 shows the number of unique ideas generated by each participant with the different brainstorming approaches. Participants using IVMS generated more unique ideas than the ones using the nominal method (8.18>4.93). Furthermore, there is a significant difference between the two sets of data, as the significance is p=0.028<0.05, which means that the number of unique ideas generated through IVMS was statistically larger than that through the nominal approach. Therefore, hypothesis 2 was not supported.

Table 7.4 Unique Ideas & P1 Ideas from the Nominal and IVMS Approaches

	Unique ideas		***Unique P1 ideas***	
Brainstorming method (Number of participants)	***Nominal (15)***	***IVMS-supported (15)***	***Nominal (15)***	***IVMS-supported (15)***
Mean	4.93	8.18	4.14	3.71
Standard deviation	2.06	4.10	1.66	2.47
Mann-Whitney (Mean rank)	12.07	19.24	17.96	14.38
Significance	p=0.028<0.05*		p=0.264>0.05	

Note: * is significant at the 0.05 level.

In Table 7.4, the number of unique P1 ideas generated per person through IVMS is smaller than that generated using the nominal method (3.71<4.14). However, there is no significant difference between the two sets of data, as the significance is p=0.264>0.05, which means that the number of unique P1 ideas generated through IVMS was not statistically larger than that using the nominal approach. Therefore, hypothesis 4 was supported.

Survey of Users' Feedback

There are three sections in the questionnaire. Section A was designed to test whether the participants have the same experience with brainstorming and tasks used in the experiment. Sections B and C were designed to determine the satisfaction of participants with IVMS.

Table 7.5 presents the means, standard deviations, and t-test significances of the questions in section A. The statistics analysis suggests that participants in session A have the same brainstorming experience and work experience relevant to the tasks used in the experiment with participants in session B. Hence, participants in different sessions were regarded as the same.

Table 7.5 T-tests of the Significance of the Questions in Section A

Question	***Session***	***Mean***	***Standard deviation***	***Test statistics***
Q1	A	3.29	0.61	p=0.143>0.05
	B	3.59	0.51	
Q2	A	2.57	0.76	p=0.212>0.05
	B	2.88	0.60	
Q3	A	3.00	0.00	p=0.793>0.05
	B	2.94	0.83	

(4: Strongly agree 3: Agree 2: Disagree 1: Strongly disagree)

Note:

Q1: I have experience in brainstorming.

Q2: I have experience in interior decoration.

Q3: I have experience in water supply activities.

For the other questions in section B and section C, the means of the answers were used to judge whether the participants felt the same with regard to the issues raised in the given questions. The results are shown in Table 7.6.

Table 7.6 Summary of the Survey Results in Sections B and C

Questions		***Mean***	***Standard deviation***	***Agree/ Disagree the issues in the given questions***
No.	**Content**			
Q4	I can express my ideas more promptly by using IVMS	2.94	0.83	Agree
Q5	I can generate more ideas on the basis of others' ideas by using IVMS	2.94	0.66	Agree
Q6	I can understand the ideas of the members of my group by using IVMS	2.88	0.93	Agree
Q7	I have more equal opportunities to express my ideas by using IVMS	3.41	0.62	Agree
Q8	I have confidence about expressing my ideas by using IVMS	3.24	0.66	Agree
Q9	I can generate more good-quality ideas by using IVMS	2.47	0.72	Neutral
Q10	I am more satisfied with the outcome of brainstorming by using IVMS	2.71	0.77	Agree
Q11	My typing speed can help me to express my ideas	2.82	0.95	Agree
Q12	I feel comfortable about using IVMS	3.29	0.69	Agree
Q13	I am satisfied with the interface of IVMS	3.12	0.78	Agree

(4: Strongly agree 3: Agree 2: Disagree 1: Strongly disagree)

Table 7.6 indicated that users agreed with most of the statements; the scores of four of 10 items are not less than 3.00, and five items more than 2.50. The results showed that the statement "I have more equal opportunities to express my ideas by using IVMS" was the one that participants agreed with most. Participants also thought that they could express ideas more promptly by using IVMS and felt confident in expressing their ideas using IVMS. As mentioned earlier, the conformance pressure and the lack of active participation are the main problems while using VM. Hence, the results provided positive evidence to support the proposition that IVMS could overcome the problems in the idea generation phase during VM workshops.

Results also suggested that the participants agreed to both the statements “I can generate more ideas on the basis of others’ ideas by using IVMS” and “I can understand the ideas of the members of my group by using IVMS”. This shows that users could understand others’ ideas better and had more chance to build ideas on others’ ideas while using IVMS.

However, participants didn’t agree with the statement “I can generate more good-quality ideas by using IVMS”, which was in line with the analysis on Hypothesis 3 and 4: there were no great differences between the quality of ideas generated by using IVMS and by using traditional brainstorming methods.

The interface of IVMS and participants’ comfort with its use could affect the results of the experiments. The results also showed that most of the users felt comfortable about IVMS (Q12, Q13).

Finally, from the above analysis, it could be concluded that the participants were more satisfied with the process and outcomes of the brainstorming using IVMS than the brainstorming with traditional brainstorming approaches.

Findings from the Observers

The observers observed and compared the activities of participants using the face-to-face approach and IVMS, especially the ones who were silent in the face-to-face brainstorming process. There were four silent participants in the face-to-face brainstorming process; three of them became more active in the IVMS-supported mode. These users may have been silent in the face-to-face process because they were shy or feared criticism. According to the observation, IVMS was shown to be useful at alleviating the evaluation apprehension that had reduced productivity in the face-to-face brainstorming method.

A correlation analysis was also made between the speed of typing (which was recorded by the observers) and productivity in the IVMS-supported process. The correlation is 0.607 and the significance is $0.01<0.05$, so there is positive correlation between the speed of typing and productivity in IVMS-supported brainstorming. Hence, the speed of typing can affect the productivity of IVMS-supported brainstorming. This is also indicated by findings from the questionnaire survey: participants agreed with the statement in Q 11.

7.3.2 Experimental Study II: Comparison (b) of Idea Generation between Traditional and GDSS-supported VM Workshops

This research can be regarded as an extension of the previous study. Based on the results and limitations of last study, this research made several modifications, including:

1. The participants were asked to conduct the full process of a VM workshop instead of only the brainstorming session;

2. More participants were invited to join this experiment (72 in this experiment, compared to only 30 in experiment I);

3. Since face-to-face brainstorming is still the most widely used approach during current VM workshops, only IVMS-supported and face-to-face brainstorming approaches were compared.

7.3.2.1 Experimental Design

This experiment was a comparison study of idea generation between VM workshops with IVMS support and VM workshops without IVMS support. This study aimed to validate the communication support of IVMS. The participants were 72 undergraduate students enrolled in a VM course at the Hong Kong Polytechnic University. The subjects were divided randomly into twelve six person groups to mirror the size of the discussion groups in real-life VM workshops in Hong Kong. Six groups used IVMS-supported brainstorming and others used face-to-face brainstorming to generate ideas for the same task, which was extracted from a real project in Hong Kong. The detailed design of the experiment is shown in Table 7.7. In order to control the impact of facilitator styles, the same facilitator was invited to facilitate the brainstorming process. Hence, the experiment was divided into two one-day sessions: six groups conducted face-to-face brainstorming on day 1; the other six groups were provided with IVMS support on the next day. Six researchers acted as observers to record useful information such as the number of ideas generated by individuals in the face-to-face brainstorming process and the typing speed of participants in the IVMS-supported brainstorming process.

Table 7.7 Framework for the Proposed Experiment

Session	***Group***	***Brainstorming Approach***
Session A	Groups 1-6	Face-to-face brainstorming: participants speak out their ideas one by one; the ideas are recorded at the same time by a recorder.
Session B	Groups 7-12	IVMS supported brainstorming: participants generate ideas in an anonymous environment through IVMS; the ideas are recorded automatically by the system.

Task

A real VM project, Stonecutters Bridge in Hong Kong, was taken as the task. The main objective was to review the look out point (LOP) and exhibition centre (EC) for Stonecutters Bridge. Detailed information was provided to all the subjects in the experiment.

Independent and Dependent Variables

There is only one independent variable in the present study: brainstorming technology. Two dependent variables are measured, including the outcome of the brainstorming and the participants' satisfaction. The outcome of the brainstorming is measured in two aspects: 1. the quantity of unique ideas; 2. the quality of the ideas which is measured by the quantity of the realistic ideas, the depth and width of the ideas. The participants' perceived satisfaction is collected through a questionnaire survey.

Experimental Procedures

In order to prepare them for the experiment, all of the participants were exposed to the concepts of group decision-making processes and GDSS technology during the training course. This helped to control individual differences in their understanding and ability in group decision making and their exposure to GDSS. At the beginning of each experimental session, the members of the GDSS-supported group were trained in the use of GDSS.

In the face-to-face session, a five minute warm-up game was played first. Then the facilitator introduced the task and the rules of the brainstorming in the VM workshops to the participants. After this, the participants were divided into six six-person groups to mirror the size of discussion groups in the real life VM workshops. All the groups were given 20 minutes to generate ideas on the task. Finally, all the ideas were collected together. In the GDSS-supported session, a warm-up game was also played. The task and the rules of the brainstorming in VM workshops were introduced. There were also six six-person groups and the ideas were collected after the brainstorming. A questionnaire survey was conducted at the end of each session.

The ideas generated were compared according to the quantity and the quality. Quality was assessed by two researchers who categorized the ideas into P1 = realistically possible, P2 = remotely possible, and P3 = fantasy. In this way, P1 ideas were considered to be ideas of good quality. First, the ideas generated in each group were collected and repeated ideas were removed; then the unique ideas were categorized by the two researchers. The quantity of unique ideas and unique ideas with good quality (equal to P1 ideas) are shown in the Table 7.8.

Table 7.8 Quantity of Unique Ideas and Unique P1 Ideas

	Unique Ideas		***Unique P1 Ideas***	
	Face-to-face (Group1-6)	IVMS （Group 7-12）	Face-to-face (Group1-6)	IVMS （Group 7-12）
	20	44	8	17
	25	60	15	11
	31	50	13	15
	23	31	14	21
	21	25	12	14
	23	24	10	19
Total	143	234	72	97
Mean	24	39	12	16
t-test	p=0.03*		p=0.04*	

*Note: * means p<0.05*

7.3.2.2 Experimental Results

Table 7.8 shows that the average of unique ideas generated by face-to-face groups was less than the average of unique ideas generated by IVMS groups. Moreover, there is a significant difference between the two sets of data (significance $p=0.03<0.05$), which means that the number of unique ideas generated through IVMS was statistically larger than that through face-to-face approach.

The quality of ideas was measured by three variables: the quantity of unique ideas with good quality, the width of ideas, and the depth of ideas. As mentioned above, the unique ideas with good quality were selected by two researchers. As Table 7.8 shows, the average number of P1 ideas generated by the IVMS-supported groups was larger than the average number of P1 ideas generated by the face-to-face groups. The results of the t-test also show that there was a significant difference between the two sets of data ($p=0.04<0.05$), which means the number of unique P1 ideas generated through IVMS was statistically larger than that through the face-to-face approach.

An idea tree (as shown in Fig. 7.5) was then developed to analyze the width and depth of ideas generated. The ideas generated by all the groups were collected together, and then repeated ideas were removed. Hence, although there were 377 ideas (FTF=143; IVMS=234) generated according to Table 6.8, there were 236 unique ideas left after the removal of repeated ideas. These unique ideas were further divided into five divisions and 24 branches. The ideas of each group were compared with the idea tree. When the width of ideas was analyzed, only the divisions were considered. If an idea related to one of the branches, a 100-score would be calculated. For example, if the ideas generated by one group related to four divisions, the width was 400. When the depth of ideas was analyzed, the branches were considered. Each branch mentioned by the ideas was calculated as a 50-score. The width and depth of ideas were shown in Table 7.9.

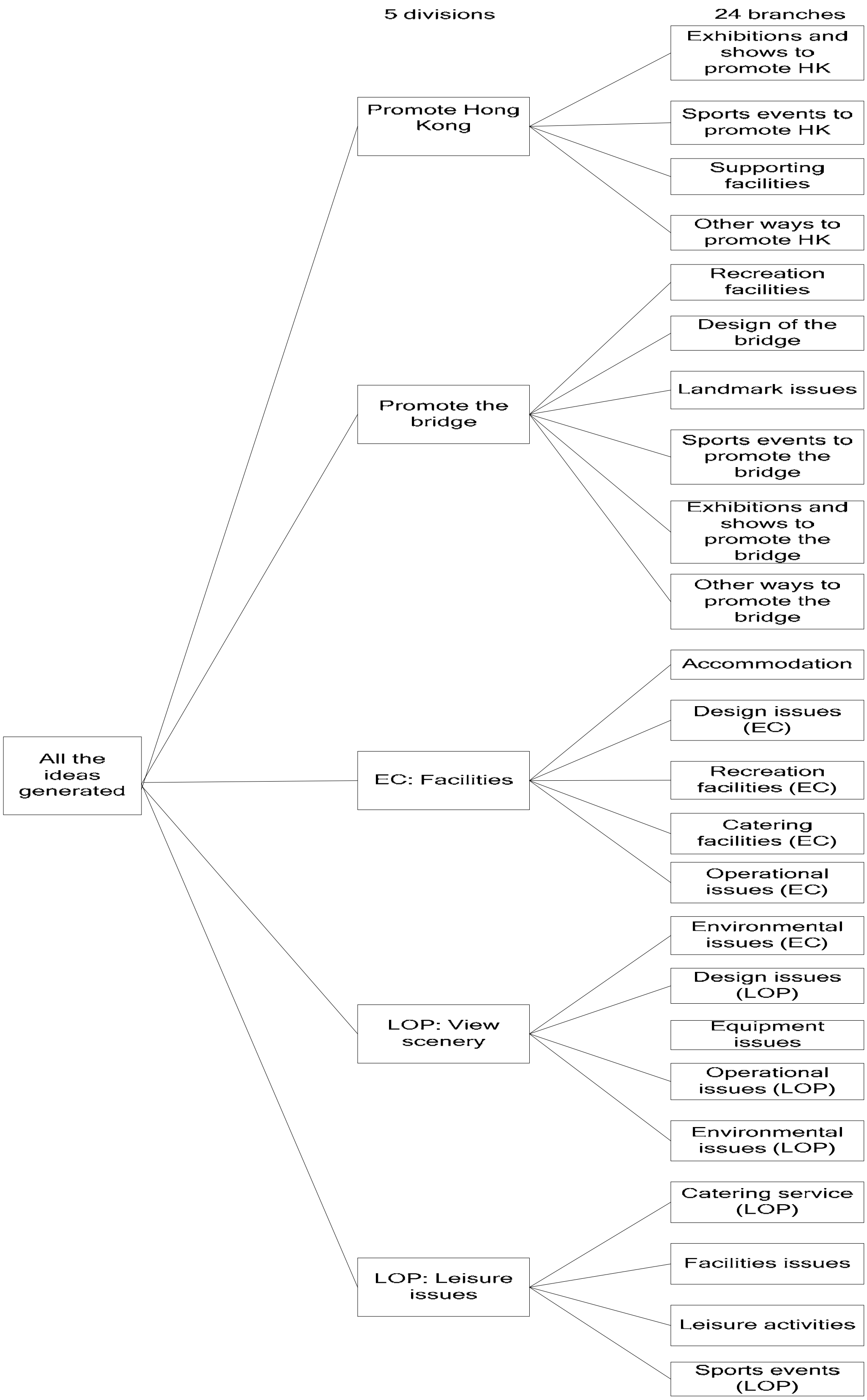


Fig. 7.5 An Idea Tree for Experimental Study II

Table 7.9 Width and Depth of Ideas

	Width of Ideas		*Depth of Ideas*	
	Face-to-face	GDSS	Face-to-face	GDSS
Group 1	400	500	200	300
Group 2	400	400	450	250
Group 3	400	500	200	400
Group 4	400	400	400	500
Group 5	400	400	300	400
Group 6	400	400	350	300
Mean	400	433	317	358
t-test	p=0.14		p=0.48	

7.3.3 Experimental Study III: Validation of Using IVMS in the Full Process of VM Workshops

7.3.3.1 Experiment Tasks

Since it is hard to conduct field studies before testing the effectiveness and efficiency of the system, an experimental study was designed and conducted. This study is designed to mirror the real VM workshops as closely as possible. There are two objectives: (1) to investigate the effectiveness and efficiency of the system, and (2) to test the support of the system.

A real project task, Stonecutters Bridge in Hong Kong, was taken as the object, instead of a contrived one. The two main sub-tasks were to review the colour of the architectural lighting for the Stonecutters Bridge and construct a look out point and an exhibition centre (LOP & EC) for the Stonecutters Bridge. The objective of the architectural lighting was to recommend architectural lighting themes and colours to be adopted on the bridge at different times of the year without creating any implications for the structural detailing. The objective of the LOP & EC was to agree on the function for the LOP & EC design and a layout for parking facilities, and decide whether a café facility and other leisure facilities should be provided based on the endorsed location of LOP & EC beside the western tower of the bridge.

The participants were asked to organize, manage and conduct a GDSS-based VM workshop with the whole process, including pre-workshop stage, workshop stage, and post-workshop stage.

7.3.3.2 Participants

The participants were 20 part-time postgraduate students enrolled in a VM course at the Hong Kong Polytechnic University. An integrated component of the course is a strategic simulation that requires students to organize a VM workshop. All of the students have been working in the construction industry for several years. There should be different stakeholders in this experiment, and each participant should play a role. If one was not familiar with the role they were playing, he/she would not act well and the performance of the whole study would be influenced. Since all of the participants were currently working on real projects, their work experience made this VM study just like a real-life VM study. Two researchers who were familiar with the use of IVMS played the role of GDSS process facilitators.

However, there is often a concern raised regarding the use of students as subjects in GDSS research. Fjermestad and Hiltz (1999) report that 94 percent of those studies involved students as subjects. The limitation of using students as participants has long been recognized (Lorge et al., 1958), but there is still a lot of research using students because of the difficulty in persuading real managers to participate in GDSS sessions.

However, Briggs et al. (1996) found no significant differences between executive business managers and graduate business students in evaluating technology. Also, Remus (1986) found no significant differences between line managers and MBA students with little business experience in production scheduling decisions. The participants in this study are not only students but also experienced practitioners in the construction industry. Besides, one of the main reasons why it is difficult to generalize results from laboratory studies to field studies is that the participants do not care about the outcomes as much as the participants in field studies. Fifty percent of a student's grade was contingent on their group performance in this VM workshop, which means that the performance and outcomes of the study were relevant to their scores. Hence, the participants had an incentive to do their utmost to conduct the workshop well. Given this, it is reasonable to use students as the subjects.

7.3.3.3 Performance Measures

Performance of VM Team with GDSS Support

As mentioned earlier in Section 7.2.1, decision quality, time and satisfaction with the process and outcomes should be measured in order to investigate the performance of VM teams using GDSS. Decision quality can be assessed by comparing the outcome of group work with a correct or desired solution for certain categories of group tasks, such as intellectual tasks (Paul et al., 2004a). However, unlike intellectual tasks, decision-making tasks do not have any correct outcome (McGrath, 1984). Yet decision quality as perceived by the participants is an important dependant variable for decision-making work. Perceived decision quality includes group members' confidence in the decision outcome and their perceptions of the usefulness of the decision outcome (George et al., 1990). In this experimental study, the author intends to focus on the effectiveness rather than the efficiency of GDSS use and, thus, will exclude decision time from the current experiment study. Except for the satisfaction with process and outcomes, another interesting issue is the participation of the VM team members in the study. Hence, the author also focuses on team members' perceptions about participation, which has received considerable attention in GDSS research (Fjermestad and Hiltz, 1999).

Variable Identification

The study aims to test the effect of using GDSS on the processes and outcomes of VM workshops. Four dependant variables were measured: satisfaction with the VM process, perceived participation, perceived decision quality, and satisfaction with the IVMS support. Nine items were designed according to the tasks and needs in each phase of the VM workshops to measure satisfaction with the VM process. Similarly, five items were developed to measure the perceived participation. In the survey, these five items and the nine items mentioned above were combined to form one part. Perceived outcomes quality was measured by four items. The twelve items, which were designed to measure the satisfaction with the IVMS support, were adapted from the research by Shen, et al. (2004). Each item was measured on a five-point Likert-type scale, with 1 as "strongly disagree" and 5 as "strongly agree". Five open-ended questions were also designed to collect the suggestions from the participants on the design of IVMS.

7.3.3.4 Training

All of the participants were experienced with the internet, but none had previously used the collaboration software in this study. The tool used was IVMS, which is introduced in Chapter 6. It aims to supply a useful toolbox for VM practitioners to employ in conducting VM workshops.

Subjects were scheduled into a training session that dealt with all phases of the study. The training was conducted by two assistants, both of whom had extensive experience in the IVMS, its features, and its use. The training session that was conducted in the computer laboratory lasted about two hours.

Participants were supplied with appropriate training materials during this session. These included a manual which contained the commands and the features of the software together with the description of each feature and how to use it. During the training session, the trainers demonstrated a fictitious task, making use of the system's commands and features that were also used in the actual study. Students were seated at a computer workstation and were able to view the use of the tool's features and commands and the procedures to carry out the fictitious task. Any questions asked by the participants were answered by the trainers.

7.3.3.5 Experimental Equipment and Procedures

A GDSS room with a face-to-face setting, as shown in Fig. 7.6, was established to simulate the environment of this GDSS-supported VM workshop. In the study, all the participants were supplied with a notebook PC equipped with a mouse. They were seated in a room in which a wireless network had been set up for the study. Users could access the IVMS using the laptop through the wireless network. The use of wireless network and laptops meant that the power cables and network wires were not needed, removing a possible cause of disruption and further allowing the users to move easily with the computer when sub-groups were needed. The projector and a large common viewing screen were also provided to display public notices or other group information.

The task description was given to the participants three weeks before the VM workshop in order to help ensure the participants were fully prepared. The training session was conducted two weeks before the workshop to provide the participants with appropriate knowledge about IVMS. The workshop was designed as a one-day VM workshop, including information, analysis, creativity, evaluation, development and presentation phases.

Fig. 7.6 A VM workshop with GDSS Support

During the whole process of the VM workshop, each session was observed unobtrusively by two researchers. The two researchers also provided technical support to ensure the system worked fluently and evaluated performance, recording any useful information relevant to performance.

7.3.3.6 Experimental Results

Support of IVMS

The findings of the VM study indicated that the application of IVMS in VM studies was highly supportive. Table 6.10 showed that most of the IVMS functions were reported as being useful in supporting and improving VM studies; the scores of nine out of 12 items are not less than 4.00, and three items are more than 3.00. This provides strong evidence to support the idea of using GDSS tools to improve VM studies.

The results also show that participants most agreed with the statements “IVMS can promote active participation in idea generation” and “IVMS can avoid conformance pressure in idea generation”. As Table 7.10 shows that the conformance pressure and a lack of active participation are the main reasons for VM problems, this suggests that IVMS could be a strong tool to solve the VM problems.

Improving the availability of information and information exchange process are both ranked as the second most useful functions. This means that IVMS could also help to alleviate the lack of information in VM studies. Participants also indicated the usefulness of the support offered by IVMS in both the analysis and evaluation phases. These functions are all in line with the difficulties described at the beginning.

The interface of the IVMS is important for its application in VM studies. If the participants do not like the interface, the performance of the VM study will be influenced. However, the interface of IVMS makes most of the participants feel comfortable, as shown in Table 7.10.

There are two functions (with scores less than 4.0) in the creativity phase that seemed not to work well as indicated in Table 7.10. First was the pop-up agent that was meant to add to the social needs of the VM team and make the atmosphere active. The possible reason is that some participants may feel being interrupted by the agents during the idea generation process. The second function is the “Tips”, which was designed to provide some tips for participants on generating ideas by using data mining technology. The unfavourable performance of “Tips” may be caused by inadequate information in the database. Since the function of “Tips” is based on data mining technology, if the database does not contain enough information, the function will not work well. For that time being, only two workshops have been conducted, so there is not enough information which may affect the performance of “Tips”.

Table 7.10 Summary of the Survey Results on the Support of IVMS

Type of Support	Average
Support in Information phase	
IVMS can improve the availability of information. …..…………….……..	4.18
IVMS can improve the information exchange process. …………………...	4.18
Support in Function analysis phase	
IVMS can simplify the function analysis processes.	4.12
IVMS can enhance the function analysis processes.	4.18
Support in Creativity phase	
IVMS can promote active participation in idea generation.	4.29
IVMS can avoid conformance pressure in idea generation. ………………..	4.24
IVMS can prevent domination in discussion. ……………………………...	3.94
The pop-up character in IVMS can enhance the atmosphere of creativity. ...	3.88
The function of “Tips” can help me in generating ideas. …………………...	3.47
Support in Evaluation phase	
IVMS can simplify the evaluation processes.	4.06
IVMS can enhance the evaluation processes.	4.00
Interface of IVMS	
I feel comfortable with the current interface of IVMS	4.00

(5: Strongly agree 4: Agree 3: Neutral 2: Disagree 1: Strongly disagree)

Satisfaction with the Process and Outcomes of the VM Study

It is hard to measure the satisfaction with the process directly, for the satisfaction with the process is too abstract for participants to evaluate. Hence, the satisfaction with the techniques used in each phase of this study and staged outcomes were used to represent the satisfaction with the whole process. Participants were asked to make a number of evaluations on these two aspects using five-point rating scales. The results are shown in Table 7.11.

Table 7.11 Participants' Satisfaction with the Process

	Average
Pre-workshop stage	
You are satisfied with the information collected in pre-workshop stage.	4.24
Information phase	
You are satisfied with the techniques used in information phase.	4.06
You are satisfied with the clarification of client's objectives.	4.00
You are clear about the givens/assumptions of the project.	4.00
Function analysis phase	
You are satisfied with the techniques used in function analysis phase.	4.00
Functions are clearly identified.	4.00
Creativity phase	
You are satisfied with the techniques used in creativity phase.	3.94
Evaluation phase	
You are satisfied with the techniques used in evaluation phase.	4.00
Development phase	
You are satisfied with the techniques used in development phase.	3.94
You are satisfied with the outcomes of the VM workshop.	4.06

(5: Strongly agree 4: Agree 3: Neutral 2: Disagree 1: Strongly disagree)

From this table, it is found the participants gave scores of around 4.00 to all of the 10 items listed, including scores of above 4.00 to eight items and more than 3.90 to the other two items. It indicated that either the techniques used in this study or the staged outcomes satisfied the participants. Deduced from this, it can be concluded that the participants were satisfied with the process and outcomes to a large extent.

Perceived Participation

Table 7.12 Perceived Participation

	Average
Information phase	
You are satisfied with the interaction between participants.	4.24
Function analysis phase	
You are satisfied with the interaction between participants............................	4.24
Creativity phase	
You are satisfied with the interaction between participants.	4.18
Evaluation phase	
You are satisfied with the interaction between participants.	3.94
Development phase	
You are satisfied with the interaction between participants.	4.35

(5: Strongly agree 4: Agree 3: Neutral 2: Disagree 1: Strongly disagree)

This VM study was conducted according to the SAVE 40-hour job plan. There are several stages in this VM study, including the information phase, function analysis phase, creativity phase, evaluation phase and development phase. Therefore, the items were designed respectively. From this table, four of five items got scores more than 4.00 with one above 3.90, which indicates that the participants felt satisfied with the interaction between them.

Perceived Decision Quality

Table 7.13 Perceived Decision Quality

	Average
The workshop helped to identify and clarify the client's requirement.	4.00
The workshop helped to improve the project quality.	4.18
You are satisfied with the outcomes of the VM workshop.	4.06

(5: Strongly agree   4: Agree   3: Neutral   2: Disagree   1: Strongly disagree)

Two of the objectives of VM, as found in its definition, can be found in the perceived decision quality survey: meeting the clients' needs, improving the project quality. These two items both got a score above 4.00, which indicates that the participants felt that the decision quality was high.

7.3.4 Experimental Study IV: Comparison between Traditional and GDSS-supported VM Workshops

7.3.4.1 Experimental Design

In order to investigate the effect of using GDSS in VM workshops, a comparative study was conducted. Two VM workshops were conducted: one workshop was conducted using the traditional method, and the other one provided GDSS support. A real project task in Hong Kong was used; a cycle track connecting North West New Territories with North East New Territories was taken as the object. There were three main objectives of this study, which were extracted from the real tasks in a real-life VM study, as follows:

- to create a structural forum whereby views from all stakeholders on the construction of new cycle track sections to create a cycle track network can be expressed;

- to discuss and decide what supporting facilities should be provided to enhance the tourism value of the existing and new cycle track network;

- to identify and agree on the functions for the education centre.

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

7.3.4.2 Experiment Equipment and Procedures

The task description was given to the participants three weeks before the VM workshop in order to help ensure the participants were fully prepared. The workshop was designed as a one and a half day VM workshop. During the whole process of the VM workshop, each session was observed unobtrusively by the author. The author recorded the selected information relevant to performance, and also provided technical support to ensure the system worked fluently during the GDSS-supported workshop. Besides, the settings for the two workshops were different. The GDSS-supported VM workshop was conducted in a GDSS room, as shown in the left part of Fig.7.7. The right part shows the traditional face-to-face VM workshop. From the figures, it can be seen that the GDSS-supported workshop was also set up in a face-to-face environment, as the aim of this study was not to replace the face-to-face environment but to integrate GDSS with it to obtain benefits from both modes.

Fig. 7.7 The IVMS-Supported & Traditional VM Workshops

In order to reduce the variables, both workshops were facilitated by the same experienced facilitator. Both workshops were also conducted according to the same agenda based on the generic VM process as shown in Fig. 6.1, including information, creativity, evaluation, development, action planning, and workshop report phases. Since this study was not a real-life one, the last phase “implementation” was not conducted. The main difference between the two workshops was that the tasks during the GDSS-supported workshop were conducted through the tools provided by GDSS, as shown in Table 7.14.

Table 7.14 Differences between the GDSS-supported Workshop and the Traditional Workshop

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

Since all the participants had obtained basic VM knowledge with the process of the VM workshop through the VM class, and IVMS was designed according to the VM process, it was easy for the participants to get familiar with the system with the guide of the facilitator. Hence, no special training was arranged before the workshop for the participants who used IVMS during the workshop. The process of the workshop also demonstrated that the system was user friendly as the participants got used to the system in no time.

7.3.4.3 Participants

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

However, there is often a concern raised regarding the use of students as subjects in GDSS research. However, as discussed in Section 7.3.3.2, it is reasonable to use students as the subjects.

7.3.4.4 Measures Used during the Study

Three aspects of the two workshops were compared to judge the effects caused by the use of GDSS:

- Process measures. The CVA framework was used to measure the perceived effectiveness of the decision process during the two workshops through a questionnaire. The largest number of items on the questionnaire pertained to the CVA framework, while others related to the outcomes and satisfaction measures. The questionnaire employed a six-point Likert-type response scale (i.e., strongly agree, generally agree, slightly agree, slightly disagree, generally disagree, and strongly disagree). Each of the eight criteria, according to Fig. 7.1, was determined through the mean of numerically coded participant responses to two or three questionnaire items. Some of the items were reverse-worded to reduce a possible response-set bias. The items comprising the CVA framework in the questionnaire are presented in Appendix A.

- Outcome measures. Unlike intellectual tasks, decision-making tasks do not have any correct outcome (McGrath, 1984). Yet decision quality as perceived by the participants is an important dependant variable for decision-making work. Perceived decision quality includes group members' confidence in the decision outcome and their perceptions of the usefulness of the decision outcome (George et al., 1990). Also, the quantity of ideas is usually taken as a factor to judge the effectiveness of VM workshops. During the workshop, the quantity of ideas and the quantity of P1 ideas which were selected by the participants as realistic possible ideas (the P1 ideas can be taken as quality ideas) can be obtained. The quantity and quality of ideas generated during the two workshops were analyzed and compared. Another factor to be considered as part of the outcome measures is perceived participation, which has received considerable attention in GDSS research (Fjermestad and Hiltz, 1999). The perceived participation was measured through the questionnaire, which asked the participants to what extent they agree that the interaction among the VM team was active in each phase and whether the workshop improved the communication and understanding among key stakeholders, etc.

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

7.3.4.5 Experimental Results

Process Measures

Fig. 7.8 presents the differences between the decision process profiles for the two VM workshops. Scale scores for the eight effectiveness measures are plotted on the axes of each profile. When perceptions of an effective decision process are more positive, the profile is extended outward on an axis. Concavities in the profile indicate aspects of decision process effectiveness that may deserve remediation.

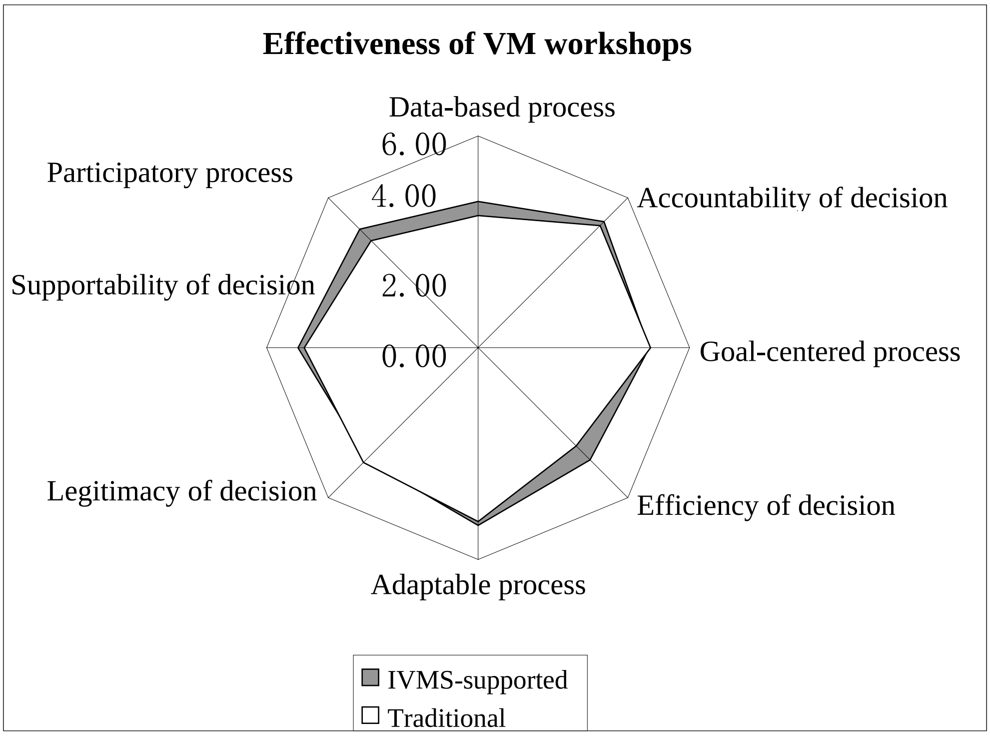


Fig. 7.8 Profiles of Decision-making Effectiveness of the Two VM Workshops

The CVA framework was used to differentiate VM workshops with respect to the methods' (IVMS-supported and traditional methods) success. From Fig. 7.8, several scales discriminate between the IVMS-supported and traditional workshops. It can be found that the IVMS-supported VM workshop outperformed the traditional VM workshop in the following aspects: efficiency of decision, data-based process, and participatory process. Moreover, according to Table 7.15, the corresponding t-test results were significant. However, it is also important to note that in other scales both workshops were evaluated quite highly (grand mean from 4.49 to 5.02). The mean and t-test results are shown in Table 7.15.

Table 7.15 Results of Variance for Process Effectiveness

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

Note: * is significant at the 0.05 level.

As seen in the above table, there were significant differences between the IVMS-supported and traditional workshops in the following three aspects: (1)

data-based process, (2) efficiency of decision and (3) participatory process. In other aspects, there were no significant differences.

Outcome Effectiveness

a. Quantity and Quality of Ideas

Table 7.16 Unique Ideas & P1 Ideas from the Face-to-Face and IVMS Approaches

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

Note: * is significant at the 0.05 level.

Table 7.16 shows the number of unique ideas generated by each participant with the different brainstorming approaches. Participants using IVMS generated more unique ideas than the ones using the face-to-face method (11.06>5.41). Furthermore, there is a significant difference between the two sets of data, as the significance is p=0.004<0.05, which means that the number of unique ideas generated through IVMS was statistically larger than that through the face-to-face approach. In Table 7.16, the number of unique P1 ideas generated per person through IVMS is also larger than that generated using the nominal method (5.24<3.00). There is a significant difference between the two sets of data, as the significance is p=0.02<0.05, which means that the number of unique P1 ideas generated through IVMS was statistically larger than that using the face-to-face approach.

b. Perceived Decision Quality and Participation

From Table 7.17, it can be found that the interaction during the IVMS-supported workshop was ranked higher. The participants also thought that the client's requirements were better identified and clarified in the IVMS-supported workshop. The corresponding t-test results of the above two items were also significant, which indicated that the perceived decision quality and participation of IVMS-supported VM workshops were better.

Table 7.17 Perceived Decision Quality & Participation

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

Note: * is significant at the 0.05 level.

(5: Strongly agree 4: Agree 3: Neutral 2: Disagree 1: Strongly disagree)

Perceived Participants' Satisfaction

The results in Table 7.17 suggest that all of the participants were more satisfied with IVMS than with the other traditional approaches (mean of 4.59 and 4.35, respectively), and the corresponding t-test result was significant at the 0.05 level.

7.4 Action Research

The main objective of this action research is to further validate the IVMS system and to investigate the effect of using GDSS in a real-life VM study. The duration of the workshop was one day, and 37 participants joined in the workshop. The client of this workshop was one department of the Hong Kong Government. The project involved was the creation of cycle tracks connecting North West New Territories with North East New Territories in Hong Kong. The main objective of this workshop was to provide a platform for all the stakeholders to discuss and make suggestions on several aspects, including how to improve the attractiveness of the cycle track, the supporting facilities and promotional issues.

The workshop followed the general VM job plan, including the following phases:

- Information phase. During this phase, the objectives of this workshop were introduced. The participants confirmed the givens and limitations of this project, and identified the needs of the final users of the cycle track. GDSS was used to collect the background information of this project from different stakeholders.

- Function analysis phase. During this phase, the functions of the cycle track were analyzed and identified. GDSS was used to support the participants in the function generation process.

- Creativity phase. The participants were asked to generate different ideas on how to achieve the functions identified in the previous phase. All the ideas were generated with the support of GDSS.

- Evaluation phase. All the ideas generated were firstly categorized into three categories (P1: realistic possible; P2: remotely possible; P3: fantasy). Then all the related P1 ideas were grouped together to form action plans. During this phase, GDSS was used to categorize ideas.

- Development phase. All the action plans were assigned to related parties to follow up.

During the workshop, the author only acted as an observer and did not make any contribution to the workshop. A questionnaire survey had been planned to be conducted to collect the feedback of the participants, however the client of this workshop asked that all the information of the workshop be kept confidential. Hence, instead of a questionnaire survey, an interview with the workshop facilitator on the support of GDSS was conducted.

7.5 Summary

This chapter presents three types of experimental studies conducted during this research, including two comparative studies of idea generation between traditional and GDSS-supported VM workshops, a validation study of using GDSS in VM workshops and a comparative study between traditional and GDSS-supported VM workshops. All of the experimental settings including the procedures, equipment, participants and variables are introduced in detail. The results from the experimental studies, questionnaire survey and the action research will be discussed in the next chapter.

Chapter 8: Research Findings & Discussions

8.1 Introduction

This chapter reports the findings from the research. Three types of experimental studies were conducted: two comparative studies of idea generation between traditional and GDSS-supported VM workshops, a validation study of using GDSS in the full process of VM workshops, and a comparative study between traditional and GDSS-supported VM workshops. Through these three different types of experimental studies, there is evidence to support the notion that GDSS is useful in improving the efficiency and effectiveness of VM workshops. Four CSFs are identified through a questionnaire survey. The findings from the action research are also introduced in this chapter.

8.2 Findings from the Experimental Studies

This section summarizes the findings from the three types of experimental studies.

8.2.1 Experimental Study (I): Comparison (a) of Idea Generation Between Traditional and GDSS-Supported VM Workshops

8.2.1.1 Hypothesis 1 and Hypothesis 2

According to the results shown in Chapter 7, it is suggested that the participants using IVMS generated more unique ideas than the ones using the face-to-face method. The potential reasons are given below.

One of the most important reasons is the parallel entry of ideas, which means that by using IVMS users did not need to wait for their turn to express their ideas. Users could express their ideas as soon as possible and then go on to generate other ideas. This is in line with the results of the questionnaire on statements Q4 and Q7. On the contrary, only one user at a time could express ideas in the face-to-face approach.

The environment of total anonymity when using IVMS could be another important reason. The results of the observation showed that IVMS could make those who were silent in the face-to-face brainstorming more active. It is probably the factor of anonymity that caused the users to become more active. Users who may fear receiving negative evaluations from others in the face-to-face brainstorming may not have this fear in the anonymous environment of the IVMS-supported process. The results of the post-session questionnaire indicated that most of the participants felt more confident in expressing their ideas while using IVMS.

Furthermore, in the face-to-face brainstorming process, some individuals were very dominant in their group. For example, one participant generated nearly half of his group's ideas. But with IVMS, the dominance was eliminated from that group. In other words, the increased possibility for ideas to be offered by all participants causes IVMS to be more productive.

Finally, in the face-to-face brainstorming process, each group needs to have one person to record ideas as soon as they are generated by the group, just as in a real-life VM workshop, so the recorder may spend most of his time recording ideas instead of generating ideas. Since all ideas can be automatically collected by the IVMS, there is no need to assign a recorder. A comparison was made of the three recorders to determine the differences in the number of ideas generated in the face-to-face brainstorming and IVMS-supported brainstorming, as shown in Table 8.1.

Table 8.1 Comparison of the Number of Ideas Generated by the Recorders

Recorder	***Number of ideas generated by recorders***		
	Face-to-Face brainstorming	**IVMS-supported brainstorming**	**Difference**
Group 4's recorder	3	12	9
Group 5's recorder	2	8	6
Group 6's recorder	1	9	8

As shown in this table, there is a sharp increase on the number of ideas when the recorder generated ideas by using IVMS. It is as if there was one more person in IVMS-supported brainstorming than in the face-to-face brainstorming, although in fact the number of participants was the same. This may therefore be another factor influencing the production of unique ideas.

Since hypothesis 2 was not supported, IVMS-supported groups also generated more unique ideas than groups using nominal technology. The potential process losses of nominal technology compared to IVMS have been suggested by the discussion and observation.

In nominal brainstorming the participants could not see ideas generated by other members of the group, so the same ideas may end up being generated by more than one participant. Since the participants all come from the same department and had nearly the same background in terms of knowledge, and the tasks for generating ideas were both common ones, the chances of the different participants generating the same ideas was much higher. On the other hand, since the participants could see the ideas of others through IVMS, there was less chance that they would generate the same ideas. Furthermore, by allowing the participants to see others' ideas on their own screens, IVMS may inspire them to think in novel directions and inspire new ideas.

8.2.1.2 Hypothesis 3 & Hypothesis 4

Regarding the number of unique P1 ideas, the results suggest that there are no differences between the participants using IVMS and traditional brainstorming approaches: nominal, face-to-face. In the post-session questionnaire, the participants also felt uncertain about the statement in Q9: I can generate more good-quality ideas by using IVMS. Furthermore, of the three approaches, groups using IVMS generated the most unique ideas; hence they also generated the greatest number of bad ideas. Some potential reasons are listed below.

Firstly, the ideas generated are listed on each participant's screen, and the participant may read every new idea that appears on the screen. The ideas generated by others may attract a participant's attention and s/he cannot concentrate on generating ideas.

Secondly, if a new idea by others appears on the screen while the participant is thinking, he may stop to read the idea and, after reading, he may forget what he had just thought about. This kind of interruption may be a barrier to the appearance of good ideas. On the other hand, in nominal brainstorming, users work independently without interruption, so they can generate ideas along a given line of thought.

Thirdly, while the anonymous environment encourages participants to express their ideas freely, it may also lead to laziness. Some may work hard and the others may do nothing or free ride on the efforts of others, while in a nominal brainstorming process, the participants are asked to generate ideas alone, giving them the stimulus to generate more ideas to prove themselves.

8.2.1.3 Satisfaction of the Participants

From the post-session questionnaire, it is suggested that all of the participants were more satisfied with IVMS than with the other traditional approaches, although the IVMS approach did not lead to the generation of more unique P1 ideas. Two possible reasons for this satisfaction are as follows: Firstly, there was less interaction in the groups that used the nominal method than in the ones with IVMS support. Research has shown that individuals believe they generate more ideas when working in a group than alone, even if in actual fact they do not (Paulus et al., 1993). Secondly, the users had not used IVMS before. The feeling of novelty may be the reason that IVMS received a good mark. Since an important aim of a VM workshop is to achieve a consensus among the members of a group and to make people feel satisfied with the decision-making process, if the participants' satisfaction is one of the most important criteria, IVMS can be regarded as the best approach of the three.

8.2.1.4 Limitations

It was expected that the designed experiment could fully simulate the situation of a real-life VM workshop; however, there were still some differences. As shown in Table 8.2, the differences lie mainly in three aspects: participants, process, and duration.

Table 8.2 Main Differences between the Real-life VM Workshops and the Experiment

	Real-life VM workshop	***Experiment***
Participants	Experts in the related disciplines of the target project	University students enrolled in a VM course
Process	A systematic job plan	A simplified process focusing on brainstorming
Duration	Several days with hours spent brainstorming	One hour per session with 15-minute of brainstorming

Participants: A VM workshop needs a combination of experts from disciplines related to the project to achieve synergy. Having participants of various backgrounds and with different knowledge bases ensures effective interaction among the working groups. The students who joined in the experiment were not as familiar with the task as experts in the construction industry. However, as is true with most laboratory research, it was difficult to ensure that the participants put forth their best effort to arrive at decisions. This was in line with the observations, which indicated that some students did not perform as professionally as experts did in VM workshops. Further research should consider methods that could inspire participants to make them fully involved in the process.

Process: There are several developed job plans that can be chosen for use in a VM workshop. Each job plan is a systematic process, which ensures the formation of a team and the achievement of objectives step by step in VM workshops. However, because of the tough experimental schedule, the experiment was designed to focus on the creativity phase of the VM workshops, namely, the brainstorming phase. The members of the group had little time to get to know each other, although a few participants might have known each other before the experiment. It would be informative to conduct experiments focusing on the whole process of the VM workshop in the future.

Duration: In a real-life VM workshop, the brainstorming process often lasts several hours and even half a day, which gives the participants plenty of time to think over the tasks. In the experiment, the participants were given only 15 minutes to generate ideas on a task. Although the tasks were not as complicated as those dealt with in real-life VM workshops, 15 minutes is considered insufficient for a comprehensive generation of ideas. Hence, the time schedule is an aspect that should be considered in future research.

Apart from these differences, the use of IVMS and the users' comfort with it may have affected the way in which members interacted to achieve the goal. Although the result of the questionnaire showed that most participants were comfortable about using IVMS, it should be always kept in mind by researchers in future studies.

Finally, typing skills may be another noticeable factor which had a positive effect on the idea generation in the experiment. According to the results of the questionnaire survey, most of the participants who took part in the experiment had good computer skills and considered that their typing speed could help them to express their ideas. The participants in a real-life VM workshop who are senior members in the companies or high-level professionals may not be as good at typing as the participants. Hence, team members' typing skills and its effect on team performance is an issue that can be explored in future research.

8.2.2 Experimental Study (II): Comparison (b) of Idea Generation between Traditional and GDSS-supported VM Workshops

8.2.2.1 Quantity of Ideas

The results of this experimental study show that the number of unique ideas generated through IVMS was statistically larger than that through the face-to-face approach. The potential reasons are listed as follows.

One of the most important reasons is the parallel entry of ideas, i.e. IVMS users did not need to wait their turn to express their ideas. Conversely, only one user at a time could express ideas in the face-to-face mode.

The environment of total anonymity while using IVMS is another important factor. The results of the observation showed that participants in the IVMS session were more active than the ones in the face-to-face session. It is the factor of anonymity that caused the users to become more active. Users who fear receiving negative evaluations from others in the face-to-face brainstorming do not have this fear in the environment of anonymity in IVMS-supported process.

8.2.2.2 Quality of Ideas

The quality of ideas was measured by three variables: the quantity of unique ideas with good quality, the width of ideas, and the depth of ideas. As mentioned in Chapter 7, the ideas generated were compared according to the quantity and the quality. Quality was assessed by two researchers who categorized the ideas into P1 = realistically possible, P2 = remotely possible, and P3 = fantasy. In this way, P1 ideas were considered as the ideas with good quality. As Table 6.8 shows, the average of P1 ideas generated by the IVMS-supported groups was larger than the average P1 ideas generated by the face-to-face groups. The results of the t-test also show that there was significant difference between the two sets of data. The potential reasons are the same as listed in 8.2.2.1.

From Table 7.9, it can be found that the width of ideas generated using GDSS was nearly the same as the width of ideas generated by the face-to-face groups, which is also supported by the t-test ($p=0.14>0.05$). The results of the t-test also show that there is no significant difference between the ideas generated through the two approaches in the depth of ideas, with everything else remaining equal. It can be concluded that the depth and width of ideas do not change with the brainstorming approaches in VM workshops. However, a possible reason for this phenomenon is that the tasks used are all simple ones related to the students' area of study; hence it is not surprising that they generate ideas with similar width and depth.

8.2.2.3 Limitations

A limitation of this study is the subjects. There is often a concern raised regarding the use of students as subjects in GDSS research. However, as discussed in 7.3.3.2, the author felt comfortable with the background of the participants.

8.2.3 Experimental Study (III): Validation of Using IVMS in the Full Process of VM Workshops

In this research, the effect of using GDSS in a VM study was investigated. In order to find the appropriate circumstances in which to use GDSS in VM studies, a literature review was conducted. This indicated that positive performance can be expected when using a level 2 GDSS tool and the team with face-to-face setting in a VM study. There are two objectives of this study: one is to investigate the effect of using GDSS in VM studies, the other is to test the support of the system which is expected to give reference for future design of GDSS in VM studies.

The results of this study showed that the perceived decision quality, process satisfaction and perceived participation are all positive. Most of the support provided by IVMS were accepted by the participants. The members also thought that the communication between them was also good. The findings of the study are positive and give the following implications:

8.2.3.1 Implications for VM Practitioners

One objective of this research is to investigate the effects of using GDSS in VM studies. The findings will give the practitioners direct information on the performance of VM studies using GDSS. Through this research, practitioners will have information about the possible outcomes of applying GDSS in real-life VM studies, allowing them to decide whether it is appropriate to apply GDSS in these real-life VM studies Through the analysis of the appropriate conditions for using GDSS, practitioners can find the circumstances that lead to the best performance of integrating GDSS with VM.

8.2.3.2 Implications for Further Research

First, this study represents a major step in the investigation of the effect of using GDSS in VM studies. The findings from this research are positive, which indicate that using GDSS in VM studies is feasible and could obtain positive performance effects and, thus, further research should be conducted to form a more solid theoretical foundation. Second, a literature review has been conducted on the factors that can affect the use of GDSS and has analyzed the appropriate circumstances for the use of GDSS in VM studies according to the characters of VM.

8.2.3.3 Limitations

One limitation of this study is that there are no control teams for comparison. Therefore, it cannot be confirmed whether the performance of a VM study using GDSS will outperform one without GDSS. There should be another team with similar knowledge background which is asked to conduct the same task using the traditional method without GDSS. The performance between the team with GDSS and team without GDSS can be compared to investigate whether GDSS use improves the performance of the VM study. This limitation has been made up by the comparative study conducted during this research.

The research should also be conducted in a real-life context. Although the participants in this study all have real-life experience and have the desire to obtain good results in order to receive good marks, the results of a real-life study will be much more valuable. The ultimate goal of this research is to apply GDSS in VM studies to improve the performance of VM; therefore it is a real success when positive results are obtained in a real-life study. Hence, the action research conducted during this research is necessary and useful.

8.2.4 Experimental Study (IV): Comparison between Traditional VM Workshops with GDSS-supported VM Workshops

As mentioned in Chapter 7, three measures were employed during this study: process measures, outcome measures and participants' satisfaction.

8.2.4.1 Process measures

The results showed that the IVMS-supported VM workshop outperformed the traditional VM workshop in the following aspects: efficiency of decision, data-based process, and participatory process. In other aspects, there were no significant differences. The reasons were interpreted correspondingly as follows:

i. **Data-based process & efficiency of decision.** The information support provided by IVMS can collect ideas generated, and store/disseminate information easily among the participants. This improved the efficiency of information sharing and enhanced the information circulation, and enabled the facilitators to easily computerize and centralize the information gathering, distribution and circulation processes throughout VM workshops. The above features of IVMS are the reasons why the IVMS-supported workshop obtained a higher score.

ii. **Participatory process.** The higher score obtained by the IVMS-supported workshop in this scale shows that the communication between participants was better during IVMS-supported VM workshops. The reason is the communication support provided by IVMS. The anonymous and parallel aspects of idea generation encouraged the participants to express their personal ideas. When concerns from all parties were raised, it would be easier for the participants to understand each other.

Referring to other aspects, there were no significant differences between the two workshops, which indicates that the use of GDSS will improve the VM process in the areas of accountability of decisions, goal-centred process, adaptable process, legitimacy of decision, participatory process, and supportability of decisions. In this study, the same facilitators were invited to facilitate both workshops, and the participants of both workshops had similar backgrounds. Hence, the more comprehensive conclusion should be that, with other conditions unchanged, the use of GDSS will not affect the process of VM workshops in the following aspects: accountability of decisions, goal-centred process, and adaptable process, legitimacy of decision, participatory process, and supportability of decisions.

8.2.4.2 Outcome Measures

The results show that the number of both unique ideas and unique P1 ideas generated through IVMS was statistically larger than that through the face-to-face approach. The following section lists the possible reasons.

The parallel entry of ideas, i.e. IVMS users did not need to wait for their turn to express their ideas, could be one of the most important reasons. Conversely, only one user at a time could express ideas in the traditional workshop.

The environment of total anonymity in IVMS is another important factor. The results of the observation showed that participants in the workshop with IVMS support were more active than the ones in the traditional workshop. The anonymity made the users more active by removing the participants' fear of receiving negative evaluations from others, as was present in the traditional workshop.

8.2.4.3 Participants' Satisfaction

As indicated by the results, all of the participants were more satisfied with IVMS than with the other traditional approaches, and the corresponding t-test result was significant at the 0.05 level. There are two possible reasons for this satisfaction. Firstly, there is less interaction in the groups using the nominal method than the ones with IVMS support. Research has shown that individuals believe they generate more ideas when working in a group than alone, even if in actual fact they do not (Paulus et al., 1993). Secondly, the users had not used IVMS before. The feeling of novelty may be the reason that IVMS received a good mark. Since one important aim of the VM workshop is to achieve a consensus among the members of a group and to make people feel satisfied with the decision-making process, if the participants' satisfaction is one of the most important criteria, IVMS should be regarded as a better approach.

8.3 Findings from the Questionnaire Survey on CSFs

8.3.1 Ranking of Critical Success Factors

The first analysis ranked the factors according to there mean values. If two or more factors happened to have the same value, the one with the lowest stand deviation would be assigned the highest rank. Table 8.3 shows the ranking of these factors according to the value of their mean.

Table 8.3 Ranking of Critical Success Factors for Using GDSS in Value Management Studies

	Mean	*Standard Deviation*	*Rank*
Facilitator's knowledge about GDSS (CSF1)	5.23	0.679	1
System reliability (CSF2)	5.06	0.910	2
Large number of participants (CSF3)	4.93	0.868	3
Facilitator's attitude about GDSS (CSF4)	4.91	0.993	4
Face-to-face environment (CSF5)	4.90	0.662	5
System responsiveness (CSF6)	4.90	0.759	6
Participants' attitude about GDSS(CSF7)	4.83	0.633	7
Short duration of workshop (CSF8)	4.83	0.913	8
Easy use of system (CSF9)	4.74	0.995	9
Computer anxiety of participants (CSF10)	4.61	0.731	10
System utility(CSF11)	4.46	0.770	11
GDSS experience of participants (CSF12)	4.13	1.383	12

From Table 7.3, it can be seen that "Facilitator's knowledge about GDSS" and "System reliability" are recognized by the respondents as the first two critical success factors.

8.3.2 Factor Analysis

Factor analysis is a statistical tool that was used to identify a relatively small number of factors that can be applied to represent relationships among sets of many interrelated variables (Norusis, 1993). It can be conducted to reduce a large number of individual variables into a small number of "underlying" group factors. An underlying factor can be regarded as a linear combination of the original variables. In this paper, factor analysis is used to explore the underlying group factors of the identified CSFs for using GDSS in VM studies. The basic steps in undertaking factor analysis are listed below:

1. Identify the critical success factors for using GDSS in VM studies;
2. Compute the correlation matrix for all the critical success factors identified;
3. Extract and rotate each factor; and
4. Interpret and label principal (grouped) factors as underlying factors.

In this survey, 12 CSFs were analyzed using principle analysis and varimax rotation. Principle components analysis transforms the original set of factors into a smaller set of linear combinations that account for most of the variation of the original set. Various tests are required for the appropriateness of the factor extraction, including the Kaiser-Meyer-Olkin (KMO) measure of sampling accuracy and the Barlett test of sphericity which tests the hypothesis that the correlation matrix is an identity matrix. Table 8.4 gives the matrix of the correlation coefficients among the CSFs. The matrix is automatically generated as a part of factor analysis results with SPSS. The Bartlett test of sphericity is 149.143 and the associated significance level is 0.000, which suggests that the population correlation matrix is not an identity matrix. The value of the Kaiser-Meyer-Olkin (KMO) measure of sampling accuracy is 0.679>0.5, which can be considered acceptable. All of these tests show that the sample data is appropriate for factor analysis.

Table 8.4 Correlation Matrix of Critical Success Factors

	CSF1	*CSF2*	*CSF3*	*CSF4*	*CFF5*	*CSF6*	*CSF7*	*CSF8*	*CSF9*	*CSF10*	*CSF11*	*CSF12*
CSF1	1.000											
CSF2	0.390	1.000										
CSF3	-0.031	0.031	1.000									
CSF4	0.719	0.438	0.096	1.000								
CFF5	-0.177	-0.287	0.048	-0.099	1.000							
CSF6	0.315	0.438	0.147	0.435	0.048	1.000						
CSF7	0.575	0.485	0.017	0.521	-0.206	0.596	1.000					
CSF8	-0.158	-0.262	0.247	-0.200	-0.200	-0.025	-0.074	1.000				
CSF9	0.440	0.592	-0.029	0.692	-0.261	0.412	0.608	-0.269	1.000			
CSF10	0.470	0.238	-0.130	0.440	0.087	0.188	0.456	-0.360	0.304	1.000		
CSF11	0.210	0.589	0.006	0.440	0.053	0.376	0.344	-0.319	0.562	0.308	1.000	
CSF12	0.627	0.300	0.065	0.531	-0.098	0.145	0.310	-0.419	0.201	0.395	0.018	1.000

Note: Kaiser-Meyer-Olkin measure of sampling adequacy=0.679; Barlett test of Sphericity=149.143; significance = 0.000

Four underlying success factors with eigenvalues greater than 1 are extracted. The principle factors matrix after varimax rotation is shown in Table 8.5. The total percentage of variance explained by each underlying success factor was examined to determine how many factors would be required to represent the whole data. Table 8.6 presents the percentage of the variance and the cumulative percentage of the variance.

Table 8.5 Principle Components Matrix with Varimax Rotation

	Underlying Success Factor			
	1	2	3	4
GDSS experience of participants (CSF12)	0.885			
Facilitator’s attitude about GDSS (CSF4)	0.624			
Computer anxiety of participants (CSF10)	0.613			
Facilitator’s attitude about GDSS (CSF4)	0.668			
Facilitator’s knowledge about GDSS (CSF1)	0.826			
System reliability (CSF2)		0.762		
System responsiveness (CSF6)		0.665		
Easy use of system (CSF9)		0.795		
System utility(CSF11)		0.834		
Large number of participants (CSF3)			0.803	
Short duration of workshop (CSF8)			0.632	
Face-to-face environment (CSF5)				0.918

Table 8.6 Percentage of Variance and Cumulative Variance of Principle Components

Underlying Success Factor	*Initial Eigenvalues*		
	Total	**% of Variance**	**Cumulative %**
1	4.590	38.247	38.247
2	1.554	12.946	51.193
3	1.349	11.239	62.431
4	1.173	9.777	72.208

As shown in Table 8.6, the extracted factors accounted for 72% of the variance in responses. All the factor loadings (See Table 8.5) were greater than 0.5, and seven of them were greater than 0.7.

8.3.3 Interpretation of Underlying Success Factors

After further investigation of the relationships among the CSFs under each of the underlying success factors, the four extracted underlying success factors can be reasonably interpreted as follows: underlying factor 1 = VM team's computer proficiency; underlying factor 2 = system capabilities; underlying factor 3 = workshop duration and number of participants; underlying factor 4 = environmental setting. These four underlying factors are explained in detail as follows.

Underlying factor 1：VM team's computer proficiency

All five CSFs under the underlying factor 1 are related to the computer proficiency of the VM team, including the participants and VM facilitator. From Table 8.4, the participants' GDSS experience and facilitator's knowledge about GDSS obtained the highest factor loading. If the participants lack experience in using GDSS, additional time has to be spent introducing the GDSS before or during the workshop. On the other hand, it also suggests that it will be better to conduct system training to educate the participants on the use of GDSS. The facilitator's knowledge is crucial to the success of integrating GDSS in VM studies. If the facilitator is not competent in the system use, he/she cannot answer the inevitable questions raised by the participants. Moreover, the facilitator should understand the features and limitations of the system in order to use the system appropriately. It is also inevitable that there will be technical problems of one kind or another that will need to be solved. Hence, it is suggested that an additional GDSS facilitator who is skilled in system use assist the VM facilitator during the workshop.

The other three factors are related to the participants' attitude towards computer. It is true that the computer is used widely nowadays. However, the stakeholders who take part in a VM workshop are usually senior staff in their companies. Their computer skills and attitudes towards computer systems may be a problem. It will be easy and useful to use GDSS when the participants have positive attitude towards computers. Above all, a VM team with an appropriate computer skill mix is required.

Underlying factor 2: System capabilities

This underlying factor is about the system capabilities, including the reliability, responsiveness, ease of use and utility. The ability to provide access to reliable data is a major issue in the system development (Poon and Wagner, 2001). The system responsiveness is another important issue. Problems, e.g. the server being too slow or simply unavailable, are often encountered, especially for web-based systems. Such problems will severely affect the level of users' satisfactory and the workshop efficiency. It is very important to develop the GDSS based on the requirements of VM studies, which will enable the system to provide necessary supports to VM studies. A software tool with user-friendly characteristics demands little effort from its users. Users will be willing to adopt such a tool with few barriers and satisfaction will be improved (Amoroso and Cheney 1991).

Underlying factor 3: Workshop duration and number of participants

It is suggested that the clients demand a shorter duration than current VM practices, and there is usually a large number of participants due the increasing complexity of projects. The main advantage of GDSS is to increase the "process gains" such as supporting parallel idea generation and information processing, allowing rapid and easy access to external information, and enabling users to interact simultaneously (DeSanctis and Galluple 1987; Turban and Aronson 2001). The main problems encountered in current VM studies are related to the short duration and large quantity of members; hence the effect of improved efficiency and effectiveness will be greater when GDSS is applied during this situation.

Underlying factor 4: Environmental setting

The results of the questionnaire show that a face-to-face environment is critical to the use of GDSS in VM workshops. It implies two situations: the participants of the VM workshops are in the same location with a face-to-face setting, or, participants disperse in different locations with some video support to allow the participants to see each other during the workshop. The author insists that both face-to-face and GDSS have their own advantages, and it will be better to integrate the two communication modes together to exploit the full benefits.

8.3.4 Limitations

The main limitation is the sample size. The subjects of the questionnaire survey should use the GDSS in VM studies before they can have an idea about the CSFs. Hence, the author designed and conducted an experimental study, and invited the potential subjects to join the study. After the experiment, the questionnaire survey was conducted. Unfortunately, there were only 42 participants. In the future, more similar studies should be carried out to achieve more samples.

8.4 Findings from the Action Research

The client – a local government department – wanted all the information about the workshop to be kept confidential, and so did not agree to the taking of a questionnaire survey. Hence, the perception of the use of GDSS was determined by asking the workshop facilitator to comment on the support of GDSS. The comments were supportive of the use of GDSS in this VM workshop. The support provided in idea generation, categorization, and also the file sharing was highlighted.

8.5 Summary

This chapter summarized the research findings from the experimental studies, the questionnaire survey and the action research. The findings from the experimental studies are briefly listed as follows:

Comparative study (I) of idea generation: The results of the experiment reveal that the workshop supported by IVMS represented a significant improvement in terms of the production of unique ideas over the traditional brainstorming approaches, including the nominal and face-to-face methods. Furthermore, IVMS had a positive influence on the behaviour of the participants, especially on participants who were silent in a VM workshop conducted in the traditional mode. Although there was no significant improvement in the quantity of P1 (quality) ideas in the process with IVMS support, IVMS can be a useful tool in solving the problems frequently encountered in traditional VM workshops.

Comparative study (II) of idea generation: The results show that the number of both unique ideas and unique P1 ideas generated through IVMS was statistically larger than that through the face-to-face approach. However, it can be concluded that the depth and width of ideas do not change with the brainstorming approaches in VM workshops.

The validation study: The results of this study showed that the perceived decision quality, process satisfaction and perceived participation were all positive. Most of the support provided by IVMS was thought to be useful by the participants.

The comparative study: The results showed that the IVMS-supported VM workshop outperformed the traditional VM workshop in the following aspects: efficiency of decision, data-based process, and participatory process. The number of both unique ideas and unique P1 ideas generated through IVMS was statistically larger than that through the face-to-face approach. The participants were also more satisfied with IVMS than with the traditional approaches.

Four CSFs have been identified through the questionnaire survey: 1) VM team's computer proficiency; 2) system capabilities; 3) workshop duration and number of participants; and 4) environmental setting. The action research confirmed the reliability of the GDSS, and supported that it can be used to support VM workshops.

The following chapter is the final chapter of this thesis. It provides the conclusions of the research study, highlights the areas for further study and lists what has been contributed to the field of knowledge.

Chapter 9: Summary and Conclusions

9.1 Introduction

This chapter summarizes the research goals and research propositions including how the research propositions have been addressed through this research. The four research outputs are summarized: development of a web-based GDSS prototype to support VM studies; a generic model that shows how GDSS can be applied in VM studies; the impact of using GDSS on the performance of VM workshops; identification of critical success factors of using GDSS in VM workshops. An overview of research conclusions from each stage of the research is presented. Finally, the limitations of the study, further recommendations and the contributions are also summarized.

9.2 Review of Research Objectives

The overall aim of this research is to investigate the extent to which the use of GDSS can improve effectiveness and efficiency in the processes and outcomes of VM studies in construction projects. The focus is on value management studies in construction projects because there has been a surge of interest in VM in the construction industry in Hong Kong, especially since the Asian financial crisis in 1997. A number of government departments and private enterprises in Hong Kong have applied VM to ensure value for money for their projects during the project feasibility study stage. The reasoning for the focus on VM studies in construction was based on a survey that suggested that VM users in Hong Kong encounter the problems of a lack of active participation and insufficient time and information in decision analysis (Shen and Chung, 2000; Chung, 2002). They have affected the performance of VM studies, and there is strong demand for improvements to the practice in order to maximize the benefits of the studies. Because of the success of GDSS in other group decision making processes, the research proposed the use of GDSS to overcome the problems currently encountered in VM studies.

The literature review examined VM and GDSS, and generated the research objectives for the thesis. A methodology comprising three key research methods (experimental study, questionnaire survey and action research) was constructed to answer them.

As mentioned in Chapter 1, there are six tasks to be completed in order to achieve the research objectives. The research tasks and how they have been completed are introduced as follows:

a. To review the available literature on value management to enclose the problems/difficulties encountered by current users;

The comprehensive literature review in Chapter 2 and 3 examined the current problems encountered in current VM studies, and investigated the general benefits that GDSS can provide in the group decision-making processes.

b. To review the available literature on the application of GDSS to determine whether it is appropriate to use it in VM studies;

The review was introduced in Chapter 4. The research examined five aspects of the characteristics of VM studies: (1) the group task, (2) the GDSS tool, (3) the composition of the group, (4) the size of the group and (5) the effect of facilitation in the group process. After the review, it was concluded that:

- *The decision quality and time, and satisfaction with process and outcomes should be measured in order to investigate the effect of using GDSS;*

- *Better performance of VM workshops could be achieved by using GDSS in the "creativity" phase;*

- *A level 2 rather than a level 1 GDSS system should be used to support the VM workshops;*

- *Groups with a face-to-face setting are more appropriate than virtual teams when using GDSS in VM workshops;*

- *The group size of VM teams is appropriate for GDSS use;*

- *A GDSS process facilitator should be provided in a GDSS-supported VM workshop.*

c. To develop a GDSS prototype that can be used as a tool to investigate the effect of using GDSS in VM studies;

According to the outcomes of the review on what type of GDSS is appropriate in VM studies, a web-based GDSS prototype was developed as a tool to investigate the effect of using GDSS in VM studies.

d. To develop a generic model of how the GDSS prototype that was developed can be applied in a VM study;

Chapter 6 introduced the main features and primary support provided by the GDSS prototype developed during this research. It also proposed a generic way of using the prototype in VM studies.

e. To determine the extent to which the use of GDSS can support VM studies;

In order to achieve this objective, three types of experimental studies and an action research study were employed during this study. The research outcomes and findings were listed in Chapters 7 and 8.

f. To identify critical success factors (CSFs) for the integration of GDSS with activities in the VM process, in order to ensure effective and efficient communication and decision-making in VM studies.

Four underlying factors were identified through a questionnaire survey, which was introduced in Chapter 8.

9.3 Research Conclusions

Through the research on the use of GDSS in VM studies, especially the three types of experimental studies, the results have shown that GDSS can improve the efficiency and effectiveness of VM workshops by supporting the VM team, and GDSS is a useful tool in facilitating the information exchange process, encouraging interaction, and promoting active participation in VM workshops. It also reveals that Web-based GDSS can overcome the common problems identified in VM workshops, e.g., lack of information, short duration, and lack of participation and interaction. Finally, the questionnaire has also identified the CSFs of using GDSS in VM studies.

9.3.1 Conclusions from the Literature Review

From the literature review on VM and GDSS, the following issues emerged: (1) VM users encounter the problems of lack of active participation and insufficient time and information for decision analysis; (2) GDSS can reduce process losses and increase process gains during the group decision-making process. Hence, GDSS has the potential to promote active participation, encourage interaction and facilitate decision analysis in VM workshops. Based on the above issues, it is proposed that the use of GDSS can provide technological efficiencies and interaction advantages, which can overcome the difficulties encountered in current VM studies.

After the examination of the characteristics of VM to decide what types of GDSS are appropriate for VM studies, the following was deduced:

- The decision quality and time, and satisfaction with process and outcomes should be measured in order to investigate the effect of using GDSS;
- Better performance of VM workshops could be achieved by using GDSS in the "creativity" phase;
- A level 2 rather than a level 1 GDSS system should be used to support the VM workshops;
- Groups with a face-to-face setting are more appropriate than virtual teams when using GDSS in VM workshops;
- The group size of VM teams is appropriate for GDSS use;
- A GDSS process facilitator should be provided in a GDSS-supported VM workshop.

According the criteria identified above, a web-based GDSS prototype named IVMS was developed during this research. IVMS can provide discussion support, information support, collaboration support and decision analysis support to VM workshops. Through these features, IVMS is designed to overcome the problems and to maximize the benefits of VM studies. Detailed problems/concerns and proposed GDSS support are shown in Table 9.1.

9.3.2 Conclusions from the Experimental Studies

In order to investigate the extent to which the use of GDSS can improve effectiveness and efficiency in the processes and outcomes of VM studies, three types of experimental studies were designed and conducted. The settings of the experiments are shown as follows:

- A level 2 GDSS system, IVMS, was employed;
- Groups with a face-to-face setting were used;
- A GDSS process facilitator was provided.

Table 9.1 The Proposed Support Provided by GDSS in VM Workshops

Problems/Concerns	***Reasons***	***Proposed Support by GDSS***
Short duration	Pressure from the client to cut the cost	Various electronic tools, including document library, electronic brainstorming, weighted evaluation tools etc. to simplify and standardize the process.
Lack of information	• Poorly organized project information in the pre-workshop stage; • Difficulty of retrieving project information in meetings	Information support such as document library, electronic discussion board, online questionnaire survey to improve the efficiency of information sharing and enhance information circulation.
Lack of participation & interaction	• Shyness about speaking in public • Domination by a few individuals • Pressure to conform	Virtual meeting rooms
Difficulty in conducting analysis and evaluation	• Insufficient time to complete analysis • Insufficient information to support analysis	Electronic tools, including ideas categorization and FAST diagram etc. to improve the productivity and accuracy of data processing and eliminate human errors.
Database of VM studies	Provide references to similar projects in the future	An electronic database that stores VM studies, including the process, the tools used, the objectives and outcomes etc.
Lack of VM knowledge	Many participants are not familiar with VM	GDSS can act as a teaching tool to introduce the generic process of VM.

a. Comparative studies of Idea Generation between Traditional and GDSS-supported VM Workshops

Two experimental studies of this kind were conducted. The first experimental study compared IVMS with the other two traditional brainstorming methods (face-to-face and nominal brainstorming) in both quantity and quality of ideas generated. The results of the experiment reveal that the workshop supported by IVMS represents a significant improvement in terms of the production of unique ideas over the traditional brainstorming approaches, including the nominal and face-to-face methods. Furthermore, IVMS had a positive influence on the behaviour of the participants, especially on participants who were silent in a VM workshop conducted in the traditional mode. Although there was no significant improvement in the quantity of P1 (quality) ideas in the process with IVMS support, IVMS can be a useful tool in solving the problems frequently encountered in traditional VM workshops.

The second experimental study focused on the comparison between IVMS and face-to-face brainstorming, since face-to-face brainstorming is the most popular brainstorming method used during VM studies. Based on the limitations of the first study, this study made several modifications on the experimental design to make the experimental results more reliable. The results revealed that the number of both unique ideas and unique P1 (quality) ideas generated through IVMS was statistically larger than that through the face-to-face approach. However, the results showed that, with everything else remaining equal, there was no significant difference between the width and depth of the ideas generated through the two approaches. A possible reason for this phenomenon is that the tasks used are all simple ones related to students' studies; hence it is not surprising that they generate ideas with a similar width and depth.

To summarize, the main conclusions are listed as follows:

- **Quantity of unique ideas.** Both experiments showed that IVMS can generate more unique ideas than other traditional brainstorming methods. Hence, it can be concluded that the use of IVMS can improve the number of unique ideas generated. The main reasons are parallel entry of ideas and anonymity.

- **Quality of ideas.** There are three aspects to measure the quality: (1) quantity of unique P1 (quality) ideas, (2) the width of ideas, and (3) the depth of ideas. The first experimental study only measured the quantity of unique P1 (quality) ideas. The results showed that there was no significant improvement in the quantity of unique P1 (quality) ideas in the process with IVMS support. One possible reason was the task chosen. The second study examined all three issues. The results revealed that the number of unique P1 (quality) ideas generated by IVMS was statistically larger than that generated through face-to-face approach, with everything else remaining equal. However, it was shown that there was no significant difference between the depth and width of ideas. Hence, it can be concluded that the use of IVMS will generate no less unique P1 (quality) ideas than other traditional methods, and, however, it will probably not change the width and depth of ideas generated with face-to-face brainstorming technique, with everything else remaining equal.

b. The Validation Study of Using IVMS in the Full Process of VM Workshops

The results of this study showed that the perceived decision quality, process satisfaction and perceived participation were all positive. Most of the functions provided by IVMS were thought to be useful by the participants. Participants thought that IVMS can promote active participation in idea generation, reduce conformance pressure in idea generation, and improve the availability of information and the information exchange process. Hence, it can be concluded that IVMS can be used in the full process of a VM workshop to improve its performance.

c. The Comparative Study between Traditional VM Workshops with GDSS-supported VM Workshops

This study compared two workshops in three aspects: process measures, outcome measures and participants' satisfaction.

1) Process measures. The use of IVMS will improve the data-based process, efficiency of decision and participatory process of a VM workshop. With other conditions unchanged, the use of GDSS will not affect the process of VM workshops in the following aspects: accountability of decision, goal-centred process, and adaptable process, legitimacy of decision, participatory process, and supportability of decision.

2) Outcome measures. The use of IVMS will generate more unique ideas and unique P1 ideas than that through the face-to-face approach during a traditional VM study.

3) Participants' satisfaction. The use of IVMS can generate a higher level of participants' satisfaction.

9.3.3 Conclusions from the Action Research

The purpose of the action research workshop was to validate the GDSS prototype, and further investigate the effect of using GDSS in a real-life VM workshop. The action research study confirmed the reliability of GDSS, and therefore GDSS can be used to support the VM workshops.

Since the workshop was confidential, the success of GDSS use was determined by asking the workshop facilitator to comment on the use of GDSS. All the comments made were positive and supportive of using GDSS in VM workshops. The support provided in idea generation, categorization, and file sharing was highlighted.

9.3.4 Conclusions from the Questionnaire Survey

Four underlying critical success factors have been identified: (1) VM team's computer proficiency; (2) system capabilities; (3) workshop duration and number of participants; and (4) environmental setting.

9.4 Contribution to Knowledge

This research has contributed to the field of knowledge, spanning across different areas: information technology and construction management. GDSS is in the field of information technology, and is applied predominantly in group meetings. Value management belongs to construction management, and its use in construction related projects is focused on during this research. This research has explored the application of GDSS in a new field: value management. The main research outcomes include new knowledge on the impact of using GDSS on the overall outcomes of VM studies, and the generation of quantitative data on the extent to which GDSS can enhance team behaviour and group facilitation in VM studies. It indicates that the use of GDSS can be one possible solution to the difficulties frequently encountered by users during VM studies. To summarize, there are four main points of contribution of this research to knowledge.

Firstly, the research has successfully integrated GDSS with VM studies, and the positive results achieved during this research suggest that GDSS is a promising technology to improve the efficiency and effectiveness of current VM studies. The framework of using GDSS in VM studies used during this research also provides a useful reference for both researchers and practitioners who would like to apply GDSS in VM studies.

Secondly, the critical success factors for using GDSS in VM workshops have been identified during this research. The factors may provide valuable references for both the practitioners and VM researchers on how to obtain a successful GDSS-supported VM study. Researchers could also obtain useful information from the research methods employed during this research to identify critical success factors.

Thirdly, a GDSS prototype is developed as the experimental tool during this research. Although it is not a perfect system for VM studies, it also provides rich information regarding issues of the future design of GDSS software in VM studies through the design and use of the GDSS prototype.

Finally, this research also makes a contribution to the area of performance evaluation of IT applications in VM studies and similar decision-making processes. A comprehensive framework to evaluate the performance of GDSS use in VM workshops is developed in this research. The framework includes three aspects: (1) outcome measures, (2) process measures, and (3) participants' satisfaction. The outcome measures take the quantity and quality of ideas as the main indicators. The process is measured by the competing value approach, which is a large conceptual framework with criteria. The participants' satisfaction is evaluated through questionnaire survey.

In Hong Kong, the Construction Industry Review Committee (2001) recommended a wider use of VM in local construction, and the newly-formed Environment, Transport and Works Bureau (2002) has pushed this further to require VM studies for every major public works project. This research has exploited the potential of the technology in improving the effectiveness and efficiency of VM studies, and has overcome the difficulties encountered that have prohibited wide use of the methodology. These outcomes are extremely valuable to the construction industry in Hong Kong, where both the government and the industry have called for wider use of VM, and yet users have encountered more difficulties than their overseas counterparts due to the large number of participants and the short duration of the workshops.

9.5 Limitations of the Study

Three limitations have been outlined with regards to this research. Firstly, the major research methods undertaken during this research were experimental studies. Only one action research study was conducted. Therefore, more field studies should be conducted to confirm the effect of GDSS use in VM studies.

Secondly, the system used is a GDSS prototype developed by the author. Although the system has been verified and validated, the system itself can still affect the research outcomes. If some researcher undertakes similar research, she/he should choose or develop a GDSS system with similar functions.

Thirdly, the sample size for the survey to identify the CSFs of using GDSS in VM studies is small. However, the subjects of the questionnaire survey to identify the CSFs should use the GDSS in VM studies if they are to have an idea about the CSFs. It is not easy to find enough subjects with GDSS experience. Hence, the author designed and conducted an experimental study, and invited the potential subjects to join this study. Then, the questionnaire survey was conducted. In the future, more similar studies should be carried out to achieve more samples.

9.6 Suggestions for Further Research

Suggestions for further research are as follows:

1. More action research should be conducted to explore the effect of using GDSS in VM studies, including team behaviour, group dynamics, facilitation, and the overall outcomes.

2. Research should be conducted to compare and contrast cultural impact on the use of GDSS in VM studies for construction projects. It is of paramount importance for researchers and practitioners to know how groups of different cultures can work together more effectively and satisfactorily. Cross-cultural studies have suggested that cultural differences influence group composition, process, and outcomes, which indicates that the proposed research should lead to profound implications for the understanding of group dynamics and group facilitation.

3. Research should be conducted to further develop GDSS software for VM studies, since this research only took the GDSS prototype developed as a tool instead of developing a perfect GDSS for VM studies.

4. Research should be conducted to investigate the effect of GDSS use in VM studies with participants dispersed in different locations. One assumption of the research generated from the literature is that GDSS should be used in VM studies with face-to-face settings. However, this assumption was developed from a theoretic perspective and the proposed research could test it.

References:

Ackermann, F., and Eden, C. (1994). "Issues in computer and non-computer supported GDSSs." *Decision Support Systems*, 12(4-5), 381 – 390.

Adelman, L. (1984). "Real-time computer support for decision analysis in a group setting: another class of decision support systems." *Interfaces*, 14(2), 75-83.

Adelman, C. (1993). "Kurt Lewin and the origins of action research." *Educational Action Research*, 1(1), 7-24

Adkins, M., Burgoon, M., and Nunamaker, J.F. (2002). "Using group support systems for strategic planning with the United States Air Force." *Decision Support Systems*, 34(3), 315-337.

Aiken, M., Vanjani, M., and Krosp, J. (1995). "Group decision support systems." *Review of Business*, 16(3), 38– 42.

Amoroso, D. L., and Cheney, P. H. (1991). "Testing a causal model of end-user application effectiveness." *Journal of Management Information Systems*, 8(1), 63-89.

Applegate, L.M., Konsynski, B.R. and Nunamaker, J.F. (1986). "A Group Decision Support System for Idea Generation and Issue Analysis in Organization Planning." IN: *Proceedings of the 1st Conference on Computer Supported Collaborative Work*.

AS/NZS 4183 (1994). *Australian/New Zealand Standard, AS/NZS 4183: Value Management*, Joint Technical Committee OB/6, Standards Australia.

AS 4183 (2007). *Australian Standard, AS 4183: Value Management*, Committee OB-006, Standards Australia.

Assaf, S., Jannadi, O., and Al-Tamimi, A. (2000). “Computerized system for Application of Value Engineering Methodology.” *Journal of computing in civil engineering*, 14(3), 206-214.

Barton, R.T. (2000). “Soft value management methodology for use in project initiation – a learning journey.” *Journal of Construction Research*, 1(2), 109-122.

Beauclair, R.A. (1987). An Experimental Study of the Effects of Group Decision Support System Process Support Applications on Small Group Decision Making, *Unpublished Doctoral Dissertation*, Indiana University.

Benbasat, I., DeSanctis, G., and Nault, B.R. (1993). “Empirical research in managerial support systems: a review and assessment.” In C. Holsapple and A. Whinston (eds.), *Recent Developments in Decision Support Systems*, NATO ASI Series F. Berlin: Spring-Verlag, 384-437.

Benbasat, I., and Lim, L.H. (1993) “The effects of group, task, context and technology variables on the usefulness of group support systems: a meta-analysis of experimental studies.” *Small Group Research*, 24(4), 430-462.

Bidgoli, H. (1998). Intelligent management support systems, *Quorum books*, Westport, Connecticut.

Briggs, R.O., Balthazard, P., and Dennis, A.R. (1996). “Graduate business students as surrogates for executives in the evaluation of technology.” *Journal of End-User Computing*, 8(4), 11-17.

British Standard Institute (2000). *BS EN12973: 2000, Value Management*.

Camacho, L.M., and Paulus, P.B. (1995). “The role of social anxiousness in group brainstorming.” *Journal of Personality and Social Psychology*, 68(6), 1071-1080.

Cass, K. Heintz, T.J. and Kaiser, K.M. (1991). “Using a Voice-Synchronous GDSS in Dispersed Locations: A Preliminary Analysis of Participant Satisfaction.” IN: *Proceedings of the 24th Hawaii International Conference on System Sciences*, III, 554-563.

Chan, A. P. C., Chan, D. W. M., Chiang, Y. H., Tang, B. S., Chan, E. H. W., and Ho, K. S. K. (2004). “Exploring Critical Success Factors for Partnering in Construction Projects.” *Journal of Construction Engineering and Management*, 130(2), 188-198.

Checkland, P. (1981). *Systems Thinking, Systems Practice*, Wiley, Chichester.

Chua, D. K. H., Kog, Y. C., and Loh, P. K. (1999). “Critical success factors for different project objectives.” Journal of Construction Engineering and Management, 125(3), 142-150.

Chun, K.J., and Park, H.K. (1998). “Examining the conflicting results of GDSS research.” *Information & Management*, 33 (6), 313-325.

Cohen, L., and Manion, L. (1994). “Case studies”, Chapter 5 in *Research Methods in Education*, 4th edn., Routledge, London.

Commission of the European Communities (1991). *Value Analysis Glossary*, European Community Strategic Program for Innovation and Technology Transfer (SPRINT), Report EUR 13774 EN, DG XIII, L-2920, Luxembourg.

Construction Industry Review Committee (2001). *Construct for Excellence – Report of the Construction Industry Review Committee.* Printing Department, Hong Kong Special Administrative Region Government.

Cox, T., Lobel, S., and McLeod P. (1991). “Effects of ethnic group cultural differences on cooperative and competitive behaviour on a group task.” *Academy of Management Journal*, 34(4), 827-847.

Connolly, T., Jessup, L.M., and Valacich, J.S. (1990). “Effects of anonymity and evaluative tone on idea generation in computer mediated groups.” *Management Science*, 36(6), 689-703.

Cooper, W.H., Gallupe, R.B., Lalonde, D. (1990). *The effects of cues on idea generation.* Unpublished manuscript, School of Business, Queen’s University, Kingston, Ontario, Canada.

Cox EP (1980). The optimal number of response alternatives for a scale: a review. *Journal of Marketing Research*, 17(4), 407-442.

Daft, R.L., and Lengel, R.H. (1986). “Organizational information requirements, media richness and structural design.” *Management Science*, 32(5), 554-571.

Davison, R. (1998). *An action research perspective of group support systems: how to improve meetings in Hong Kong*, PhD thesis, City University of Hong Kong, published by City University of Hong Kong.

Dawes, J. (2007). “Do data characteristics change according to the number of scale point used?” *International Journal of Market Research,* 50(1), 61-77.

Dell'Isola, A.J. (1982). *Value Engineering in the construction industry*, Van Nostrand Reinhold Company, Third edition.

Dell'Isola, A.J. (1997). *Value Engineering Practical Application: For Design, Construction, Maintenance and Operations*, R.S. Means Company, Kingston, Mass.

Dennis, A.R. (1991). *Parallelism, anonymity, structure and group size in electronic meetings,* Doctoral dissertation, University of Arizona, Tucson.

Dennis, A.R., and Gallupe, R.B. (1993). "A history of GSS empirical research: lessons learned and future directions." In L.M. Jessup and J.S. Valacich (eds.), *Group Support Systems: New Perspectives.* New York: Macmillan, 59-77.

Dennis, A.R., George, J.F., Jessup, L.M., Nunamaker, J.F., and Vogel, D.R. (1988). "Information technology to support electronic meetings." *MIS Quarterly*, 12(4), 591-624.

Dennis, A.R., Heminger, A.R., Nunamaker, J.F., and Vogel, D.R. (1990). "Bring automated support to large groups: the Burr-Brown experience." *Information and Management*, 18(3), 111-121.

Dennis, A.R., and Kinney, S.T. (1998). "Testing media richness theory in the new media: the effects of cues, feedback, and task equivocality." *Information Systems Research*, 9(3), 256-274.

Dennis, A.R., Nunamaker, J.F., and Vogel, D. (1989). "GDSS laboratory experiments and field Studies: closing the gap." IN: *Proceedings of the 22nd Hawaii International Conference on System Sciences*, III, 300-309.

Dennis, A.R., Nunamaker, J.F., and Vogel, D.R. (1991). "A comparison of laboratory and field Research in the study of electronic meeting systems." *Journal of Management Information Systems*, 7(3), 107-135.

Dennis, A.R., and Valacich, J.S. (1993). "Computer brainstorms: more heads are better than one." *Journal of Applied Psychology*, 78(4), 531-537.

Dennis, A.R., and Wixom B. H. (2002). "Investigating the moderators of the group support systems use with meta-analysis." *Journal of Management Information Systems,* 18(3), 235-257.

Denzin, N. K., and Lincoln, Y. S (1998). *Strategies of Qualitative Inquiry*, Sage Publications.

DeSanctis, G., and Galluple, R.B. (1987). "A foundation for the study of group decision support systems." *Management Science*, 33(5), 589-609.

DeSanctis, G.L. and Poole, M.S. (1994). "Capturing the Complexity in Advanced Technology Use: Adaptive Structuration Theory." *Organization Science*, 5(2), 121-147.

Diehl, M., and Stroebe, W. (1987). "Productivity loss in brainstorming groups: Toward the solution of a riddle." *Journal of Personality and Social Psychology*, 53(3), 497-509.

Diehl, M., and Stroebe, W. (1991). "Productivity loss in idea-generating groups: Tracking down the blocking effects." *Journal of Personality and Social Psychology*, 61(3), 392-403.

Diener, E. (1980). "Deindividuation: the absence of self-awareness and self-regulation in group Mmembers." IN: Paulus, P.B. (Ed.) *Psychology of Small Group Influence*, Hillsdale, NJ: Erlbaum.

Drazin, R., and Van de Ven, A.H. (1985). "Alternative forms of fit in contingency theory." *Administrative Science Quarterly,* 30(4), 514-539.

ETWB-Environment, Transport and Works Bureau (2002). *Technical Circular No. 35/2002: Implementation of value management in public works projects,* The Government of the Hong Kong Special Administrative Region.

Er, M.C., and Ng, A.C. (1995). "The anonymity and proximity factors in group decision support systems." *Decision Support Systems,* 14(1), 75-83.

FAN, S. C., Shen, Q. P., and Kelly, J. (2008). "Using group decision support system to support value management workshops." *Journal of Computing in Civil Engineering (ASCE)*, 22 (2), 100-113.

Fellows, R., and Liu, A. (2003). *Research Methods for Construction*, *2nd Edition*, Blackwell Science, London.

Ferraro, G.P. (1998). *The cultural dimensions of international business,* Prentice Hall, New Jersey.

Fjermestad, J., and Hiltz, S.R. (1999). "An assessment of group support systems experimental research methodology and results." *Journal of Management Information Systems,* 15(3), 7-149.

Flavin, G., Totton, E. (1996). *Computer Aided Decision Support in Telecommunications,* Chapman & Hall, London.

Fong, P. S. (1999). "Organisational knowledge of responses of public sector clients towards value management." *The International Journal of Public Sector Management*, 12(5), 445-454.

Fong, P.S. (2003). “Managing value in construction project development process.” IN: *Proceedings of Second International Conference on Construction in the 21st Century-Sustainability and Innovation in Management and Technology*, 10-12 December, Hong Kong.

Friend, J., and Hickling, A. (1987). *Planning Under Pressure: the Strategic Choice Approach*, Pergamon, Oxford.

Garland, R. (1991). “The mid-point on a rating scale: is it desirable?” *Marketing Bulletin*, 2, 66-70.

Galliers, R.D., and Land, F.F. (1987). “Choosing appropriate information systems research methodologies.” *Communications of the ACM*, 30(11), 900-902.

Gallupe, R.B., Bastianutti, L., and Cooper, W.H. (1991). “Unblocking brainstorms.” *Journal of Applied Psychology*, 76(1), 137-142.

Gallupe, R.B., Cooper, W.H., and Bastianutti, L.M. (1990). “Why is electronic brainstorming more productive than traditional brainstorming? an experimental study.” IN: *Proceedings of the Administrative Sciences Association of Canada Conference*.

Gallupe, R.B., Dennis, A.R., Cooper, W., Valacich, J.S., Bastianutti, L.M., and Nunamaker, J.F. (1992). “Electronic brainstorming and group size.” *Academy of Management Journal*, 35(2), 350-369.

Gary, P. (1987). “Group decision support systems.” *Decision Support Systems*, 3(3), 233–242.

George, J.F., Easton, G.K., Nunamaker, J.F., Jr., and Northcraft, G.B. (1990). "A study of collaborative group work with and without computer-based support." *Information Systems Research*, 1(4), 394-415.

George, J.F., Northcraft, G.B., and Nunamaker, J.F. (1987). *Implications of Group Decision Support System Use for Management: Report of a Pilot Study*, Tucson, Arizona: College of Business and Public Administration, University of Arizona.

Gibson, C.B. (1999). "Do they do what they believe they can? group efficacy beliefs and effectiveness across tasks and cultures." *Academy of Management Journal*, 42, 138-152.

Gregory, S.A. (1984). "Design technology transfer." *Design Studies*, 5(4), Butterworth &Co (Publishers) Ltd, 203-218.

Greenbery, S. (1991). "Computer-supported cooperative work and groupware." *Academic Press*, London, 1991, 133-154.

Green, S. D. (1992). *A SMART Methodology for Value Management*, Chartered Institute of Building, Occasional Paper No. 53, UK.

Green, S.D. (1994). "Beyond value engineering: SMART value management for building projects." *International Journal of Project Management*, 12(1), 49-56.

Green, S.D. (2001). "Towards an integrated script for risk and value management." *International Project Management Journal*, 7(1), 52-58.

Harkins, S.G., and Pretty, R.E. (1982). "Effects of task difficulty and task uniqueness on social loafing." *Journal of Personality and Social Psychology*, 43(6), 1214-1229.

Heale, G (2003). "Applying theory to practice: an action research resource pack for professionals." *Clinical Chiropractic*, 6(1), 4-14.

Henry, E. (2000). "Quality management standarisation in the French construction industry, singularities and internationalization projects." *Construction Management and Economics*, 18(6), 667-677.

Hicks, C. R. (1982). *Fundamental Concepts in the Design of Experiments*, 3rd Edition, Holt-Saunders International, Philadelphia.

Hiltz, S.R., and Turoff, M. (1981). "The evolution of user behavior in a computerized conferencing system." *Communication of the ACM*, 24(11), 739-751.

Hofstede, G. (1980). *Culture's Consequences: International Differences in Work Related Value*, Sage Publications: London.

Hofstede, G. (1991). *Cultures and Organizations: Software of the mind*, McGraw-Hill Book Company, London.

Hofstede, G.H. (2001). *Culture's consequences: comparing values, behaviors, institutions, and organizations across nations*, Thousand Oaks, California: Sage Publications.

Huber, G. (1984). "Issues in the Design of Group Decision Support Systems." *Management Information Systems Quarterly*, 8(3), 195-204.

Hunt, J.W. (1992). *Managing People at work: a manager's guide to behavior in organizations*, 3rd ed. McGraw-Hill, London.

Hunter, K. (2006). *The application of value management to the public service sector with a view to best value*, PhD thesis, Glasgow Caledonian University.

Jarvenpaa, S.L., Rao, V.S., and Huber, G.P. (1988). “Computer support for meetings of medium-sized groups working on unstructured problems: a field experiment.” *Management Information Systems Quarterly*, 12(4), 645-666.

Jessup, L.M., Connolly, T. and Galegher, J. (1990). “The effects of anonymity on GDSS group process with an idea-generating task.” *Management Information Systems Quarterly*, 14(3), 313-321.

Jessup, L.M., Connolly, T., and Tansik, D.A. (1990). “Toward a theory of automated group work: the de-individuating effects of anonymity.” *Small Group Research*, 21(3), 333-348.

Jessup, L.M., and Tansik, D.A. (1991). “Decision making in an automated environment: the Effects of anonymity and proximity with a group decision support system.” *Decision Sciences*, 22(2), 266-279.

Kelly, J., and Male, S. (1991). *Value Management: Enhancing value or cutting costs?* RICS Occasional Paper, Surveyors Publication.

Kelly, J.R., MacPherson S, and Male S.P. (1992). *The Briefing Process: A Review and Critique, Royal Institution of Chartered Surveyors*, Surveyors Publications, Paper No 12, London.

Kelly, J.R., and Male S.P. (1993). *Value Management in Design and Construction: The Economic Management of Projects,* E&FN Spon, London.

Kelly, J., Male S., and Graham D. (2004). *Value Management of Construction Projects*, Blackwell Science.

Kelly, J.R., and Male S.P. (1996). "International benchmarking of value management." EPSRC IMI Conference Paper.

Kerr, N.L., and Bruun, S.E. (1983). "Dispensability of member effort and group motivation losses: free-rider effects." *Journal of Personality and Social Psychology*, 44(1), 78-94.

Knowles, E.S. (1980). "An affiliative conflict theory of personal and group spatial behaviour." IN: Paulus, P.B. (Ed.) *Psychology of Group Influence*, Hillsdale, NJ: Erlbaum, 133-188.

Kim, K., Park, H., and Suzuki, N. (1990). "Reward allocation in the United States, Japan and Korean: a comparison of individualistic and collectivistic cultures." *Academic of Management Journal*, 33(1), 188-198.

Krauss, R.M., and Weinheimer, S. (1966). "Concurrent feedback, confirmation, and the encoding of referents in verbal communication." *Journal of Personality and Social Psychology*, 4(4), 343-346.

Kraut, R.E., Lewis, S.H., and Sweezy, L.W. (1982). "Listener responsiveness and the coordination of conversation." *Journal of Personality and Social Psychology*, 43(4), 718-731.

Lamm, H., and Trommsdorf, G. (1973). "Group versus individual performance on tasks requiring ideational proficiency (brainstorming): A review." *European Journal of Social Psychology*, 3(4), 361-387.

Latane, B., Williams, K., and Harkins, S. (1979). "Many hands make light the work: the cause and consequences of social loafing." *Journal of Personality and Social Psychology*, 37(6), 822-832.

Lee, S.H., Peña-Mora, F., and Park, M. (2006). "Web-enabled system dynamics model for error and change management on concurrent design and construction projects." *Journal of Computing in Civil Engineering*, 20(4), 290-300.

Lewin, K. (1946). "Action research and minority problems." *Journal of Social Issues*, 2(4), 34-46

Lewis, L.F. (1982). *FACILITATOR: A Microcomputer Decision Support System for Small Groups*, Doctoral Dissertation, University of Louisville, University Microfilms: Ann Arbor, Mich.

Liu, G.W. (2003). *A Framework for implementing Value Management in China's Construction Industry*, PhD thesis, The Hong Kong Polytechnic University, March, Hong Kong.

Liu, M. (1997). *Fondements et Practiques de la Recherche-action*, Logiques sociales, L'Harmattan, Paris.

Loo, R. (2002). "The Delphi method: a powerful tool for strategic management." *An International Journal of Police Strategies and Management*, 25(4), 762-769.

Lorge, I., Fox, D., Davitz, J., and Brenner, M.A. (1958). "A survey of studies contrasting the quality of group performance and individual performance, 1920-1957." *Psychological Bulletin*, 55(6), 337-372.

Macedo, M.C., Dobrow, P.V. and O'Rourke, J.J. (1978). *Value Management for Construction*, Wiley-interscience, New York.

Male, S.P., Kelly, J.R., Fernie, S., Gronqvist, M., and Bowles, G. (1998). *Value management benchmark: A good practice framework for clients and practitioners*, Thomas Telford, London

Mason, O., and Mitroff, I. (1981). *Challenging Strategic Planning Assumptions*, Wiley, New York.

Massey, A.P., and Clapper, D.L. (1995). "Element finding: the impact of a GSS on a crucial component of sense making." *Journal of Management Information Systems*, 14(1), 1-22.

McCartt, A.T., and Rohrbaugh, J. (1989). "Evaluating group decision support system effectiveness: a performance study of decision conferencing." *Decision Support Systems*, 5(2), 243-253.

McCaskey, M.B. (1979) "The hidden messages managers send." *Harvard Business Review*, 57(6), 135-148.

McGeorge D. and Palmer A. (1997). *Construction Management – New Directions*, Blackwell Science, London.

McGrath, J.E. (1984). *Groups: Interaction and Performance.* Englewood Cliffs, NJ: Prentice Hall.

Mejias, R.M., Vogel, D.R., and Shephard, M. (1997). "GSS meeting productivity and participation equity: a U.S. and Mexico cross-cultural field study." In: *Proceedings of* *the Thirtieth Annual Hawaii International Conference on System Sciences*, 2, Los Alamitos, CA: IEEE Computer Society Press, 469-478.

Mennecke, B.E., Hoffer, J.A., and Wynne, B.E. (1992). “The implications of group development and history for group support system theory and practice.” *Small Group Research*, 23(4), 524-572.

Miles, L.D. (1961). *Techniques of value analysis and engineering*, McGraw-Hill, New York.

Miles L.D. (1972). *Techniques of value analysis and engineering*, 2nd Ed. McGrawHill, Inc.

Mullen, B., Johnson, C., and Salas, E. (1991). “Productivity loss in brainstorming groups: A meta-analytic integration.” *Basic and Applied Social Psychology*, 12(1), 3-23.

Mullen, B., Symons, C., Hu, L.T., and Salas, E. (1989). “Group size, leadership behavior and subordinate satisfaction.” *The Journal of General Psychology*, 116(2), 155-170.

Murray, L.C. (1988). “The computer and the value engineer.” In: *Proceedings of the 23rd SAVE International Annual Conference*, 216-226.

Nitithamyong, P., and Skibniewski, M.J. (2004). “Web-based construction project management systems: how to make them successful?” *Automation in construction*, 13(4), 491-506.

Norton, B.R., and McElligott, C.W. (1995). *Value management in construction: A practical guide*, London: Macmillan Press Ltd.

Norusis, M. J. (1993). *SPSS for Windows, Professional Statistical Release 6.0.*, Statistical Package for Social Science (SPSS) Inc., Chicago, Illinois, USA.

Nunamaker, J.F., Applegate, L.M., and Konsynski, B.R. (1988). “Computer aided deliberation: model management and group decision support.” *Journal of Operations Research*, 36(6), 826-848.

Nunamaker, J.F., Briggs, R.O., Mittleman, D.D., and Vogel, D.R. (1996). “Lessons from a dozen years of group support systems research: a discussion of lab and field findings.” *Journal of Management Information Systems*, 13(3), 163-207.

Nunamaker, J. F., Dennis, A. R., Valacich, J. S., Vogel, D. R., and George, J. F. (1993). “Group support systems research: experience from the lab and field.” In L. M. Jessup, & J. S. Valacich, Group support systems: new perspectives (125-145). New York: Macmillan.

Nunamaker, J.F., Vogel, D.R., Heminger, A., Martz, W.B., Grohowski, R., and McGoff, C. (1989) “Experiences at IBM with group decision support systems: a field Study.” *Decision Support Systems*, 5(2), 183-196.

Nunamaker J.F., Vogel D.R., and Potter R. (1997). “Individual and team trends and implications for business firms.” *Advances in the Study of Entrepreneurship, Innovation, and Economic Growth*, 9, 199-247.

Olaniran, B.A. (1994). “A model of group satisfaction in computer-mediated and face-to-face communication media.” *Management Communication Quarterly*, 7(3), 256-281.

Otero, F. (1997). “Real time integrated computer tools for value engineering events.” In: *Proceedings of the 32nd SAVE International Annual Conference*, 221-227.

Palmer, A. (1992). *An investigation study of value engineering in the United States of American and its relationship to United Kingdom cost control procedures*, PhD thesis, Loughborough University, England.

Palmer, A., Kelly, J. and Male, S. (1996). “Holistic appraisal of value engineering in construction in United States.” *Journal of Construction Engineering and Management (ASCE)*, 122(4), 324-328.

Palaneeswaran, E., and Kumaraswamy, M.M. (2005). “Web-Based Client Advisory Decision Support System for Design–Builder Prequalification”. *Journal of Computing in Civil Engineering,* 19(1), 69-82.

Park, P.E. (1993). “Creativity and value engineering teams.” IN: Proceedings of the 28th SAVE International Annual conference, SAVE International, Fort Lauderdale, Florida, USA.

Paul, S., Samarah, I.M., Seetharaman P., Peter P., and Mykytyn JR. (2004). “An empirical investigation of collaborative conflict management style in group support system-based global virtual teams.” *Journal of Management Information Systems*, 21(3), 185-222.

Paul, S., Seetharaman, P. and Ramamurthy, K. (2004). “User satisfaction with system, decision process, and outcome in GDSS based meeting: an experimental investigation.” In: *Proceedings of the 37th Hawaii International Conference on System Sciences.*

Paulson, L.W. and Simpson, J.J. (1989). “VE-PRO, software for value engineering program management.” In: *Proceedings of the 24th SAVE International Annual Conference*, 197-201.

Paulus, P.B., Brown, V., Ortega, A.H., Purser, R.E., and Montuori, A. (1997). *Group creativity, Social Creativity in Organization*, Hampton Press, Cresskill, NJ.

Paulus, P.B., Dzindolet, M.T., Poletes, G., and Camacho, L.M. (1993). “Perceptions of performance in group brainstorming: the illusion of productivity.” *Journal of Personality and Social Psychology Bulletin*, 19(1), 78-89.

Paulus, P.B., Larey, T.S., and Ortega, A.H. (1995). “Performance and Perceptions of Brainstormers in an Organizational Setting.” *Basic and Applied Social Psychology*, 17(1/2), 249-265.

Penley, L.E., Alexander, E.R., Jernigan, I., and Henwood, C.I. (1991). “Communications abilities of managers: the relationship to performance.” *Journal of Management*, 17(1), 57-76.

Pervan, G.P. (1994). “The measurement of GSS effectiveness: a meta-analysis of the literature and recommendations for future GSS research.” IN: *Proceedings of the 27th Hawaii International Conference on Systems Science*, IV, 562-571.

Pervan, G.P. (1998). “A review of research in group support systems: leaders, approaches and directions.” *Decision Support Systems*, 23(2), 149-159.

Pinsonneault, A., Barki, H., Gallupe, B.R., and Hoppen, N. (1999). “Electronic brainstorming: The illusion of productivity.” *Information Systems Research*, 10(2), 110-130.

Pinsonneault, A., and Kraemer, K.L. (1990). "The effects of electronic meetings on group processes and outcomes: An assessment of the empirical research." *European Journal of Operational Research*, 46(2), 143-161.

Pinsonneault, A., and Kraemer, K.L. (1990). "The effects of electronic meetings on group processes and outcomes: an assessment of the empirical research." *European Journal of Operational Research*, 46(2), 143-161.

Poon, P., and Wagner, C. (2001). "Critical success factors revisited: success and failure cases of information systems for senior executives." *Decision Support Systems*, 30(4), 393-418.

Quinn, R.E., and Rohrbaugh, J. (1981). "A competing values approach to organizational analysis." *Public Productivity Review*, 5(2), 141-159.

Rao, V.S., and Jarvenpaa, S.L. (1991). "Computer support of groups: theory based models for GDSS research." *Management Science*, 37(10), 1347-1362.

Reagan, P., and Rohrbaugh, J. (1990). "Group decision process effectiveness: A competing values approach." *Group & Organization Studies*, 15(1), 20-43.

Reichling, L. (1995). "What makes a successful team?" In: *Proceedings of the 35th SAVE International Annual Conference*, 99-102.

Remus, W. (1986). "Graduate students as surrogates for managers in experiments on business decision making." J*ournal of Business Research*, 14(1), 19-25.

Rohrbaugh, J. (1987). "Assessing the effectiveness of expert teams." In J.L. Mumpower, L.D. Phillips, O. Renn, & V.R.R. Uppuluri (Eds.), *Expert judgment and expert system.* Berlin: Springer-verlag.

SAVE International (1998). *Value methodology standard*, 2nd Revised, Northbrook: SAVE International.

SAVE International (2007). *Value standard and body of knowledge*, SAVE International.

SAVE International (2008a). VM in construction, Available: http://www.value-eng.org/benefits_government.php, [Accessed: 29 April 2009].

SAVE International (2008b). VM in construction, Available: http://www.value-eng.org/benefits_construction.php, [Accessed: 29 April 2009].

Scott, M., Davidson, J., and Edwards, H. (2002). "Application of template analysis in information systems research: a technique for novice researchers." IN: *Proceedings of European Conference on Research Methodology for Business and Management Studies*, Reading University, UK, 29-30 April, Edited by Dan Remenyi.

Shaw, G.J. (1998). "User satisfaction in group support systems research: a meta-analysis of experimental results." In: *Proceedings of the Thirty-First Annual Hawaii International Conference on System Sciences*. Los Alamitos, CA: IEEE Computer Society Press, 360-369.

Shen, Q.P. (1993). *A knowledge-based structure for implementing value management in the design of office buildings,* PhD thesis, the University of Salford for the degree of doctor of philosophy, UK.

Shen, Q.P. (1995). "A knowledge-based model for co-ordinating design through VM, Int. workshop modelling buildings through Their Life Cycle." CIB W78 & TG10, Stanford University, USA, 21-23 Aug., 382-391.

Shen, Q.P. (1996). “Enhancing value management studies through information technology.” IN: *Proceedings of CIB International Conference Construction Modernisation and Education*, 21-24 Oct., Beijing, China, CD-ROM, 10 pages.

Shen, Q.P. (1997). “Value management in Hong Kong’s construction industry: lessons learned.” In: *Proceedings of the 32nd SAVE International Annual Conference*, 260-265.

Shen, Q.P. (2005). *Unpublished Value Management Reading Materials*, Hong Kong Polytechnic University.

Shen, Q.P., and Brandon P.S. (1992). “Function-cost analysis in value management.” IN: *Proceedings of ARCOM 8th Annual Conference*, Douglas, Isle of Man, UK, 18-20 September, 15-26.

Shen, Q.P., and Chung, K.H. (2000). “Overcome difficulties in VM studies: the use of information technology.” *In: Proceedings of the 4th HKIVM Int. Value Management Conference*, 22–23rd November. Hong Kong: HKIVM, 2000, 28-36.

Shen, Q.P., and Chung J.K.H. (2001). “Using information technology to overcome difficulties in value management studies – Hong Kong’s experience.” *Journal of Construction Research*, 2(2), 147-156.

Shen, Q.P., and Chung J.K.H. (2002). “A group decision support system for value management studies in the construction industry.” *International Journal of Project Management*, 20(3), 247-252.

Shen, Q.P., Chung, K.H., Li, H., and Shen, L.Y. (2004). “A group support system for improving value management studies in construction.” *Automation in Construction*, 13(2), 209-224.

Shen, Q.P., and Fan, S.C. (2005). “A group decision support systems for Value Management studies.” In: *Proceedings of 2nd International Conference on Value Engineering & Technology Innovation,* 19-28.

Shen, Q. P., and Liu, G.. W. (2003). “Critical success factors for value management studies in construction.” *Journal of Construction Engineering and Management,* 129(5), 485-491.

Shen Q.P., and Liu G.W. (2002). “Value management applications in China’s construction industry.” *Journal of Construction Procurement,* 8(1), 35-47.

Shen, Q.P., and Kwok, E. (1999). “The economic downturn in Hong Kong: crisis or opportunity for sustainable VM applications?” IN: *Proceedings of the 3rd International VM Conference, Hong Kong Institute of Value Management*, 6-7.

Shen, Q.P., and Shen, L.Y. (1999). “Value management as a vehicle for scope management of construction projects.” *Journal of Harbin university of Civil Engineering and Architecture*, 32(5), 107-115.

Siegel, J.V., Kiesler, S., and McGuire, T,W. (1986). “Group processes in computer-mediated communication.” *Organizational Behavior and Human Decision Processes*, 37(2), 157-187.

Smith, J.Y., and Vanacek, M.T. (1989). “A nonsimultaneous computer conference as a component of group decision support systems.” IN: *Proceedings of the 22nd Hawaii International Conference on System Sciences,* III, 370-377.

Stroebe, W., and Diehl, M. (1994). “Why groups are less effective than their members: On productivity loss in idea generating groups.” *European Review of Social Psychology*, 5, 271-304.

Sutton, R.I., and Hargadon, A. (1996). “Brainstorming groups in context: Effectiveness in a product design firm.” *Administrative Science Quarterly,* 41(4), 685-718.

Thierauf, R.J. (1989). *Group Decision Support Systems for Effective Decision Making*, Westport: Greenwood Press Inc.

Tung L.L., and Uaddus M.A. (2002). “Cultural differences explaining the differences in results in GSS: implications for the next decade.” *Decision Support Systems*, 33(2), 177-199.

Turban E., and Aronson J.E. (2001). *Decision support systems and intelligent systems,* 6th Ed., Prentice Hall, New Jersey.

Turoff, M., and Hiltz, S.R. (1982). “Computer support for group versus individual decisions.” *IEEE Transactions on Communications*, 30(1), 82-90.

Valacich, J.S. (1989). *Group Size and Proximity Effects on Computer Mediated Idea Generation: A Laboratory Investigation,* Doctoral Dissertation, University of Arizona.

Valacich, J.S., Dennis, A.R., and Connolly, T. (1994). “Idea generation in computer-based groups: A new ending to an old story.” *Organizational Behavior and Human Decision Process*, 57(3), 448-467.

Walker, D. H. T. (1997). “Choosing an appropriate research methodology.” *Construction Management and Economics,* 15(2), 149-159.

Walker, H. A., Ilardi, B. C., McMahon, A. M., and Fennell, M. L. (1996). "Gender, interaction, and leadership." *Social Psychology Quarterly*, 59(3), 255-272.

Waser, H., and Johns, N. (2003). "An evaluation of action research as a vehicle for individual and organizational development in the hotel industry." *International Journal of Hospitality Management*, 22 (4), 373-393.

Watson, W.E., Kuman, F., and Michaelsen, L.K. (1993). "Cultural diversity's impact on interaction process and performance: comparing homogeneous and diverse task groups." *Academy of Management Journal*, 36(3), 590-602.

Watson, R.T., DeSanctis, G.L., and Poole, M.S. (1988). "Using a GDSS to facilitate group consensus: some intended and unintended consequences." *Management Information Systems Quarterly*, 12(3), 463-478.

Watson, R.T., Ho, T.H., and Raman, K.S. (1994). "Culture: a fourth dimension of group support systems research." *Communications of the ACM*, 37(10), 44-55.

Williams, K., Harkins, S., and Latane, B. (1981). "Identifiability as a deterrent to social loafing: Two cheering experiments." *Journal of Personality and Social Psychology*, 40(2), 303-311.

Woodhead, R., and Downs, C (2001), *Value Management: Improving Capabilities*, Thomas Telford.

Works Bureau (1998). *Technical Circular No. 16/98, Planning, Environment & Lands Bureau Technical Circular No. 9/98: Implementation of Value Management*, The Government of the Hong Kong Special Administrative Region.

Xie, H., and Yapa, P.D. (2006). “Developing a web-Based system for large-scale environmental hydraulics problems with application to oil spill modeling.” *Journal of Computing in Civil Engineering*, 20(3), 197-209.

Yin, R. K (2003), *Case study research: designs and methods*, 3rd Edition, Sage Publications, London.

Zigurs, I., and Dickson, G.W. (1990). *Computer Support for Decision Making Teams: The Issue of Outcome Quality*, Faculty Working Paper Series, College of Business and Administration, University of Colorado.

Zigurs, Z., Poole, I., and DeSanctis, L. (1988). “A Study of Influence in Computer-Mediated Group Decision Making.” *Management Information Systems Quarterly*, 12(4), 625-644.

Zimmerman, L.W., and Hart, G.D. (1982). *Value Engineering: A Practical Approach for Owners, Designers and Contractors*, Van Nostrand Reinhold Company Inc.

APPENDIX 1: Questionnaire used in Experimental Study I

Participant Feedback Questionnaire

This questionnaire is designed to gather information to measure the performance of the VM workshop. The results will not be used to assess individual performance. Thank you very much in advance for your help in completing this questionnaire!

INSTRUCTIONS:

Unless otherwise stated, please indicate your answer by circling the appropriate numbers. The meanings of the acronyms are given under the tables.

1. Background Information

	SA	A	D	SD
I have experience in brainstorming.	4	3	2	1
I have experience in interior decoration	4	3	2	1
I have experience in water supply activities.	4	3	2	1

(SA: Strongly Agree A: Agree D: Disagree SD: Strongly Disagree)

2. Comparison Between Manual Method and IVMS Method

	SA	A	D	SD
I can express my ideas more promptly by using IVMS.	4	3	2	1
I can generate more ideas on the basis of others' ideas by using IVMS.	4	3	2	1
I can understand the ideas of the members of my group by using IVMS.	4	3	2	1
I have more equal opportunities to express my ideas by using IVMS.	4	3	2	1
I have confidence about expressing my ideas by using IVMS.	4	3	2	1
I can generate more good-quality ideas by using IVMS.	4	3	2	1
I am more satisfied with the outcome of brainstorming by using IVMS.	5	3	2	1

(SA: Strongly Agree A: Agree D: Disagree SD: Strongly Disagree)

3. About IVMS

	SA	A	D	SD
My typing speed helps me to express ideas	4	3	2	1
I feel comfortable to use IVMS	4	3	2	1
I am satisfied with the interface of IVMS.	4	3	2	1

(SA: Strongly Agree A: Agree D: Disagree SD: Strongly Disagree)

Open-ended questions

5. What are the things that you like <u>MOST</u> about IVMS?

a)____
____

b)____
____

c)____
____

6. What are the things that you like <u>LEAST</u> about IVMS?

a)____
____

b)____
____

c)____
____

Personal Particulars

Name of Respondent: ___________________ Position: _______________________

Thank you very much for completing this questionnaire!

- THE END -

APPENDIX 2: Questionnaire used in Experimental Study II

Participant Feedback Questionnaire

This questionnaire is designed to gather information to measure the performance of the VM workshop. The results will not be used to assess individual performance. Thank you very much in advance for your help in completing this questionnaire!

INSTRUCTIONS:

Unless otherwise stated, please indicate your answer by circling the appropriate numbers. The meanings of the acronyms are given under the tables.

1. To what extent do you agree with the following statement?

	SA	A	N	D	SD
You are satisfied with the time when the VM workshop is conducted.	5	4	3	2	1
You are satisfied with the venue where the VM workshop is conducted.	5	4	3	2	1
You are familiar with how VM workshop is conducted.	5	4	3	2	1
The VM workshop is fully supported by client.	5	4	3	2	1
Client representatives participate actively in the VM workshop.	5	4	3	2	1
The VM workshop has a clear objective.	5	4	3	2	1
The VM workshop is fully supported by the relevant department.	5	4	3	2	1

(SA: Strongly Agree A: Agree N: Neutral D: Disagree SD: Strongly Disagree)

2. Are you satisfied with the process of the VM workshop?

	SA	A	N	D	SD
Pre-workshop stage					
You are satisfied with the information collected in pre-workshop stage.	5	4	3	2	1
Information phase					
You are satisfied with the techniques used in information phase.	5	4	3	2	1
You are satisfied with the interaction between participants.	5	4	3	2	1
You are satisfied with the clarification of client's objectives.	5	4	3	2	1
You are clear about the givens/assumptions of the project.	5	4	3	2	1
Function analysis phase					
You are satisfied with the techniques used in function analysis phase.	5	4	3	2	1
You are satisfied with the interaction between participants.	5	4	3	2	1
You are functions clearly identified.	5	4	3	2	1
Creativity phase					
You are satisfied with the techniques used in creativity phase.	5	4	3	2	1
You are satisfied with the interaction between participants. ..	5	4	3	2	1
Evaluation phase					
You are satisfied with the techniques used in evaluation phase.	5	4	3	2	1
You are satisfied with the interaction between participants. ..	5	4	3	2	1
Development phase					
You are satisfied with the techniques used in development phase.	5	4	3	2	1
You are satisfied with the interaction between participants. ..	5	4	3	2	1

(SA: Strongly Agree A: Agree N: Neutral D: Disagree SD: Strongly Disagree)

3. What is your assessment on the outcomes of the VM workshop?

	SA	A	N	D	SD
The workshop helped to identify and clarify the client's requirement.	5	4	3	2	1
The workshop helped to improve the project quality.	5	4	3	2	1
The workshop helped to improve the project shape.	5	4	3	2	1
You are satisfied with the outcomes of the VM workshop.	5	4	3	2	1

(SA: Strongly Agree   A: Agree   N: Neutral   D: Disagree   SD: Strongly Disagree)

Personal Particulars

Name of Respondent:_______________________ Position: _______________________

Thank you very much for completing this questionnaire!

- THE END -

APPENDIX 3: Questionnaire used in Experimental Study III

Participant Feedback Questionnaire

This questionnaire is designed to gather information to measure the performance of the VM workshop. The results will not be used to assess individual performance. Thank you very much in advance for your help in completing this questionnaire!

INSTRUCTIONS:

Unless otherwise stated, please indicate your answer by circling the appropriate numbers. The meanings of the acronyms are given under the tables.

1. To what extent do you agree with the following statement?

	SA	A	N	D	SD
You are satisfied with the time when the VM workshop is conducted.	5	4	3	2	1
You are satisfied with the venue where the VM workshop is conducted....	5	4	3	2	1
You are familiar with how VM workshop is conducted.............................	5	4	3	2	1
The VM workshop is fully supported by client.	5	4	3	2	1
Client representatives participate actively in the VM workshop................	5	4	3	2	1
The VM workshop has a clear objective.	5	4	3	2	1
The VM workshop is fully supported by the relevant department.	5	4	3	2	1

(SA: Strongly Agree A: Agree N: Neutral D: Disagree SD: Strongly Disagree)

2. Are you satisfied with the process of the VM workshop?

	VS	S	N	U	VU
Pre-workshop stage					
Are you satisfied with the information collected in pre-workshop stage?	5	4	3	2	1
Information phase					
Are you satisfied with the techniques used in information phase?	5	4	3	2	1
Are you satisfied with the interaction between participants?	5	4	3	2	1
Are you satisfied with the clarification of client's objectives?	5	4	3	2	1

Are you clear about the givens/assumptions of the project?	5	4	3	2	1
Function analysis phase					
Are you satisfied with the techniques used in function analysis phase?	5	4	3	2	1
Are you satisfied with the interaction between participants?	5	4	3	2	1
Are the functions clearly identified?	5	4	3	2	1
Creativity phase					
Are you satisfied with the techniques used in creativity phase?	5	4	3	2	1
Are you satisfied with the interaction between participants?	5	4	3	2	1
Evaluation phase					
Are you satisfied with the techniques used in evaluation phase?	5	4	3	2	1
Are you satisfied with the interaction between participants?	5	4	3	2	1
Development phase					
Are you satisfied with the techniques used in development phase? ...	5	4	3	2	1
Are you satisfied with the interaction between participants?	5	4	3	2	1

(VS: Very satisfied S: Satisfied N: Neutral U: Unsatisfied VU: Very unsatisfied)

3. What is your assessment on the outcomes of the VM workshop?

	E	G	N	B	T
Identification and clarification of client's requirement.	5	4	3	2	1
Improvement on project quality.	5	4	3	2	1
Improvement on project shape.	5	4	3	2	1
Your satisfaction of the VM workshop.	5	4	3	2	1

(E: Excellent G: Good N: Neutral B: Bad T: Terrible)

4. **To what extent do you agree with the following statement on the support of IVMS?**

	SA	A	N	D	SD
Support in Information phase					
IVMS can improve the availability of information.……….…….	5	4	3	2	1
IVMS can improve the information exchange process.…………...	5	4	3	2	1
Support in Function analysis phase					
IVMS can simplify the function analysis processes.	5	4	3	2	1
IVMS can enhance the function analysis processes.	5	4	3	2	1
Support in Creativity phase					
IVMS can promote active participation in idea generation.	5	4	3	2	1
IVMS can avoid conformance pressure in idea generation.………..	5	4	3	2	1
IVMS can prevent domination in discussion.……………………...	5	4	3	2	1
The pop-up character can enhance the atmosphere of creativity....	5	4	3	2	1
The function of "Tips" can help me in generating ideas.………...	5	4	3	2	1
I used the function of "Tips" frequently in generating ideas.…….....	5	4	3	2	1
Support in Evaluation phase					
IVMS can simplify the evaluation processes.	5	4	3	2	1
IVMS can enhance the evaluation processes.	5	4	3	2	1
Interface of IVMS					
I feel comfortable with the current interface of IVMS	5	4	3	2	1

(SA: Strongly Agree A: Agree N: Neutral D: Disagree SD: Strongly Disagree)

Open-ended questions

5. What are the things that you like <u>MOST</u> about IVMS?

a)____

b)____

c)____

6. What are the things that you like <u>LEAST</u> about IVMS?

a)____

b)____

c)____

7. What are the functions that you think should be added to IVMS in the future?

a)____

b)____

c)____

8. What are the functions that you think could be excluded in the current IVMS?

a)____

b)____

c)____

9. What are your comments or suggestions to improve IVMS?

a)____

b)____

c)____

Personal Particulars

Name of Respondent: ____________________ Position: ________________________

Thank you very much for completing this questionnaire!

- THE END -

APPENDIX 4: Questionnaire used in Experimental Study IV

VM WORKSHOP FEEDBACK FORM

This VM workshop feedback form is designed to gather your opinions on the performance of the VM workshop. The information collected in this feedback form will help the facilitator prepare the follow-up workshops if applicable. All your comments will be taken serious consideration for preparing the VM report. Please be assured that your personal information will be keep strictly confidential.

INSTRUCTIONS: Please indicate your answer by circling the appropriate numbers.

1. To what extent do you agree with the following statement about the VM workshop?

	Strongly Agree	**Generally Agree**	**Slightly Agree**	**Slightly Disagree**	**Generally Disagree**	**Strongly Disagree**
This VM workshop has clear objectives.	6	5	4	3	2	1
The client supported the implementation of the VM workshop.	6	5	4	3	2	1
The client participated in the VM workshop process.	6	5	4	3	2	1
Adequate background information has been collected.	6	5	4	3	2	1
Interaction among the VM team was active in each phase.	6	5	4	3	2	1
Client's objectives have been clarified in the information phase.	6	5	4	3	2	1
Project givens/assumptions have been clarified in the information phase.	6	5	4	3	2	1
Primary functions have been identified in the function analysis phase.	6	5	4	3	2	1
Communication and understanding among key stakeholders have been improved.	6	5	4	3	2	1
Client's requirements have been identified and clarified.	6	5	4	3	2	1
The workshop expedited the decision making process.	6	5	4	3	2	1
You are satisfied with the performance of the workshop.	6	5	4	3	2	1

2. The effectiveness of the workshop （Note: Please read carefully, some items were reverse coded. ）

	Strongly Agree	Generally Agree	Slightly Agree	Slightly Disagree	Generally Disagree	Strongly Disagree
Data-based Process						
The process was based too much on subjective judgments rather than factual considerations...............	6	5	4	3	2	1
All information relevant to the workshop was available to the group..	6	5	4	3	2	1
Accountability of Outcome						
A record was made to document the resolutions of all key issues.	6	5	4	3	2	1
As the result of the process, the group was well prepared to be fully accountable for the decisions made during the workshop	6	5	4	3	2	1
The process recognized the need for the group to be answerable for the action plan.	6	5	4	3	2	1
Goal-centered Process						
The process encouraged you to consider the workshop's goals and objectives.	6	5	4	3	2	1
All the potential effects of all the alternatives were carefully weighed...	6	5	4	3	2	1
The process made the discussions specifically relate to the objectives	6	5	4	3	2	1
Efficiency of Process						
Important resources were wasted in the process of this workshop..	6	5	4	3	2	1
Results were achieved in much less time that it ordinarily would have taken	6	5	4	3	2	1
It was a productive process involving a lot of had but worthwhile work	6	5	4	3	2	1
Adaptable Process						
The process was very flexible in dealing with the problem	6	5	4	3	2	1

The process stimulated innovative ways of looking at the problem	6	5	4	3	2	1
Legitimacy of Decision						
An effort was made to find a solution that would not in any way damage the standing of your organization .	6	5	4	3	2	1
The feasibility of each decision was seriously considered	6	5	4	3	2	1
An effort was made to find a solution that would not in any way damage how others perceived the group	6	5	4	3	2	1
Participatory Process						
You were always encouraged to express your personal concerns, even when divergent	6	5	4	3	2	1
A great effort was made to understand the interests and concerns of every party of the workshop.......	6	5	4	3	2	1
Conflict was dealt with constructively......................	6	5	4	3	2	1
Supportability of Decision						
At the end of the workshop, the group displayed a strong team spirit	6	5	4	3	2	1
During the process the group achieved a common understanding of the problem	6	5	4	3	2	1
Serious reservations about proposed action make it impossible to get a full consensus.......................................	6	5	4	3	2	1

Open-ended questions

3. What are the things that you like <u>MOST</u> about IVMS?

____

____

4. What are the things that you like <u>LEAST</u> about IVMS?

____

____

5. What are the functions that you think should be added to IVMS in the future?

____

____

6. What are your comments or suggestions to improve IVMS?

____

____

Personal Particulars

Name of Respondent: ____________________ Position: _______________________

Name of Company: _______________________

Thank you very much for completing this feedback form!

- THE END -

APPENDIX 5: Questionnaire Survey on Critical Success Factors

This questionnaire is part of a research project entitled “The effect of using Group Decision Support System (GDSS) on the processes and outcomes of Value Management (VM) Studies”. One of the research objectives is to identify critical success factors for the integration of GDSS with activities in the VM process. This questionnaire is designed to collect your opinion about the critical factors of using GDSS in VM workshops. Your replies will be valuable for us to further design a GDSS prototype and investigate the most appropriate way to use GDSS in VM studies. Your support to this survey is much appreciated.

INSTRUCTIONS:

Unless otherwise stated, please indicate your answer by circling the appropriate numbers. The meanings of the acronyms are given under the tables. **Questions marked with a * are required.**

A. Basic information

1.* Your present role in the project team:

☐ Architect

☐ Client

☐ Consultant

☐ Contractor

☐ Engineer

☐ Surveyor

Other: ______

2.* Years of experience in the construction industry ______________________

3.* How many VM workshops have you attended? _______________________

4. Company: _______________

5. To what extent do you agree with the following statement about the VM workshop?

	Strongly Agree	Generally Agree	Slightly Agree	Slightly Disagree	Generally Disagree	Strongly Disagree
I believe that working with computers is very difficult.	6	5	4	3	2	1
I believe that working with computers makes a person more productive at his/her job.	6	5	4	3	2	1
Working with a computer would make me very nervous.	6	5	4	3	2	1
I feel confident using Internet, e.g., using search engines, and locating necessary information on the Internet etc.	6	5	4	3	2	1

B. Critical Success Factors

	Strongly Agree	Generally Agree	Slightly Agree	Slightly Disagree	Generally Disagree	Strongly Disagree
Participant perspective						
Participants' attitude toward computers will influence the workshop performance.	6	5	4	3	2	1
Participants' computer anxiety will influence the workshop performance.	6	5	4	3	2	1
Facilitator perspective						
Facilitator's attitude towards GDSS will influence the workshop performance.	6	5	4	3	2	1

Facilitator's knowledge about GDSS will influence the workshop performance.	6	5	4	3	2	1
Workshop perspective						
GDSS is applied in a Face-to-face environment.	6	5	4	3	2	1
GDSS is applied in the workshops with large number of participants.	6	5	4	3	2	1
GDSS is applied in the workshops with short duration.	6	5	4	3	2	1
System design perspective						
System reliability will influence the workshop performance.	6	5	4	3	2	1
System response will influence the workshop performance.	6	5	4	3	2	1
Perceived easy of use will influence the workshop performance.	6	5	4	3	2	1
Perceived usefulness will influence the workshop performance.	6	5	4	3	2	1
Others (Please specify)						
	6	5	4	3	2	1
	6	5	4	3	2	1
	6	5	4	3	2	1
	6	5	4	3	2	1

Personal Particulars

Name of Respondent: ________________________ Position: ________________________

Thank you very much for completing this questionnaire!