A FRAMEWORK FOR DEVELOPING A KNOWLEDGE-BASED DECISION SUPPORT SYSTEM FOR MANAGEMENT OF VARIATION ORDERS FOR INSTITUTIONAL BUILDINGS

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SUMMARY: This study describes the framework for developing a knowledge-based decision support system (KBDSS) for making more informed decisions for managing variation orders in institutional buildings. The KBDSS framework consists of two main components, i.e., a knowledge base and a decision support shell. The database will be developed through collecting data from source documents of 80 institutional projects, questionnaire survey, literature review and in-depth interview sessions with the professionals who were involved in these institutional projects. The knowledge base will be developed through initial sieving and organization of data from the database. The decision support shell would provide decision support through a structured process consisting of building the hierarchy between the main criteria and the suggested controls, rating the controls, and analyzing the controls for selection through multiple analytical techniques. The KBDSS would be capable of displaying variations and their relevant details, a variety of filtered knowledge, and various analyses of available knowledge. This would eventually lead the decision maker to the suggested controls for variations and assist in selecting the most appropriate controls. The KBDSS would assist project managers by providing accurate and timely information for decision-making, and a user-friendly system for analyzing and selecting the controls for variation orders for institutional buildings. The study would assist building professionals in developing an effective variation management system. The system would be helpful for them to take proactive measures for reducing variation orders. The findings from this study would also be valuable for all building professionals in general.

***KEYWORDS*:** decision support, institutional buildings, knowledge base, variations, change orders.

1. INTRODUCTION

The fact is that variation orders are an unwanted, but inevitable, reality of any construction project (the term “change orders” is used in North America). The construction process can be influenced by changing variables and unpredictable factors that could result from different sources (Mokhtar et al, 2000). These sources include the performance of construction parties, resource availability, environmental conditions, involvement of other parties and contractual relations. As a consequence of these sources, the construction of projects may face problems which could cause delay in the project completion time (Arain et al, 2004).

The need to make changes in a construction project is a matter of practical reality (Arain and Low, 2005a). Even the most thoughtfully planned project may necessitate changes due to various factors (Ibbs et al, 2001). Developments in the education sector and the new modes of teaching and learning also foster the need for the renovation or extension of existing academic institutions (Arain and Low, 2005a).

In project management, variations in projects can cause substantial adjustments to the contract duration time, total direct and indirect cost, or both (Ibbs et al, 1998; Gray and Hughes, 2001; Ibbs et al, 2001). Every building project involves a multi-player environment and represents a collaborative effort among specialists from various independent disciplines (Arain et al, 2004). Because variations are common in projects, it is critical for project managers to confront, embrace, adapt and use variations to impact positively the situations they face and to recognize variations as such (Ibbs, 1997; Arain and Low, 2005a). The variations and variation orders can be minimized when the problem is studied collectively as early as possible, since the problems can be identified and beneficial variations can be made (CII, 1994b; Lazarus and Clifton, 2001). The variations and variation orders can be deleterious in any project, if not considered collectively by all participants. From the outset, project controls should take advantage of lessons learned from past similar projects (Ibbs et al, 2001).

Decision making is a significant characteristic that occurs in each phase of a project (design, implementation, construction, and maintenance). In almost every phase, decision making is necessary. Often, these decisions will, or can affect the other tasks that will take place (Arain and Low, 2005b). To achieve an effective decision-making process, project managers and the other personnel of one project need to have a general understanding of other related or similar past projects (CII, 1994a). This underscores the importance of having a good communication and documentation system for better and prompt decision making during various project phases.

Decision support systems are systems under the control of one or more decision makers that provide an organized set of tools to impart structure to portions of the decision-making situation and to improve the ultimate effectiveness of the decision outcomes (Marakas, 1999; Dyche, 2000). Decision support systems are widely used to solve ill-structured construction problems through formulating an explicit statement of goals for the problem to be solved, identifying the scope and boundaries of feasible solutions, and selecting the optimal solution between a set of alternatives (Li and Love, 1998).

During the various project phases, in order to take rectifying actions for any variations in the project, project managers often need timely information and analysis reports to assist in making more informed and precise decisions (Vanegas and Chinowsky, 1996). It was found that in most reporting and analysis, much time was spent on collecting data from various systems before the analysis could be made. Project managers wanted and needed more information for making decisions, but analysts could provide only minimal information at high cost within the desired time frames (Dyche, 2000). In order to provide information for predicting patterns and trends more convincingly and for analyzing a variation more efficiently, a knowledge-based decision support system designed for this particular purpose is needed (Arain, 2005; Arain and Low, 2005b).

If professionals could have a knowledge base established on past similar projects, it would assist the professional team to plan effectively before starting a project, during the design phase, and during the construction phase, as well as, to minimize and control variations and their effects (Arain, 2005). The current technological progress does not allow the complete computerization of all the managerial functions or the creation of a tool capable of carrying out automatically all the required management decisions. To insure the success of this important management function, it is believed that human involvement in this process remains essential. Thus the Decision Support System (DSS) approach for this kind of application seems to be the most natural idea (Miresco and Pomerol, 1995).

It is important to understand that the KBDSS for the management of variation orders is not designed to make decisions for users, but rather it provides pertinent information in an efficient and easy-to-access format that allows users to make more informed decisions (Arain, 2005; Arain and Low, 2005c).

From the outset, project strategies and philosophies should take advantage of lessons learned from past similar projects (Ibbs et al, 2001). Lessons learned signify the importance of an organized knowledge base of similar past projects. The importance of a knowledge base for better project control was stressed by many researchers (Miresco and Pomerol, 1995; Mokhtar et al, 2000; Gray and Hughes, 2001; Ibbs et al, 2001).

Information is a prerequisite in all construction activities and can be regarded appropriately as the life-blood within which construction business interactions unfold (Low, 1993). Knowledge acquisition is the major bottleneck in the construction industry (Skibniewski et al, 1997). In view of the transfer and acquisition of construction knowledge and experience, a DSS can help to conserve the knowledge and experience and make these more widely, easily and quickly available for assisting in the decision-making process (Alkass et al, 1992; Turban and Aronson, 2000). The decision aid can also facilitate the knowledge acquisition process once it has acquired the necessary construction knowledge and experience and transferred these into a usable form (McCoy and Levary, 1988). The decision aid also enables the professionals to consider more factors that can affect designs during the decision-making process, conduct more thorough decision processing, and influence their preferred information (Poe et al, 1998).

A knowledge-based decision support system is a system that can undertake intelligent tasks in a specific domain that is normally performed by highly skilled people (Miresco and Pomerol, 1995). Typically, the success of such a system relies on the ability to represent the knowledge for a particular subject (Fischer and Kunz, 1995). Computerized decision support systems can be used by project participants to help make more informed decisions regarding the management of variation orders in projects by providing access to useful, organized and timely information (Arain and Low, 2005b). The objective of this study is to develop a framework for establishing a knowledge-based decision support system for the management of variation orders for institutional building projects in Singapore.

The litmus test for successful management should not be whether the project was free of variation orders, but rather, if variation orders were resolved in a timely manner to the benefit of all the parties and the project (Arain and Low, 2003; Arain and Low, 2005d). A clearer view of the causes and their impacts and controls will enable the project team to take advantage of beneficial variations when the opportunity arises without an inordinate fear of negative impacts (Arain and Low, 2005e). Eventually, a clearer and comprehensive view of causes, their effects and potential controls based on past projects will assist the project team to learn from past experiences and to make more informed decisions for effective management of variation orders (Arain, 2005; Arain and Low, 2005b). No such studies have been undertaken on the management and control of variation orders on a large scale using a knowledge-based decision support system (KBDSS) platform.

The traditional knowledge acquisition methods (i.e., through interviews, literature research, and source documents) are used to develop the KBDSS and its components in this study (Note: source documents include the contract documents, variation orders documents, contract drawings and as-built drawings). The information collected from the source documents was pertinent to the projects and variations in projects, specifically, project profile information (e.g. name of the project, project type, work scope, programme, contract duration, date of commencement, date of completion, and contingency sum) and project variations information (variation description, reason for originating variation, type of variation, and approving authority). This research is timely as the programme for rebuilding and improving existing institutional buildings is currently under way in Singapore; and it provides the best opportunity to address the contemporary issues relevant to the management of variation orders. The KBDSS framework is also helpful in developing a knowledge-based decision support system that eventually would assist professionals in taking proactive measures for reducing potential variations in institutional building projects. The knowledge-based system should present a comprehensive scenario of the causes of variations, their relevant effects and potential controls that would be helpful in decision making at the early stage of the variations. The knowledge-based decision support system would assist project management teams in responding to variations effectively in order to minimize their adverse impact to the project.

2. SCOPE OF RESEARCH

This paper presents a system model and a framework for establishing a knowledge-based decision support system that is being developed for institutional building projects to provide information technology support in areas of project management and control of variation orders. The institutional building projects under study are carried out under the major program of rebuilding and improving existing institutional buildings initiated by the government of Singapore. The number of completed school projects is 80.

A total of about 290 institutional buildings will be upgraded or rebuilt by a government agency over a period of seven years, at an estimated cost of $2.48 billion from 1999 to 2005. The projects are of three types, namely, upgrade, rebuild and grass root (new) buildings under the major programme of rebuilding and improving. The construction of an institutional building poses similar risks to the construction of any other large projects. Developing a knowledge-based decision support system for management of variation orders for institutional building projects will contribute towards the more efficient control of variation orders through prompt and more informed decisions. Hence, this research concentrated on the institutional building projects under this major rebuilding and improvement programme in Singapore.

3. BACKGROUND

The issue of managing variations has received much attention in the literature. Many researchers have proposed principles and theoretical models for managing variations.

A theoretical model was proposed by Gray and Hughes (2001) for controlling and managing variations. The central idea of the proposed model was to recognize, evaluate, resolve and implement variations in a structured and effective way. CII (1994a) and Ibbs et al (2001) proposed a project change management system (CMS) that was founded on five principles. The five principles included: promote a balance change culture, recognize change, evaluate change, implement change, and improve from lessons learned. The change management system was a two-level process model, with principles as the foundation, and management processes to implement those principles. The proposed system, however, lacked the basic principle and process of implementing controls for future variations in the construction projects. The basic principles, on which the operational sequence of the proposed KBDSS was developed, were adapted from the research works by CII (1994a) and Ibbs et al (2001). The basic principles are presented in the following section.

Despite many articles and much discussion about decision support systems in practice and academic literature, the issue of learning from the past projects in order to make timely and more informed decisions for effective management of variation orders has not been explored in the literature (Ibbs et al, 2001; Lazarus and Clifton, 2001; Arain, 2005; Arain and Low, 2005b).

3.1 Fundamental Principles of Variation Management

The fundamental objective of any variation management system is to anticipate, recognize, evaluate, resolve, control, document, and learn from past variations in ways that support the overall viability of the project (s) (Ibbs et al, 2001; Sutrisna et al, 2003). Learning from past variations is imperative, because the professionals can improve and apply their experience in the future (Sweetman, 1990). This would help the professionals in taking proactive measures for reducing potential variations.

This study proposes six basic principles of variation management. As shown in Fig. 1, the six basic principles for promoting a balanced variation culture include: identify variation, recognize variation, diagnose the variation, implement variation, implement controlling strategies, and learn from past experiences. Each of these principles should work hand-in-hand with the others.

The first principle of variation management is to identify variations. As shown in Fig. 1, referring to past projects for early recognition of a problem is very important, because it will assist in identifying the issue at the early stage. Furthermore, this will help the project manager to encourage beneficial variations and discourage detrimental ones. Beneficial variations are those that actually help to reduce cost, schedule, or degree of difficulty in the project. Detrimental variations are those that reduce owner value or have a negative impact on a project.

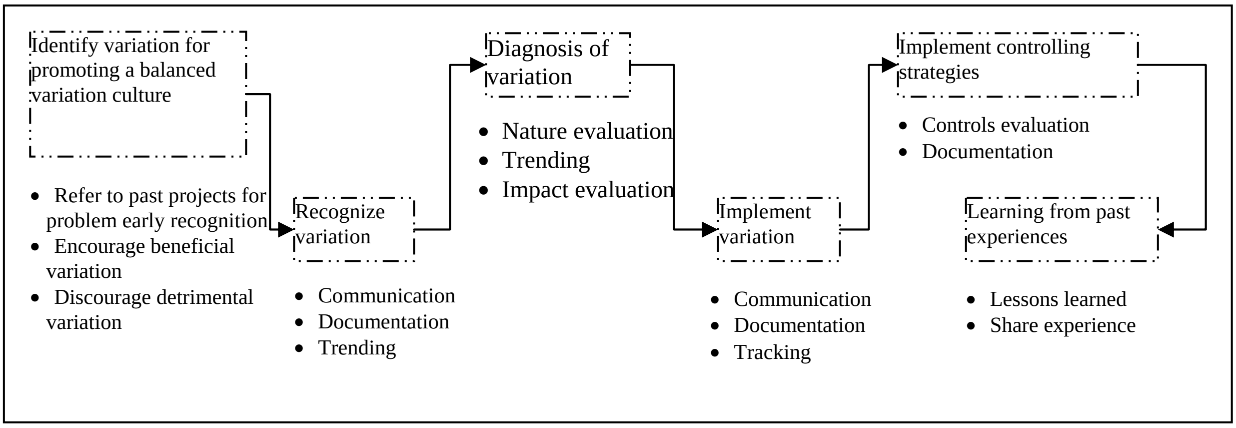


FIG. 1: Fundamental principles of variation management (Source: adapted from CII, 1994b)

The second principle of variation management is to recognize variations, before they actually occur. In this principle, communication, documentation and awareness about trending (trending refers to structured information about the frequency of occurrence of variations in a certain type of past projects, and frequency of occurrence of variations in all types of past projects) are very important, because these would assist in identifying variations prior to their actual occurrence (Ibbs et al, 2005; Arain and Low, 2005b).

The third principle of variation management is to diagnose the variation, as it occurs. As shown in Fig. 1, nature (character) evaluation (pinpointing the potential areas i.e., architectural works, civil and structure works, mechanical and electrical works, etc., on which to focus to reduce potential variations), trending, and impact evaluation are very important aspects. This is because these would assist in determining whether the management team should accept and implement the proposed variation (Arain and Low, 2005b).

Implementing the specific variation is the fourth principle of variation management. This principle of "implementing variation" is the most important step, after "evaluating the variation". As shown in Fig. 1, communication, documentation and tracking tasks are very important in this principle. This is because these three tasks would greatly assist in implementing variations by properly communicating information between team members and developing a database for documenting and tracking of the variations (Arain and Low, 2005c).

The fifth principle of effective variation management is implementing controlling strategies. It is a very important one, since this is one of the main objectives of the variation management system. As shown in Fig. 1, evaluating and documenting controls are very important, because assessing potential controls would assist in selecting effective controls (strategies for controlling and minimizing variations) for variations, and documenting the controls would assist in learning lessons from the variation (Arain and Low, 2005b).

The sixth principle of variation management is to learn from past experiences. In this principle, learning lessons and sharing experiences are very important because the main idea is to evaluate mistakes made so that errors can be systematically corrected both within the ongoing project and the future projects. Such analysis should be shared between team members so that everyone can have a chance to understand the root causes of the variations and to control problems in a proactive way (Arain and Low, 2005c).

3.2 System Model for Management of Variations

Construction projects are complex because they involve many human and non-human factors and variables (Arain et al, 2004). They usually have long duration, various uncertainties, and complex relationships among the participants. To identify and analyze potential variations in a project as early as possible can enhance both the assessment and the implementation of the project (Ibbs et al, 2001).

If professionals could use a knowledge base established on past similar projects, it would assist the professional team to plan effectively before starting a project, during the design phase as well as during the construction phase. This would minimize and control variations and their effects on the project. The current technology does not allow the complete computerization of all the managerial functions (Skibniewski et al, 1997). To ensure the success of this important management function of using existing knowledge about past variations, human involvement in this process remains essential. Thus, a Decision Support System (DSS) approach for this kind of application seems to be the most natural (Miresco and Pomerol, 1995). The knowledge-based decision support system should present a comprehensive scenario of the causes of variations, their relevant effects and the potential controls that would be helpful in decision-making at the early stage of the variations occurring.

As shown in Fig. 2, the basis for developing a model for management of variation orders is to utilize a KBDSS platform for effective variation management (Arain and Low, 2005b). The project team can carry out the structured process based on the six effective variation management principles, as discussed earlier. The knowledge base is the most integral part of this model as it assists the process for management of variations (Arain and Low, 2005c).

Based on the aforementioned six principles of effective variation management, a system model was developed, as shown in Fig. 3 that presents the operational sequence for a KBDSS for making more informed decisions for management of variation orders. The system model consists of six fundamental stages linked to two main components, (1) knowledge base and (2) a decision support shell. As shown in Fig. 3, the six fundamental stages are: identify variation, recognize variation, diagnose variation, implement variation, implement controls/strategies, and establish knowledge base. These stages are used for making more informed decisions for effective management of variation orders. The knowledge base will be developed through initial sieving and organization of data from the database. The decision support shell provides decision support for selecting the most effective controls from the suggested controls through a structured process consisting of building the hierarchy between the main criteria and the suggested controls, rating the controls, and analyzing the controls for selection through multiple analytical techniques (Arain, 2005).

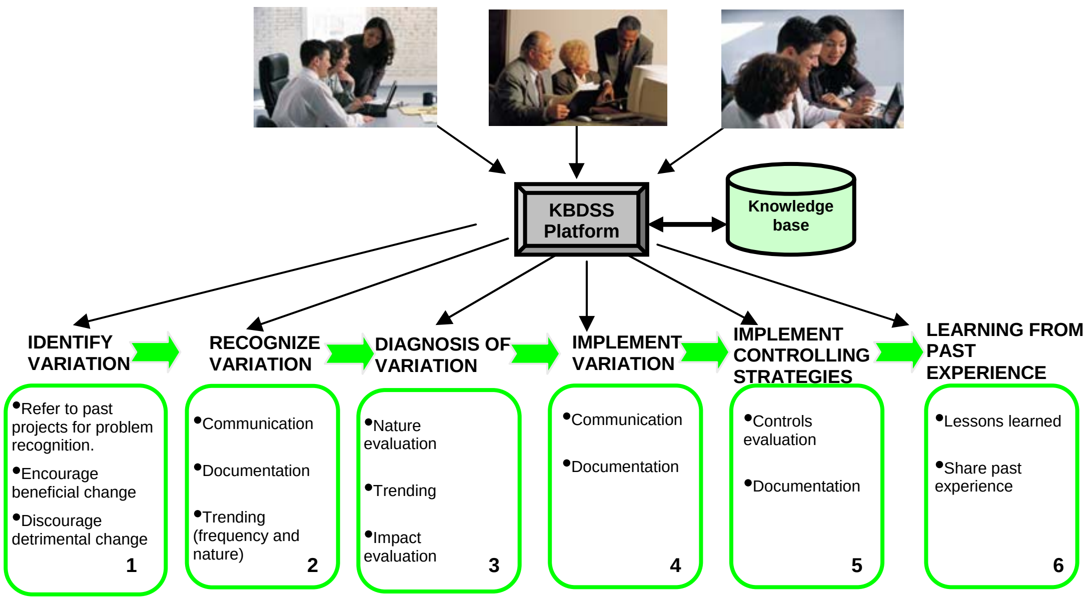


FIG. 2: Basis for developing model for management of variation orders

The knowledge base should be capable of displaying: (1) variations and their relevant details, (2) a variety of filtered knowledge, and (3) performing various analyses of the knowledge available. This would eventually assist the decision makers in selecting the most appropriate controls for variations (Arain and Low, 2005c).

As shown in Fig. 3, the need for a variation can originate from the client, user, design consultant, project manager and contractor. Considering the underlying principles of effective variation management mentioned earlier, the first step of the theoretical model for management of variation orders is to identify variations, which assists in encouraging beneficial variations and discouraging detrimental variations at the early stage of variation occurrence. Once a variation is proposed, the proposal must be analyzed through a knowledge base (level 1) for initial decision support to recognize the variation at an early stage so as to encourage beneficial variations and prevent detrimental variations. If a cost effective proposal for a variation is required, then a request for a variation proposal is made.

The second step of the proposed model is to recognize the variation. Therefore, it is important that an environment be created that allows team members to openly communicate with one another. In this stage, team members are encouraged to discuss and to identify potential variations (Ibbs et al, 2001). Identifying variations prior to their actual occurrence can help the team to manage variations better and earlier in the project life cycle (Lazarus and Clifton, 2001; Arain and Low, 2005c). As shown in Fig. 3, the knowledge base (level 2) provides structured information about past projects that can assist in effective communication between team members. The codes and categorized information relating to the effects on programme, cost implications, and frequency of occurrence of variations would eventually assist in recognizing variations at the early stage of their occurrence (Arain, 2005; Arain and Low, 2005c).

After the team recognizes the variation, the diagnosis of the variation is carried out through the knowledge base (updated), as shown in Fig. 3. The knowledge base (updated) contains information about the frequency of variations and variation orders in the present project, their root causes, and potential effects. This information assists the management team in evaluating the variation. The purpose of the evaluation is to determine whether the management team should accept and implement the proposed variation (Arain and Low, 2005b).

After the diagnosis phase, the team selects the alternatives of variation orders and communicates the details of the proposed variation to all affected parties. Better team communication assists in implementing the variation proposed (Ibbs et al, 2001; Arain, 2005).

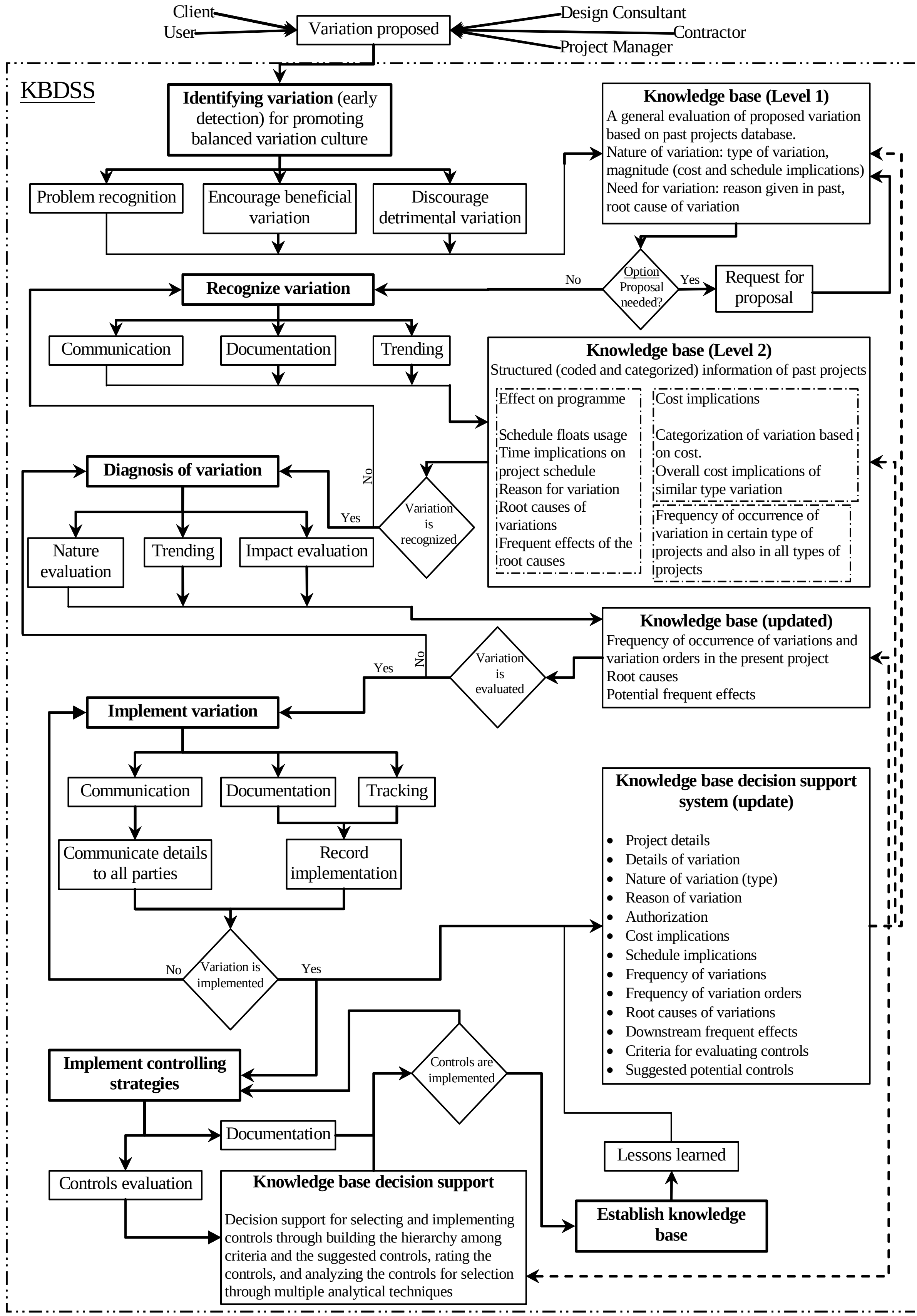


FIG. 3: System model for management of variations

Documentation of the variation implemented is an integral part of the implementation phase of variation. The documentation contributes to the knowledge base decision support system as shown in Fig. 3.

After the implementation phase, selecting and implementing controls for variations are important as shown in Fig. 3. The knowledge base eventually leads the decision makers to the suggested controls for variations and assists them in selecting the most appropriate controls.

After selecting and implementing the controls for variations, establishing and updating the knowledge base is the last but significant phase of the proposed model for the management of variation orders. The updated knowledge base will improve with every new building project. The knowledge base established may assist project managers by providing accurate and timely information for decision-making, and a user-friendly system for analyzing and selecting the controls for variation orders (Arain and Low, 2005c).

4. KNOWLEDGE-BASED DECISION SUPPORT SYSTEM FRAMEWORK

Computerized decision support systems can be used by project participants to help make more informed decisions regarding the management of variation orders on projects. This can be accomplished by providing access to useful, organized and timely information. It is therefore important to understand that the knowledge-based decision support system is not designed to make decisions for users, but rather to provide pertinent information in an efficient, consistent, and easy-to-access format that allows users to make more informed decisions (Turban and Aronson, 2000; Arain, 2005). Although the proposed model does not take over the role of the human experts or force them to accept the output of the system, it provides more relevant evidence and facts to help the human experts make well-informed final decisions. In providing a systematic way to manage variations through the KBDSS, the efficiency of the building project and the likelihood of project success can be enhanced (Arain, 2005).

The architecture of the main components of the proposed KBDSS framework is shown in Fig. 4. The KBDSS framework contains two main components, i.e., a knowledge base and a decision support shell. These two components support the process for selecting appropriate potential controls for variation orders for institutional buildings outlined in Fig. 3.

The database in this case study was developed through collecting data from source documents of the 80 completed institutional projects, questionnaire survey, literature review and interview sessions with the professionals. As shown in Fig. 4, the knowledge base is developed through initial sieving and organization of data from the database. The knowledge base is integrated with a decision support shell. The decision support shell provides decision support through a structured process consisting of building the hierarchy among the main criterions and the suggested controls, rating the controls, and analyzing the controls for selection through multiple analytical techniques.

4.1 Knowledge base

The knowledge base contains the sieved and organized information about the variations and variation orders for institutional building projects in Singapore. As shown in Fig. 4, the knowledge base is divided into three main segments, namely, macro layer, micro layer and effects/controls layer. These three main segments of the knowledge base are discussed below.

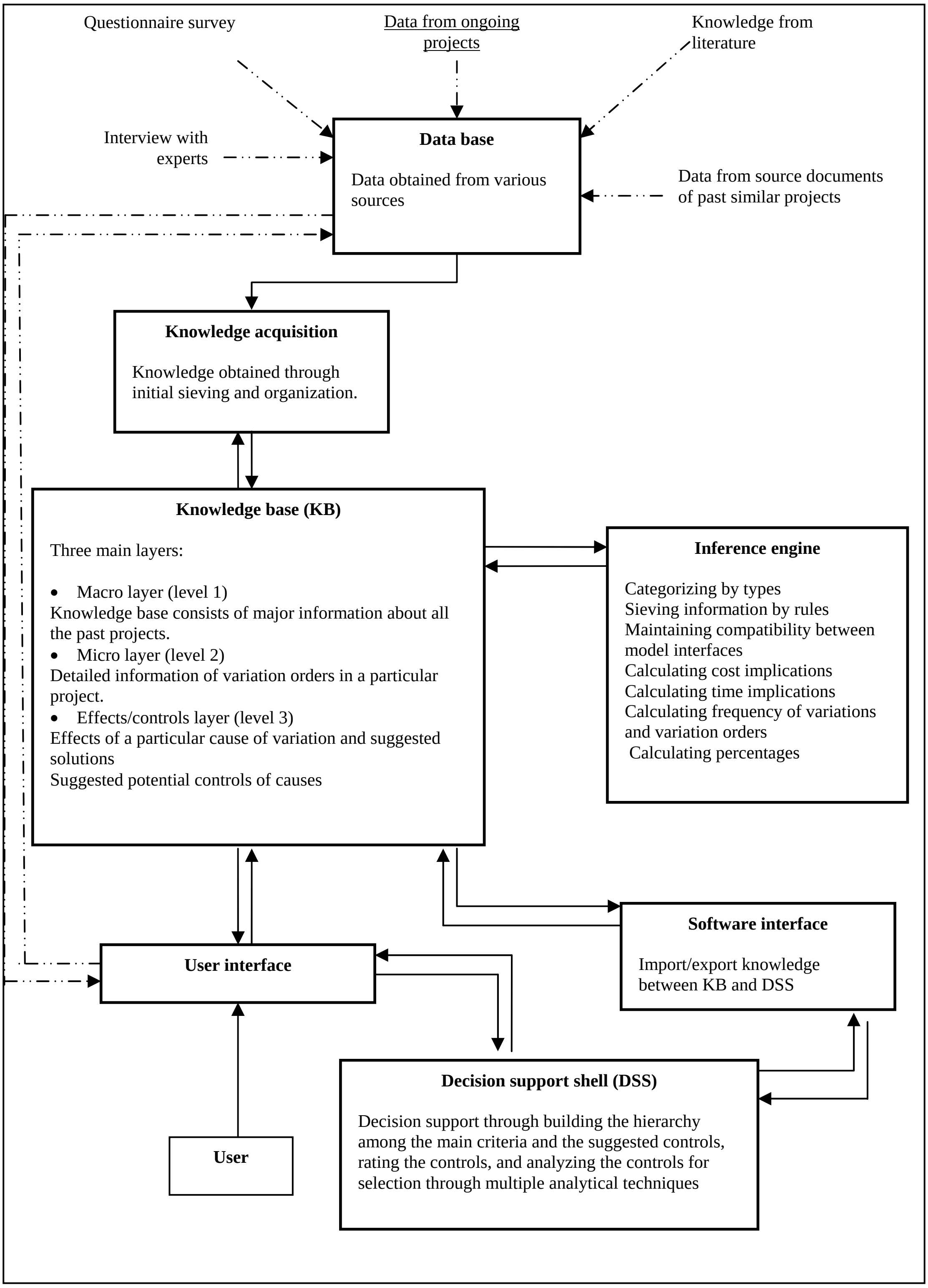


FIG. 4: Framework for knowledge-based decision support system

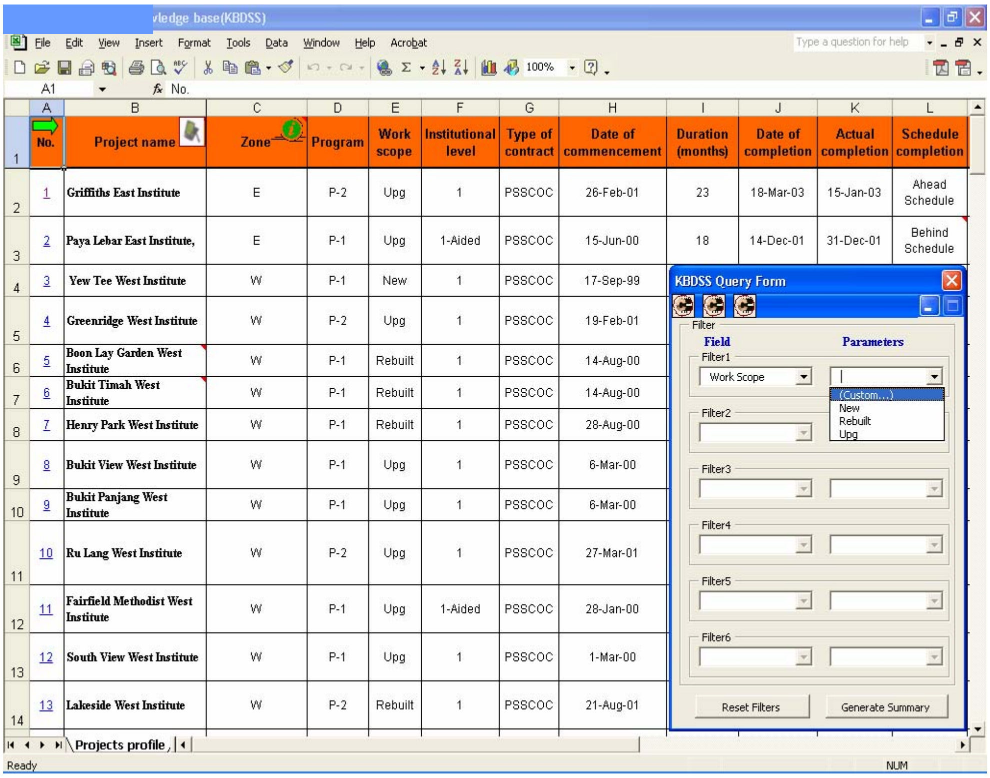
4.1.1 Macro layer

The first segment of the knowledge base is the macro layer that consists of the "major information" gathered from source documents of 80 institutional projects and through interview sessions with the professionals. The macro layer contains the major information about the institutional projects completed, mentioned below.

- project name,
- program phase,
- work scope,
- institutional level,
- date of commencement,
- project duration,
- date of completion,
- actual completion,
- schedule completion status,
- schedule difference,
- contract final sum,
- contingency sum percent,
- contingency sum,
- contingency sum used,
- total number of variation orders,
- total cost of variation orders,
- total time implication,
- total number of variations,
- frequency of variation orders,
- frequency of variations and
- main contractors and consultant.

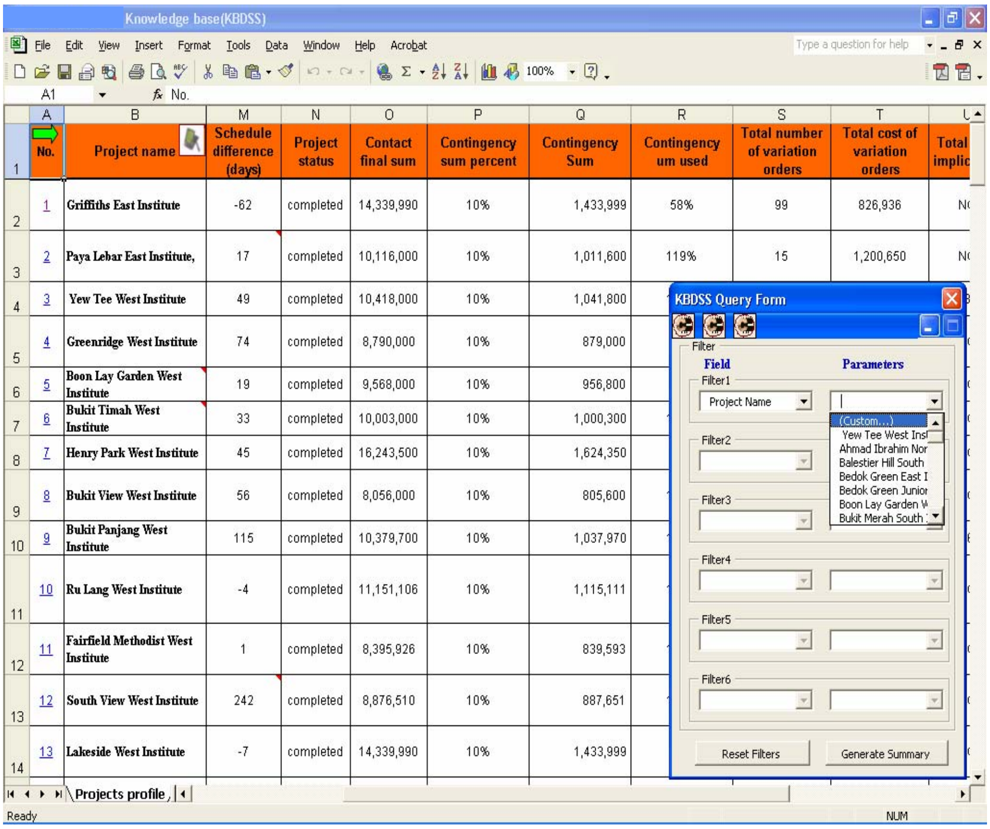
The user interface allows the user to access, edit, modify, add and view the information displayed on the macro layer. In this segment, the user may add new project information. The inference engine computes the project duration, schedule completion status, schedule difference, and contingency sum from the information given in the macro layer.

The inference engine will create interface between the macro layer and the micro layer to retrieve the information about the total number of variation orders, total cost of variation orders, total time implications, total number of variations, frequency of variation orders and frequency of variations in each individual project. Furthermore, a variety of filters will be provided on the macro layer that will assist in sieving information by certain rules. Furthermore, the inference engine will also provide a comprehensive summary of the information available on the macro layer. This would assist the user in analyzing and identifying the nature and frequency of variation orders in certain type of institutional projects. A sample screenshot of the macro layer prototype developed is shown in Fig. 5a, 5b, 5c and 5d.



No.	Project name	Zone	Program	Work scope	Institutional level	Type of contract	Date of commencement	Duration (months)	Date of completion	Actual completion	Schedule completion
1	Griffiths East Institute	E	P-2	Upg	1	PSSCOC	26-Feb-01	23	18-Mar-03	15-Jan-03	Ahead Schedule
2	Paya Lebar East Institute,	E	P-1	Upg	1-Aided	PSSCOC	15-Jun-00	18	14-Dec-01	31-Dec-01	Behind Schedule
3	Yew Tee West Institute	W	P-1	New	1	PSSCOC	17-Sep-99				
4	Greenridge West Institute	W	P-2	Upg	1	PSSCOC	19-Feb-01				
5	Boon Lay Garden West Institute	W	P-1	Rebuilt	1	PSSCOC	14-Aug-00				
6	Bukit Timah West Institute	W	P-1	Rebuilt	1	PSSCOC	14-Aug-00				
7	Henry Park West Institute	W	P-1	Rebuilt	1	PSSCOC	28-Aug-00				
8	Bukit View West Institute	W	P-1	Upg	1	PSSCOC	6-Mar-00				
9	Bukit Panjang West Institute	W	P-1	Upg	1	PSSCOC	6-Mar-00				
10	Ru Lang West Institute	W	P-2	Upg	1	PSSCOC	27-Mar-01				
11	Fairfield Methodist West Institute	W	P-1	Upg	1-Aided	PSSCOC	28-Jan-00				
12	South View West Institute	W	P-1	Upg	1	PSSCOC	1-Mar-00				
13	Lakeside West Institute	W	P-2	Rebuilt	1	PSSCOC	21-Aug-01				

FIG. 5a: Macro layer of the knowledge base that consists of the major information regarding institutional building projects



No.	Project name	Schedule difference (days)	Project status	Contact final sum	Contingency sum percent	Contingency Sum	Contingency um used	Total number of variation orders	Total cost of variation orders	Total implic
1	Griffiths East Institute	-62	completed	14,339,990	10%	1,433,999	58%	99	826,936	N(
2	Paya Lebar East Institute,	17	completed	10,116,000	10%	1,011,600	119%	15	1,200,650	N(
3	Yew Tee West Institute	49	completed	10,418,000	10%	1,041,800				
4	Greenridge West Institute	74	completed	8,790,000	10%	879,000				
5	Boon Lay Garden West Institute	19	completed	9,568,000	10%	956,800				
6	Bukit Timah West Institute	33	completed	10,003,000	10%	1,000,300				
7	Henry Park West Institute	45	completed	16,243,500	10%	1,624,350				
8	Bukit View West Institute	56	completed	8,056,000	10%	805,600				
9	Bukit Panjang West Institute	115	completed	10,379,700	10%	1,037,970				
10	Ru Lang West Institute	-4	completed	11,151,106	10%	1,115,111				
11	Fairfield Methodist West Institute	1	completed	8,395,926	10%	839,593				
12	South View West Institute	242	completed	8,876,510	10%	887,651				
13	Lakeside West Institute	-7	completed	14,339,990	10%	1,433,999				

FIG. 5b: Macro layer of the knowledge base (cont'd)

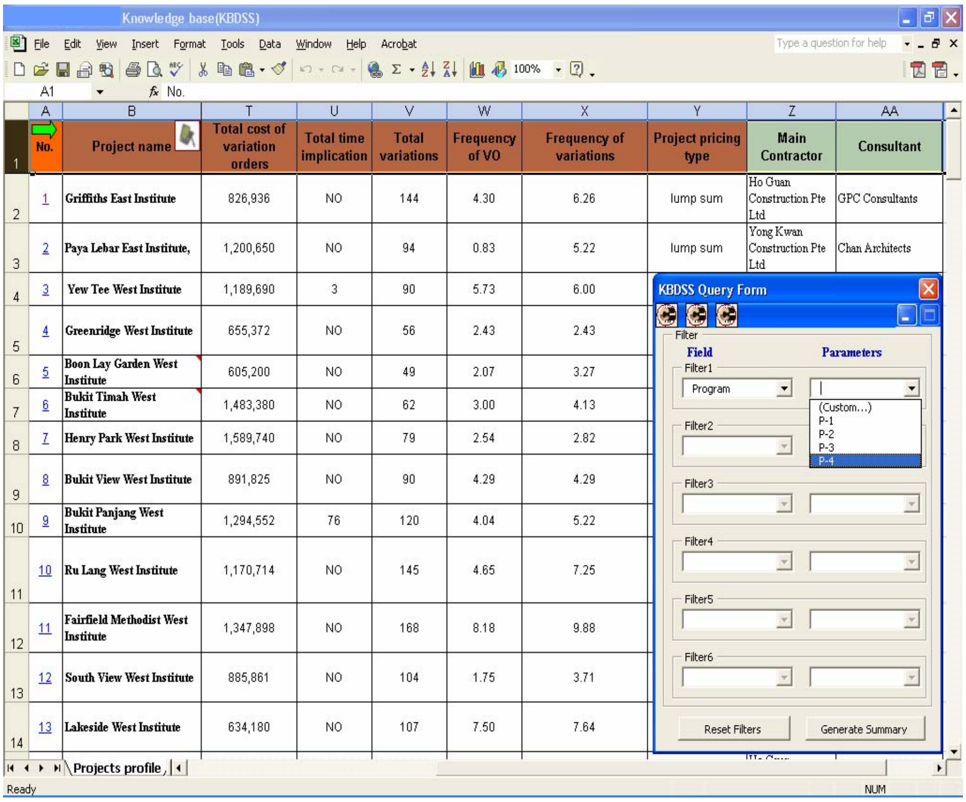


FIG. 5c: Macro layer of the knowledge base (cont'd)

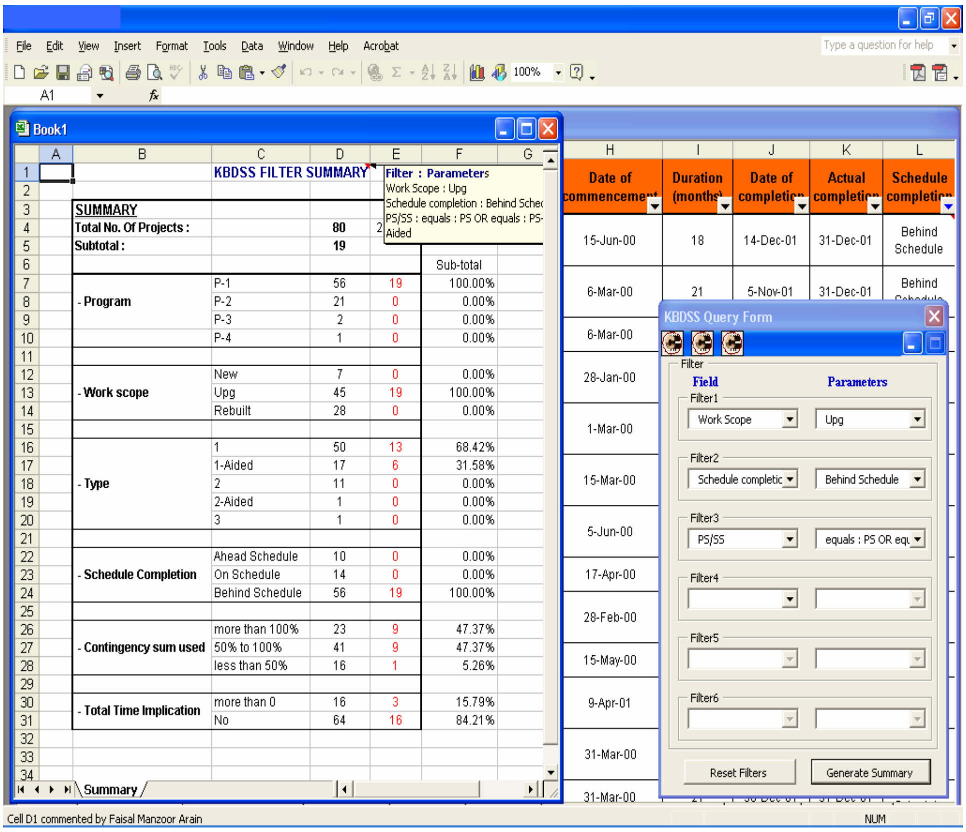


FIG. 5d: Summary section displaying the results of the filters applied on the macro layer

4.1.2 Micro layer

The micro layer is the second segment of the knowledge base that contains "detailed information of variation orders" based on the 80 institutional projects, discussed earlier. The micro layer will contain the detailed information regarding variations and variation orders for the institutional project. The detailed information includes the variation order code that assists in sieving information, detailed description of a particular variation collected from source documents, reason for carrying out the particular variation provided by the consultant, root cause of variation, type of variation, cost implication, time implication, approving authority, and endorsing authority. Here, the information regarding the description of particular variation, reason, type of variation, cost implication, time implication, approving authority, and endorsing authority will be obtained from the source documents of the institutional projects. The root causes for the variation will be determined based on the description of variations, reasons given by the consultants, and the project source documents. Arain and Low (2005f) identified and have discussed the 53 potential causes of variations in institutional building projects in Singapore. Change in plans or scope by owner, unforeseen problems, defective workmanship, change in specifications by owner and safety considerations are considered to be the prime reasons identified for variation orders for institutional buildings in Singapore.

The user interface will allow the user to access, edit, modify, add and view the information at the micro layer. In this layer, the user may add new project's detailed information. The inference engine will compute the total number of variation orders, total number of variations, total cost of variation orders, and total time implication for the particular project. In addition to computing the abovementioned information, the inference engine will also compute and enumerate the number of variations according to various types of variations. The information will be coded and categorized for easy accessibility to relevant information. Furthermore, the inference engine will also assist in computing the actual contingency sum by deducting the cost of variations requested and funded by the institution or other sources. A prototype of the micro layer developed is shown in Fig. 6a, 6b and 6c.

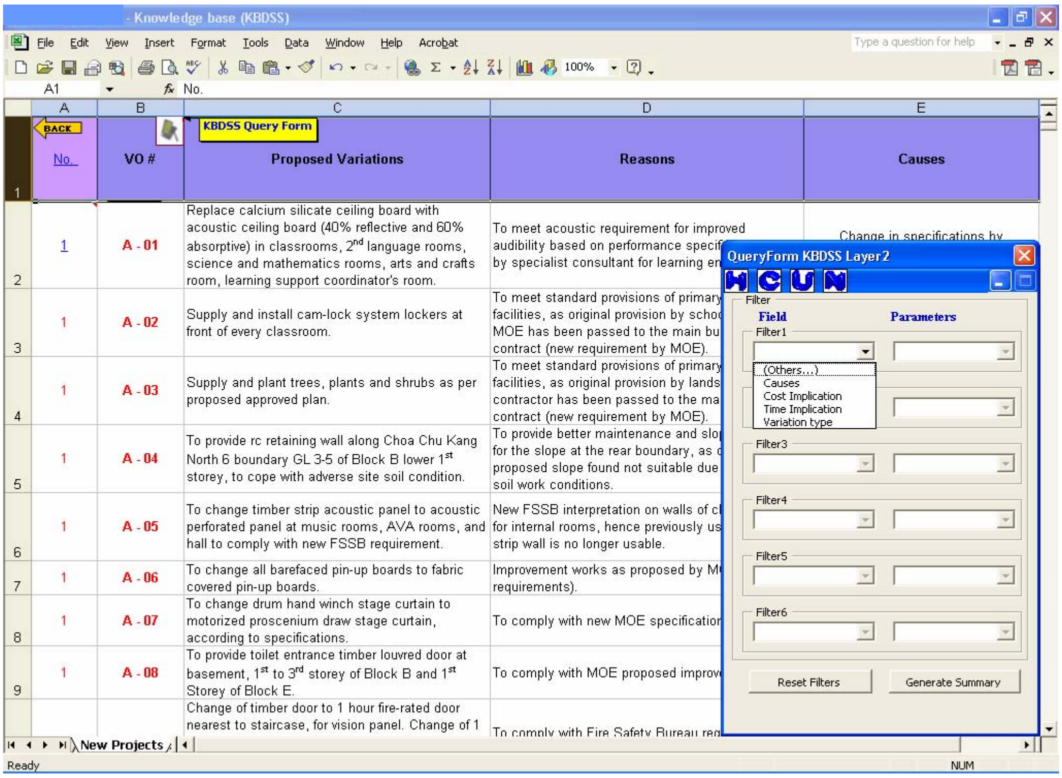


FIG. 6a: Micro layer of the knowledge base that contains the detailed information regarding variation orders for the Institutional project

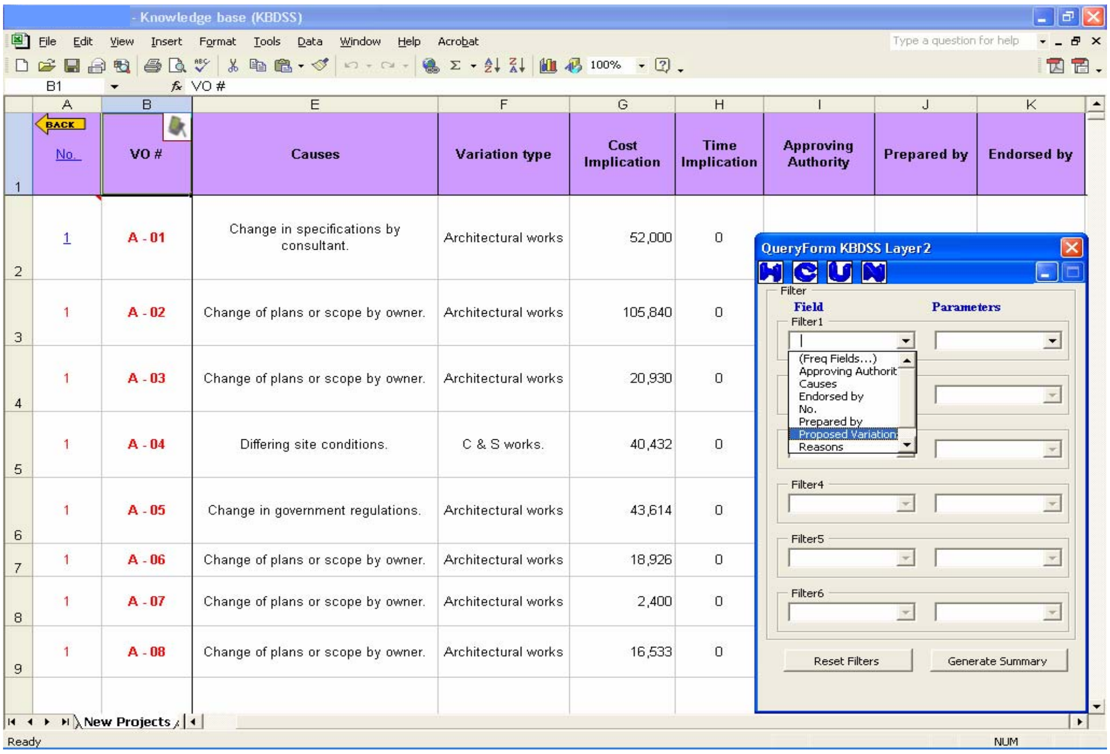


FIG. 6b: Micro layer of the knowledge base (cont'd)

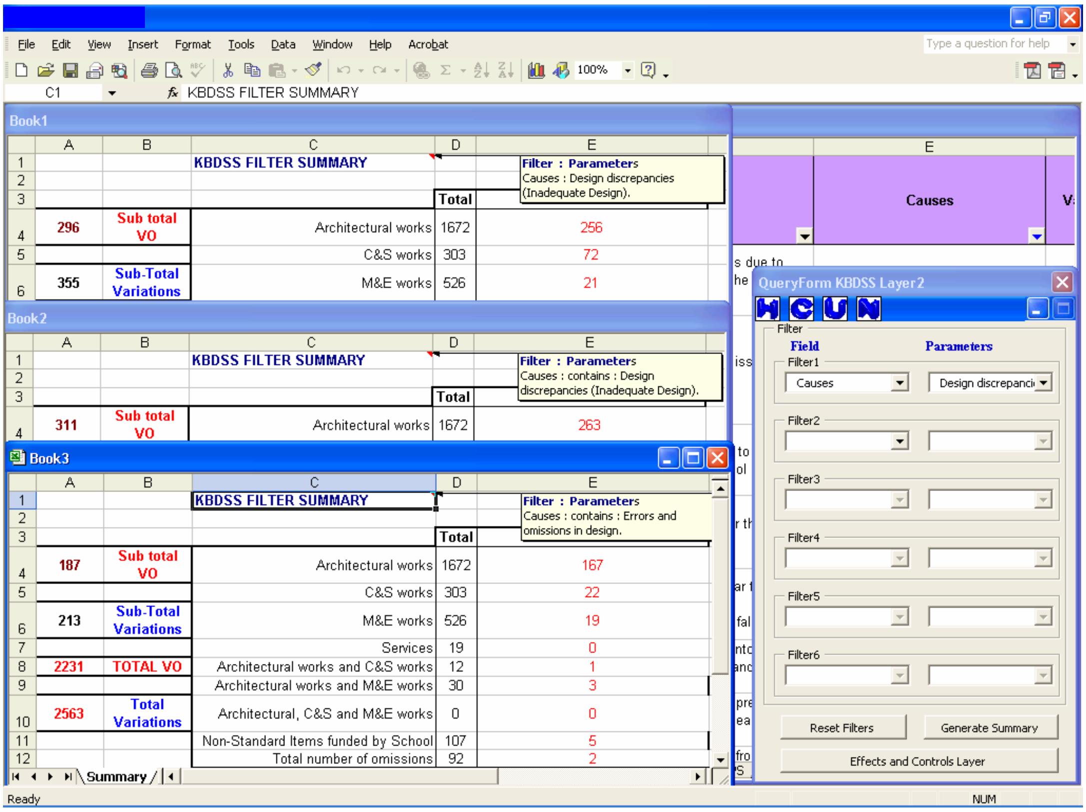


FIG. 6c: Multiple summary sections displaying the results of the filters applied on the micro layer, and the KBDSS query form showing the effects and controls layer tab that connects the micro layer with the effect and controls layer of the knowledge base

4.1.3 Effects and controls layer

The third segment of the knowledge base is the effects and controls layer that suggests most important effects and most effective controls for each cause of variations. This layer will contain sub-layers based on the potential causes of variations (Note: the causes will be identified from the literature review, analysis of information given in the source documents and in-depth interviews with the developers, consultants and contractors). Here the effects and controls for variation orders will be tabulated according to the survey results. Arain and Low (2003) identified 30 potential strategies (controls) for minimizing adverse impact of variations to institutional buildings in Singapore. Furthermore, Arain and Low (2005e) also identified the 16 potential effects of variations on institutional buildings. The 16 effects and 30 potential strategies for controlling variations are not discussed in this paper because of the given space constraint. A prototype of the effects and controls layer developed is shown in Fig. 7.

The user interface in the effects and controls layer will allow the user to access, edit, modify, add and view a graphical presentation of the cause of variations and its potential effects and effective controls. As shown in Fig. 4, the knowledge base is linked with the decision support shell.

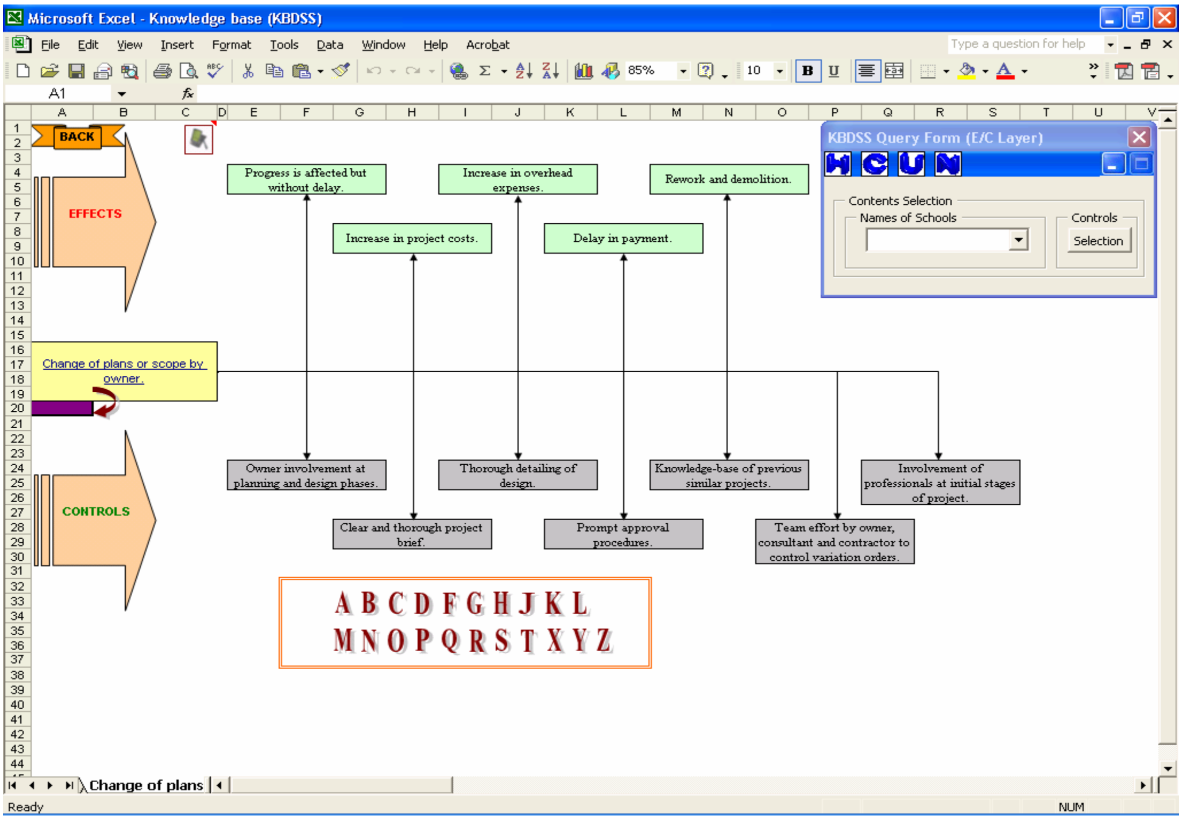


FIG. 7: Effects and controls layer of the knowledge base that pinpoints the most important effects and most effective controls for each cause of variations

4. 2 Decision Support Shell

As shown in Fig. 4, the decision support shell is integrated with the knowledge base to assist the user in selecting the appropriate controls of variations and variation orders. The decision support shell would provide decision support through a structured process consisting of building the hierarchy among the main criterions and the suggested controls, rating the controls, and analyzing the controls for selection through multiple analytical techniques. The decision support shell will contain four layers that are based on the structured process of decision-making, namely, main panel, building the hierarchy between criterions and controls, rating the controls, and selecting the best controls.

4.2.1 Main panel

The main panel will contain the goal, main criteria and the most effective controls for variations. The decision support shell will contain layers based on each cause of the variations and their most effective controls (Note: the number of layers will correspond to the number of causes identified). These layers will be developed considering the three main criterions, i.e., time, cost and quality, for evaluating the suggested controls. The suggested controls would be evaluated based on the given criteria. The user interface will allow the user to add any suggested controls that are considered to be important. A prototype of the main panel of the decision support shell developed is shown in Fig. 8.

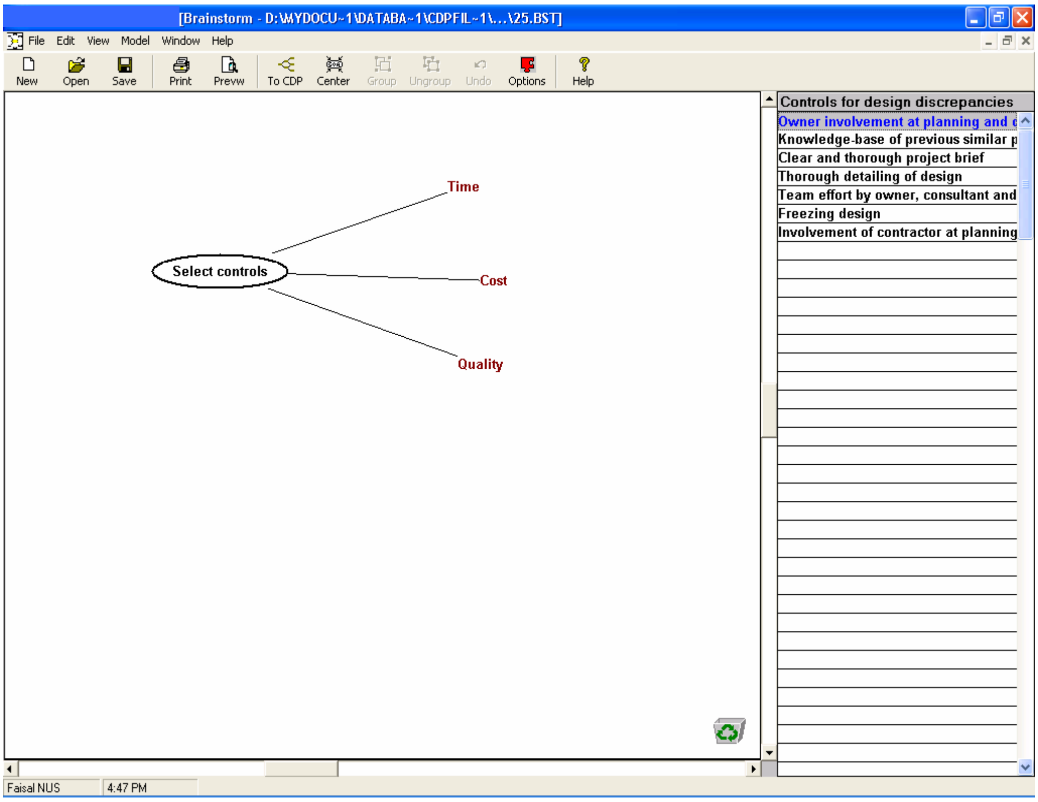


FIG. 8: Main panel of controls selection shell that contains the goal, main criteria and the most effective controls for variations (focusing on Time, Cost and Quality)

4.2.2 Building the hierarchy between criterions and controls

The main objective of this layer is to generate the hierarchy between the main criteria and the suggested controls for variations. The shell will generate and graphically present the hierarchy among the goal, the criteria and the suggested controls. The hierarchy assists in rating all the suggested controls. A prototype of the hierarchy generated between criterions and controls is shown in Fig. 9.

4.2.3 Rating the controls

The rating process includes four main activities. These activities: are choosing a rating method, selecting rating scale views, assigning rating scales and entering weights or scores. This layer will provide multiple techniques for rating. This layer essentially provides analytical hierarchy process (AHP) and simple multiple attribute rating technique (SMART) as rating techniques. This is because the decision will be based on purely qualitative assessments of the suggested controls. Skibniewski and Chao (1992) suggested that the AHP was an effective rating and evaluating technique for evaluation of advanced construction technologies. There are three rating methods available, i.e., direct comparison, full pair-wise comparison, and abbreviated pair-wise comparison. A prototype of rating the suggested controls is shown in Fig. 10a, 10b, 10c, and 10d.

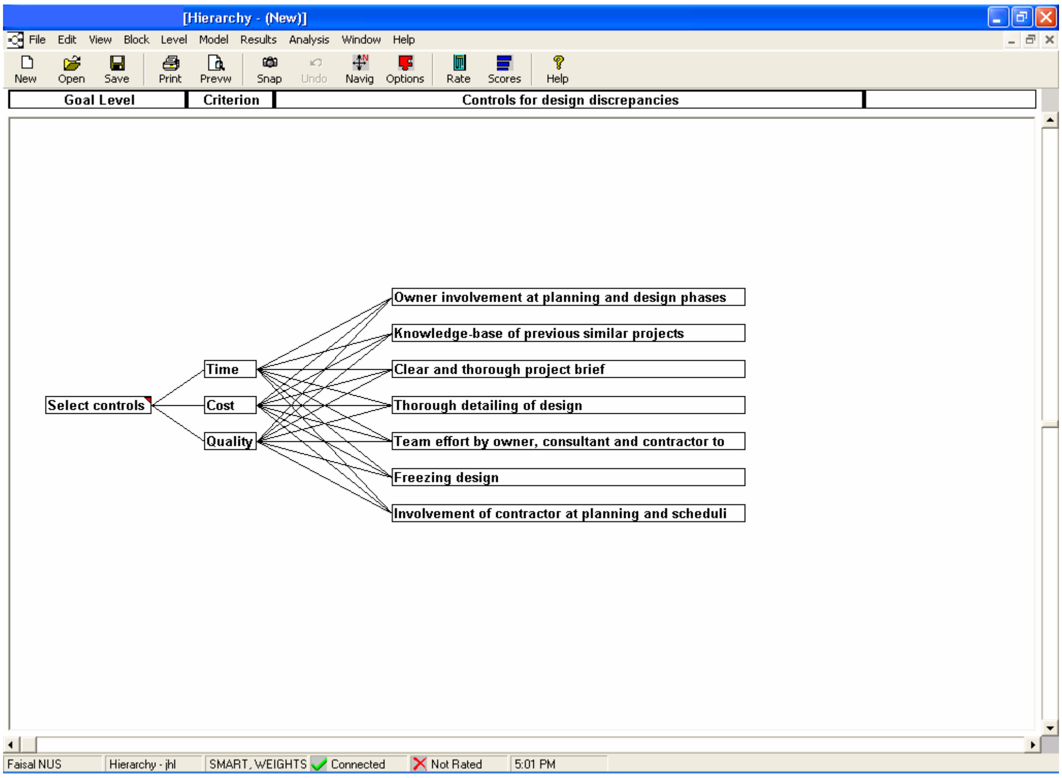


FIG. 9: Building the hierarchy among the goal, main criteria and controls for variations

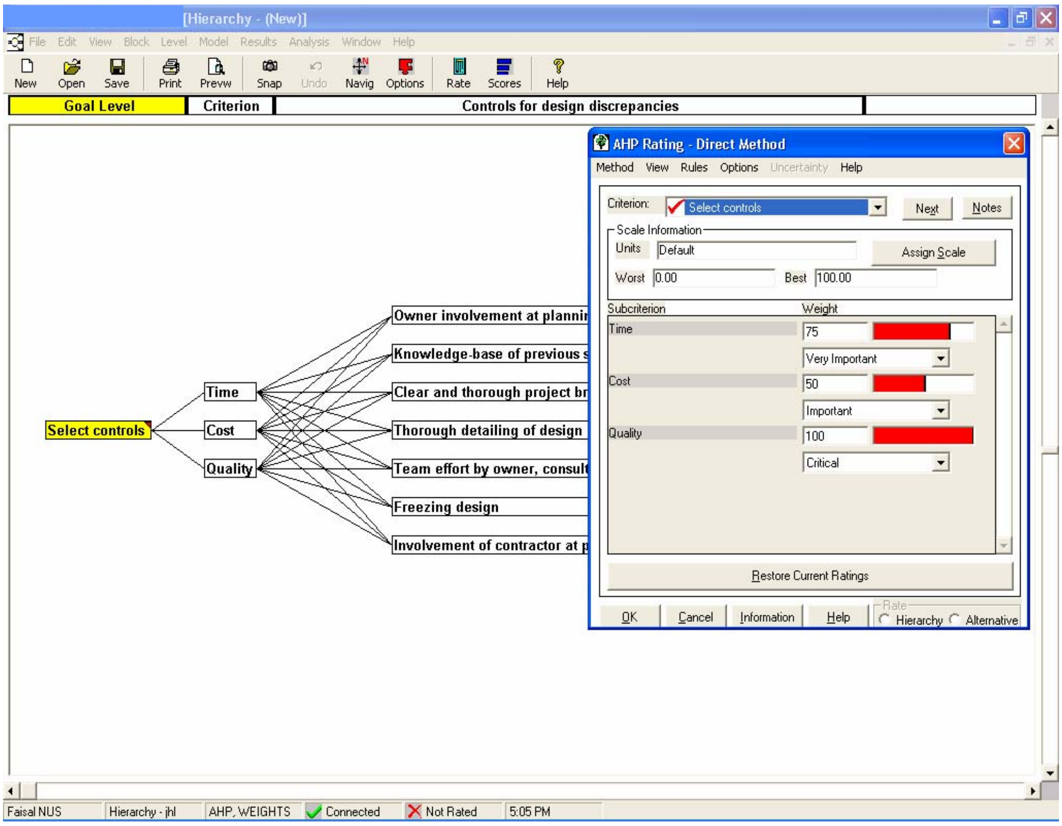


FIG. 10a: Rating the main criteria using the AHP rating direct method provided in the KBDSS

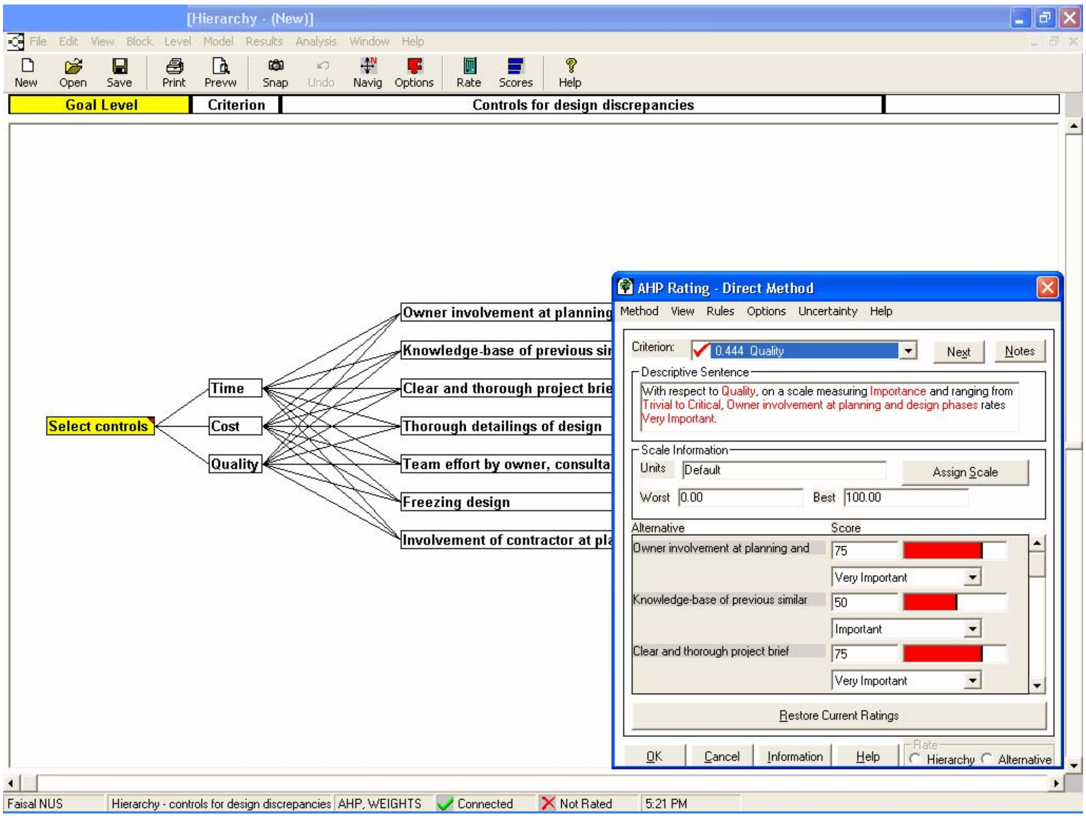


FIG. 10b: Rating the controls for variations with respect to quality

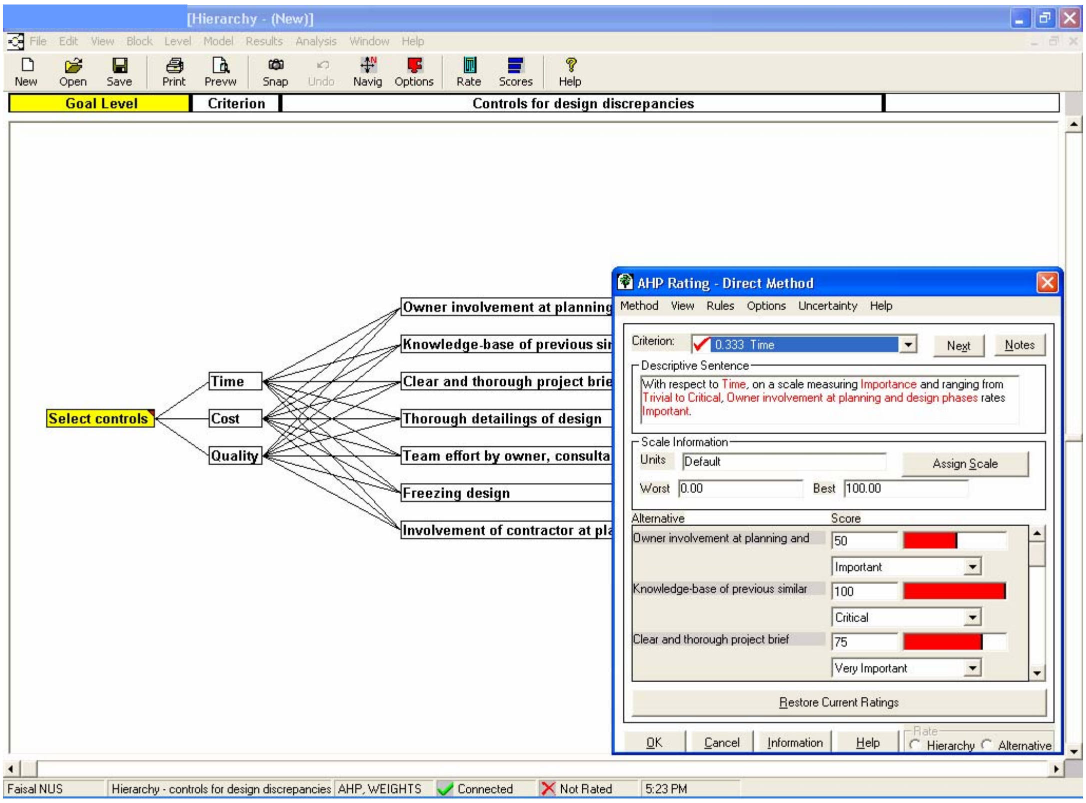


FIG. 10c: Rating the controls for variations with respect to time

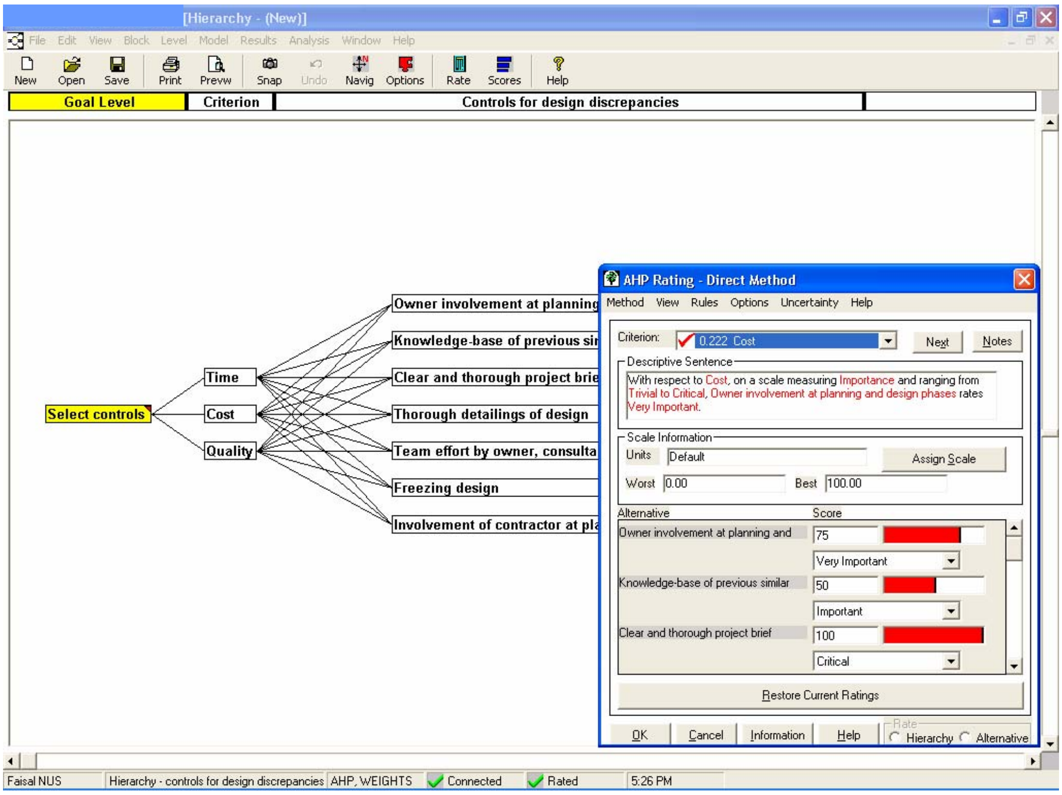


FIG. 10d: Rating the controls for variations with respect to cost

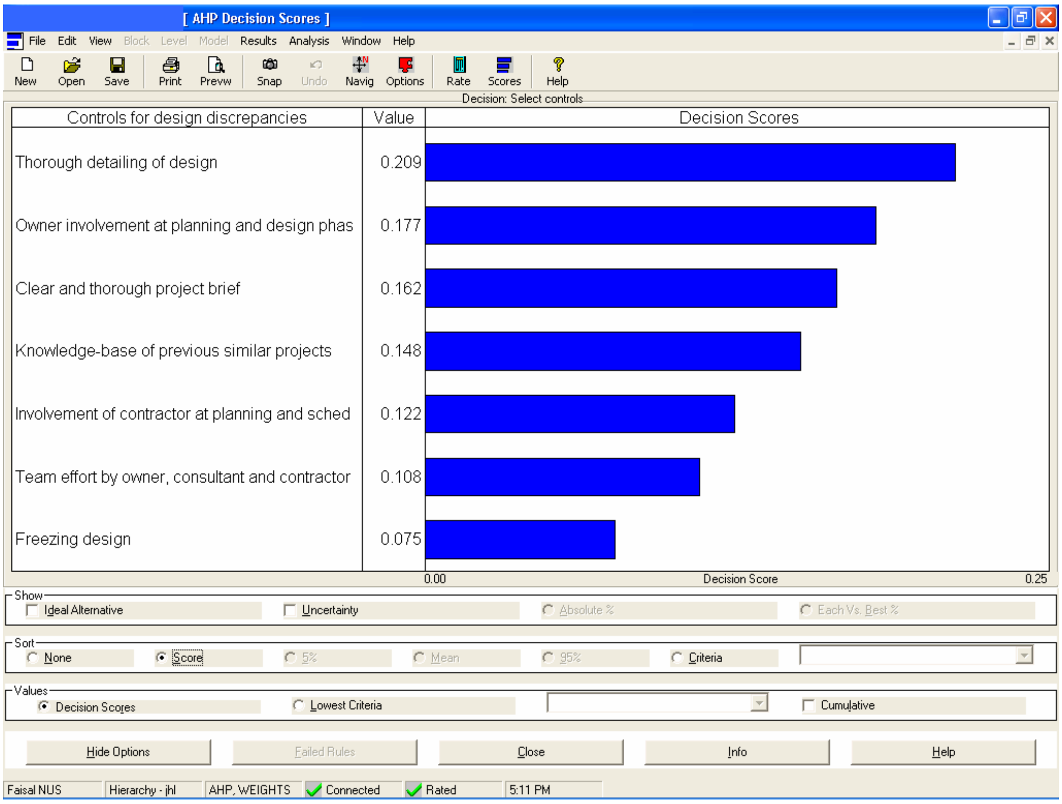


FIG. 11a: The controls for variations sorted according to the decision scores

4.2.4 Selecting the best controls

After completing the rating of the controls, the shell calculates the decision scores and displays a graphical presentation of the results. The decision score can be sorted according to ascending or descending orders, which assist in viewing the comprehensive scenario. The suggested controls will be displayed with their corresponding decision score and its graphical presentation. This would assist the user in selecting the best controls based on the decision scores. For further analysis, various analysis modes will also be provided. All these modes assist in analyzing and presenting the decision. A prototype of the graphical presentations of the results is shown in Fig. 11a, and 11b.

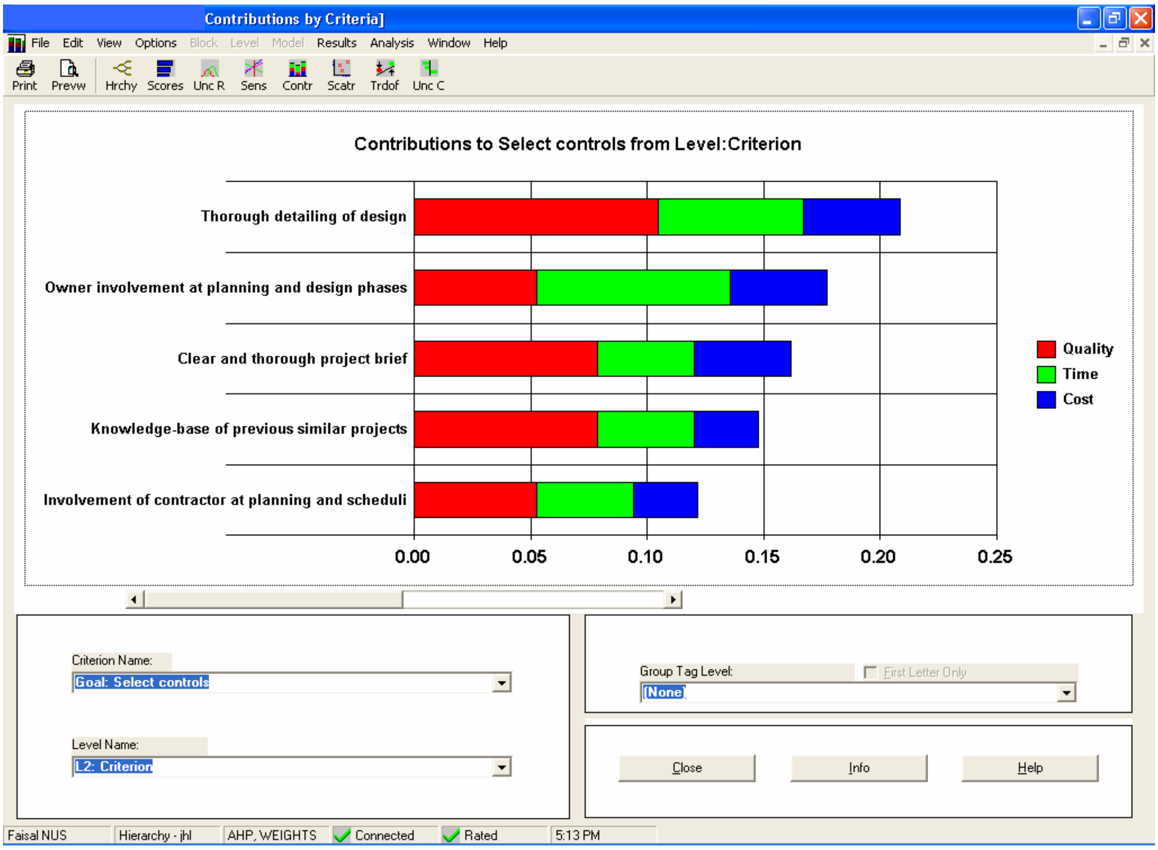


FIG. 11b: The suggested controls sorted according to contributions by criteria

5. CONCLUSION

This case study has presented a proposed framework for a knowledge-based decision support system (KBDSS) for making more informed decisions for managing variation orders in institutional buildings. Furthermore, the study proposed a novel KBDSS for managing variations in institutional building projects in Singapore. Hence, the study is a unique contribution to the body of knowledge about KBDSS towards the management of variations in construction.

Based on the identified principles of effective variation management, the operational sequence of a KBDSS for making more informed decisions for managing variation orders was developed. The KBDSS framework consists of two main components, i.e., a knowledge base and a decision support shell for making more informed decisions for effective management of variation orders. The database will be developed through collecting data from source documents of 80 institutional projects completed, questionnaire survey, literature review and in-depth interview sessions with the professionals who were involved in these institutional projects.

The system model presented a structured format for management of variation orders. The model would enable the project team to take advantage of beneficial variations when the opportunity arises without an inordinate fear of the negative impacts. By having a systematic way to manage variations, the efficiency of project work and the likelihood of project success should increase. The model emphasized on sharing the lessons learned from existing/completed projects with project teams of future projects. The lessons learned should be identified throughout the project life cycle and communicated to current and future project participants.

Although every construction project has its own specific condition, professionals can still obtain certain useful information from past experience. This information will enable building professionals to better ensure that their project goes smoothly without making unwarranted mistakes, and it should be helpful to improving the performance of the project. Furthermore, it is imperative to realize which variation orders will produce significantly more cost variation effect for a construction project.

The KBDSS would be capable of displaying variations and their relevant details, a variety of filtered knowledge, and various analyses of available knowledge. This would eventually lead the decision maker to the suggested controls for variations and assist in selecting the most appropriate controls. The KBDSS may assist project managers by providing accurate and timely information for decision-making, and a user-friendly system for analyzing and selecting the controls for variation orders for institutional buildings. The study would assist building professionals in developing an effective variation management system. The system would be helpful for them to take proactive measures for reducing variation orders. Hence, the study is valuable for all building professionals in general.

6. BENEFICIAL OUTCOME

The study presented research into development of the framework for a knowledge-based management system for effective management of variations in projects. This may assist professionals in analyzing variations, and selecting the appropriate controls for minimizing their adverse impacts. The litmus test for successful management should not be whether the project was free of variations, but rather, if variations were resolved in a timely manner to the benefit of all the parties and the project (Ibbs et al, 2001). Furthermore, by having a systematic way to manage variations, the efficiency of project work and the likelihood of project success should increase. The system emphasized on sharing the lessons learned from existing projects with project teams of future projects. The study would assist building professionals in establishing an effective management system. The system would be helpful for them to take proactive measures for reducing variations in projects. Hence, the study is valuable for all the professionals involved with building projects. Furthermore, this study also contributed to knowledge as the research into development of the system, can be used by future researchers to carry out studies on the development of similar management systems for other aspects of management in any specific type of projects.

The KBDSS will help to enhance productivity and cost savings in that: (1) timely information will be available for decision makers/project managers to make more informed decisions; (2) the undesirable effects [such as delays and disputes] of variations may be avoided as the decision makers/project managers would be prompted to guard against these effects; (3) the knowledge base and pertinent information displayed by the KBDSS will provide useful lessons for decision makers/project managers to exercise more informed judgments in deciding where cost savings may be achieved in future institutional building projects; and (4) the KBDSS will also provides a useful tool for training new professionals.

7. FUTURE WORK

This study presented the framework for developing a knowledge-based decision support system (KBDSS) for making more informed decisions for managing variation orders in institutional buildings. Eventually, the main focus of future work could be the development and validating a knowledge-based decision support system for effective management of variation orders that would enable the professionals to be aware of factors which initiate variations, their frequent effects and effective controls. This would provide the professionals with requisite knowledge to make more informed decisions and to take proactive measures for reducing potential variations in future projects.

This study is part of a larger research study that is being carried out in Singapore for developing a knowledge-based decision support system for effective management of variations in institutional building projects.

As mentioned earlier, the traditional knowledge acquisition methods i.e., through interviews, literature research, and source documents are used to develop the KBDSS and its components in this study. Automated knowledge acquisition techniques are the key to effective analysis (Yu and Skibniewski, 1999). Future research in this area should consider the integration of automated knowledge acquisition techniques with the KBDSS process.

8. ACKNOWLEDGMENTS

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