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Leveraging on Information Technology to Teach Construction Law to Built Environment Students: A Knowledge-Based System (KBS) Approach

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Abstract: Construction law is a vital component of the body of knowledge that is needed by construction professionals in order to successfully operate in the commercial world of construction. Construction law plays an important role in shaping building projects. Construction projects are complex because they involve many human and non-human factors and variables. Teaching construction law is therefore a complex issue with several dimensions. In recent years, Information Technology (IT) has become strongly established as a supporting tool for many professions, including teachers. If faculty members have a knowledge base established on similar past projects, it would assist the faculty members to present case studies and contractually based scenarios to students. This paper proposes potential utilisation of a Knowledge-based System (KBS) for teaching construction law to built environment students. The KBS is primarily designed for building professionals to learn from similar past projects. The KBS is able to assist professionals by providing accurate and timely information for decision making and a user-friendly tool for analysing and selecting the suggested controls for variations in educational buildings. It is recommended that the wealth of knowledge available in the KBS can be very helpful in teaching construction law to built environment students. The system presents real case studies and scenarios to students to allow them to analyse and learn construction law. The KBS could be useful to students as a general research tool because the students could populate it with their own data and use it with the reported educational projects. With further generic modifications, the KBS will also be useful for built environment students to learn about project management of building projects; thus, it will raise the overall level of professional understanding, and eventually productivity, in the construction industry.

Keywords: Knowledge-based System, Construction, Law, Teaching, Case study

INTRODUCTION

Construction law is a vital component of the body of knowledge that is needed by the construction profession in order to successfully operate in the commercial world of construction. Practical applications of the principles of law are common in the construction industry. Thus, students of construction project management need to acquire the relevant, basic legal knowledge and practical skills for solving problems that they may encounter with legal implications. However, at many universities, traditional

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lectures and tutorials still seem to be the preferred methods for teaching law in construction education.

Now, construction professionals need to handle many more applications of law than previously (Arain and Low, 2007a). The regulations that affect construction professionals are building up while the expectations from society and clients become more and more demanding. The responsibilities and liabilities of construction professionals are expanding (Brooker, 2002).

At universities around the world, the increasing number and success of combined engineering and law undergraduate and postgraduate programmes is also evidence of a growing awareness among construction educators, students and professionals of the importance of learning and applying legal knowledge to daily situations that construction professionals need to handle (Ng, 1997). However, teaching law is challenging in itself (Arain and Low, 2007b). Teaching law to construction students can be even more challenging in view of the usual limited time that is assigned in such programmes, the scope and depth of the topics to cover and, in many cases, the limited exposure to legal education of construction professionals and students from their prior training (Oloke et al., 2007).

Construction contracts are the bridge between the concerned parties who build a project (O'Brien, 1998). Ideally, a contract should reflect the project's goals and scope, as well as provide a clear delineation of each party's responsibilities (Arain and Low, 2005a). They should be used constructively and not coercively, which implies that an element of cooperation and negotiation be present.

Sophisticated construction participants recognise the importance of the risks related to contract types. Risk is the possibility of a gain or loss that may occur during the course of a project (Arain and Low, 2005b). One fundamental purpose of developing a legally defined relationship among the participating parties in any construction process is to assign or allocate risk (Clough and Sears, 1994).

Great concern has been expressed in recent years regarding the adverse impact of improper clauses in construction projects (Ibbs, et al., 2001; Arain and Low, 2005b). Project variations, which are based on contractual ambiguities in the construction industries of many countries, were identified as a major source of conflict and dispute (Yates and Hardcastle, 2003). The need to make changes in a construction project is a matter of practical reality. Even the most thoughtfully planned project may necessitate changes due to various factors; therefore, proper clauses should be established in order to reduce the adverse impact of detrimental changes (O'Brien, 1998; Arain and Low, 2007a).

The variation clause establishes the right of the owner to make variations within certain limitations and through a defined mechanism (Barrie and Paulson, 1992). As noted by Cox (1997), the change clause was most frequently relied on by contractors and subcontractors when seeking recovery of extra money. The change clause is often the source of project disputes (Cox, 1997; Arain and Low, 2005b).

Construction problems are usually solved by a combined and balanced use of technical knowledge, management skills and legal principles. Contractual incompleteness and opportunism are identified as the root causes of conflicts in construction projects (Arain et al., 2004). A client who wishes to reduce the number of conflicts should therefore proactively endeavour to limit or reduce contractual incompleteness and to establish balanced clauses. It is highly recommend to establish clear and balanced clauses that assist in reducing the issues in construction projects (Arain and Low, 2007a).

In recent years, Information Technology (IT) has become strongly established as a supporting tool for many professions, including the teaching profession. One application of information technology, namely the knowledge management system, has attracted significant attention and requires further exploration because it has the potential to enhance processes that are based on the expertise of the decision-makers. A Knowledge-based System (KBS) can undertake intelligent tasks that are normally performed by highly skilled people in a specific domain.

Typically, the success of such a system relies on its ability to represent knowledge on a particular subject. Construction projects are complex because they involve many human and non-human factors and variables. They usually have a long duration, various uncertainties and complex relationships among the participants. Teaching construction law is therefore a complex issue with several dimensions.

If faculty members have a knowledge base established on similar past projects, it would assist the faculty members to present case studies and contractually based scenarios to students (Arain and Low, 2007b). The current technological progress does not allow for the complete computerisation of all of the managerial functions or the creation of a tool that is capable of automatically carrying out all of 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 knowledge-based approach for this kind of application seems to be the most natural idea (Miresco and Pomerol, 1995).

This paper capitalises on a Knowledge-based System (KBS) for teaching construction law to built environment students. The Knowledge-based System (KBS) is developed for educational building projects in order to provide information technology support in areas of design improvement, project management and control for the better management of variations (Arain and Low, 2006a, 2006b). The Knowledge-based System (KBS) consists of two main components: A knowledge base and a controls selection shell. The system is expected to help students gain an understanding of how contract variations might be avoided because the most likely areas on which to focus in order to reduce unwise decisions can be identified during the early stage of the construction projects. By tapping in on the past experiences of contractually based issues and scenarios, the KBS provides a wealth of pertinent and useful information for built environment students to learn, which will eventually enhance collaborative ventures in the construction industry.

Experiential education is a core component of construction studies. In the Knowledge-based System (KBS), students will learn from real-world problems. The KBS assists such learning in a borderless environment where the students can explore and learn based on real life principles. The paper proposes the potential utilisation of a KBS for teaching construction law to built environment students for the first time. The study contributes to the knowledge because the innovative approach can be used by faculty members to expose students to real life problems and scenarios in an academic environment.

The following section briefly discusses the Knowledge-based System (KBS) that was developed by Arain and Low (2006a).

KNOWLEDGE-BASED SYSTEM (KBS)

Arain and Low (2006a) suggested that the Knowledge-based System (KBS) can be used by project participants to help make better-informed decisions regarding the management of variations in projects by providing access to pertinent and timely information. This would eventually assist professionals by improving designs for educational building projects because the variations can be identified at an early stage of the design where their impact is not severe. In this case, it is therefore important to understand that the KBS is not designed to make decisions for the users but to rather provide pertinent information in an efficient and easy-to-access format that allows users to make better-informed decisions. Although this system does not try to take over the role of human experts or force them to accept the output of the system, it does provide more relevant evidence and facts in order to facilitate the human experts in making well-informed final decisions. By providing a systematic way to manage variations through the KBS, the efficiency of the building project and the likelihood of the project's success would be enhanced.

The main components of the KBS are shown in Figure 1. As presented in Figure 1, the data were collected from various sources: project documents, site data, interviews with experts, literature review and variation documents. This data were stored in a database. From the database, the data was sieved through an inference engine in order to develop the knowledge base. Eventually, the knowledge-base provided decision support to the project teams for making better informed decisions for the effective management of variations.

The KBS model contains two main components: A knowledge base and a control selection shell. The shell is for selecting the appropriate potential controls for variations in educational buildings. The database has been developed through data collection from source documents of 80 completed educational projects, questionnaire surveys, a literature review and interview

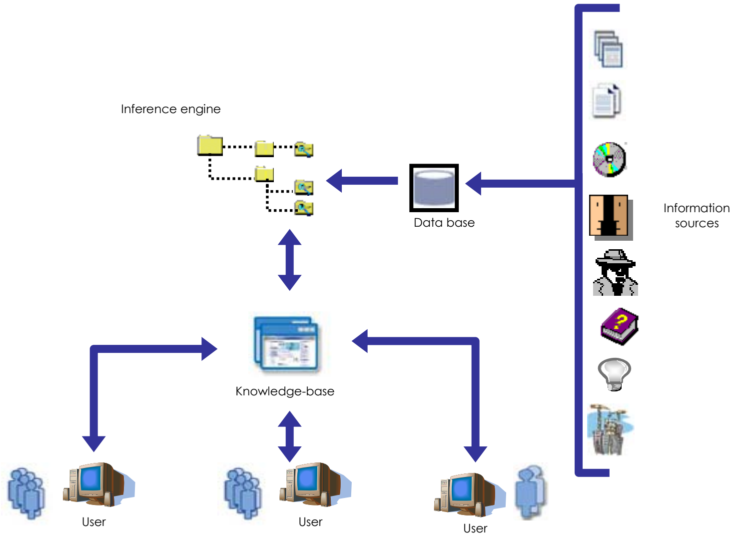


Figure 1. The Main Components of a Knowledge-based System (KBS)

sessions with the professionals who were involved in these projects. The first step in processing the data was to edit this data in order to ensure completeness, consistency and readability. All of the responses were checked to ensure that they had been properly and substantially completed. Simple statistical techniques were used to analyse the data. The information that was collected from the source documents was pertinent to the school projects and variations in the projects, specifically, the project profile information (e.g., the name of the project, project type, work scope, programme, contract duration, date of commencement, date of completion and contingency sum) and the project variations information (variation description, reason for originating the variation, type of variation and approving authority). The data was manually inserted into the database.

The knowledge base was initially developed through sieving and organising data from the database. Furthermore, the knowledge base was divided into three main segments: the macro layer, the micro layer and the effects and controls layer. The system contains one macro layer that consists of the major information that was gathered from the source documents and the 80 micro layers that consist of detailed information that is pertinent to variations and variation orders for each project. Overall, the system contains 155 layers of information. The segment that contains information that was pertinent to the possible effects and controls of the causes of the variation orders for educational buildings was integrated with a controls selection shell. The controls selection shell contains 53 layers that are based on each cause of variation and its most effective control. The controls selection shell provides decision support through a structured process that consists of building the hierarchy among the main criterions and the suggested controls, rating the controls and analysing the controls for selection through multiple analytical techniques.

The KBS has been developed in the MS Excel environment with numerous macros for developing the user interface that carry out the stipulated functions. These are incorporated within a controls selection shell. The Graphical User Interface (GUI) assists users in interacting with the system on every level of the KBS. The user interface that is provided in the KBS allows the user to access, edit, modify, add and view the information on every available layer in the KBS. In addition, the GUI and the inference engine maintain the compatibility between the layers that are within the knowledge base and the control selection shell. The GUI and the inference engine create an interface between the macro layer and the micro layers in order to retrieve the pertinent information. Furthermore, the inference engine carries out all of the stipulated functions that are required by the user and also provides comprehensive summaries of the information that is available on every layer of the KBS.

KBS FOR TEACHING CONSTRUCTION LAW TO BUILT ENVIRONMENT STUDENTS

The KBS provides an excellent opportunity to the faculty members to learn from professional experiences on past construction projects. The faculty members and students are able to learn about the root causes of variations that are based on contractual ambiguities and their downstream effects that may assist them in their evaluation of project conflicts in the context of construction law and contracts. The KBS can be efficiently used to increase students' understanding of the issues that are pertinent to variation clauses and variations. It may assist students in learning about variance performance in the particular reported case studies (educational buildings in Singapore). The students will be able to analyse the causes; their effects and the controls for variations are based on accurate and real knowledge that is provided in the KBS. Furthermore, the students would be able to apply numerous filters to the consolidated knowledge in order to analyse the various situations that are related to different projects.

The system would assist students in learning about contract variance and variance performance in the particular case studies that are reported, i.e., educational building projects in Singapore. Specifically, the KBS would be useful for Architecture, Building and Quantity Surveying students. The relevant modules would be "Contract Administration" or "Professional Practice" for building and quantity surveying students and "Professional Practice" or "Architectural Practice" for architecture students. The system would assist them in learning about the issues of contracts, management and project variance through the wealth of information that is provided in the KBS by the past educational projects. The KBS would be useful to students as a more general research tool because students could populate it with their own data and use it with the educational projects that are reported in this paper for comparison.

Referring to the developed KBS that was in a recent study by Arian and Low (2007a), it was revealed that the top five most frequent and expensive root causes of consultant-related variations in school building projects were noncompliance of the design with government regulations, design discrepancies and changes in the design by the consultant. Arain and Low (2007a) suggested that design consultants should pay close attention to the more frequent and expensive causes of variations in the context of Clauses 19 and 20 of the local construction contract (PSSCOC).

The KBS presents cases studies that have already been developed and analysed in the system. There are opportunities for faculty members that teach construction law to analyse information and reveal the various impacts of the contraction contract clause to the project's success. The system assists in analysing information and presenting trend analysis on the impact of the project's cost and time because the system is dynamic and designed to accommodate information that is pertinent to ongoing projects and recent changes in construction law.

By considering the system that was developed by accommodating the educational building project's data into the system, it is interesting to mention that the KBS reveals interesting analyses that consider construction law changes when the projects were being completed. The KBS reveals all of management's decisions that were made in response to specific construction law changes, i.e., provision of handicapped facilities in all educational building projects.

The detailed information that is available in the various layers of the KBS is briefly discussed below. The information and various filters that can be applied to the developed knowledge base may assist professionals in learning from past projects in order to improve future designs and enhance the management of variations in educational building projects.

INFORMATION AVAILABLE ON THE MACRO LAYER

As mentioned earlier, the macro layer is the first segment of the knowledge base. It consists of the major information that was gathered from the source documents of 80 educational projects and through interview sessions with professionals. As shown in Figures 2a, 2b and 2c, the macro layer contains the major information about the completed educational projects: the project name, program phase, work scope, institutional level, date of commencement, project duration, date of completion, actual completion, completion schedule status, schedule difference, final contract 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, main contractors and consultants.

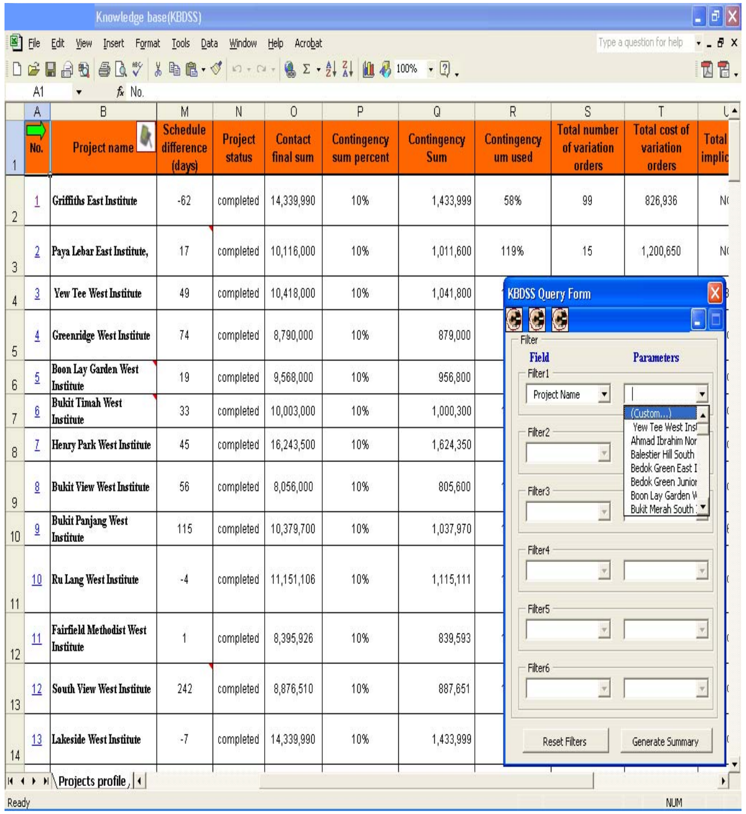


Figure 2a. Macro Layer of the Knowledge Base that Consists of the Major Information Regarding Educational Building Projects

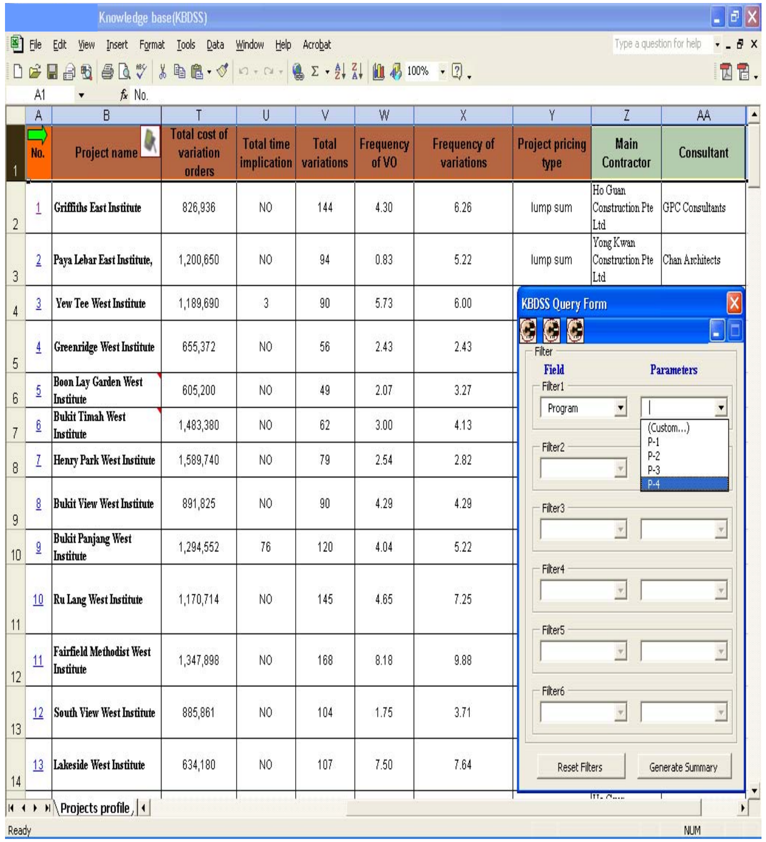
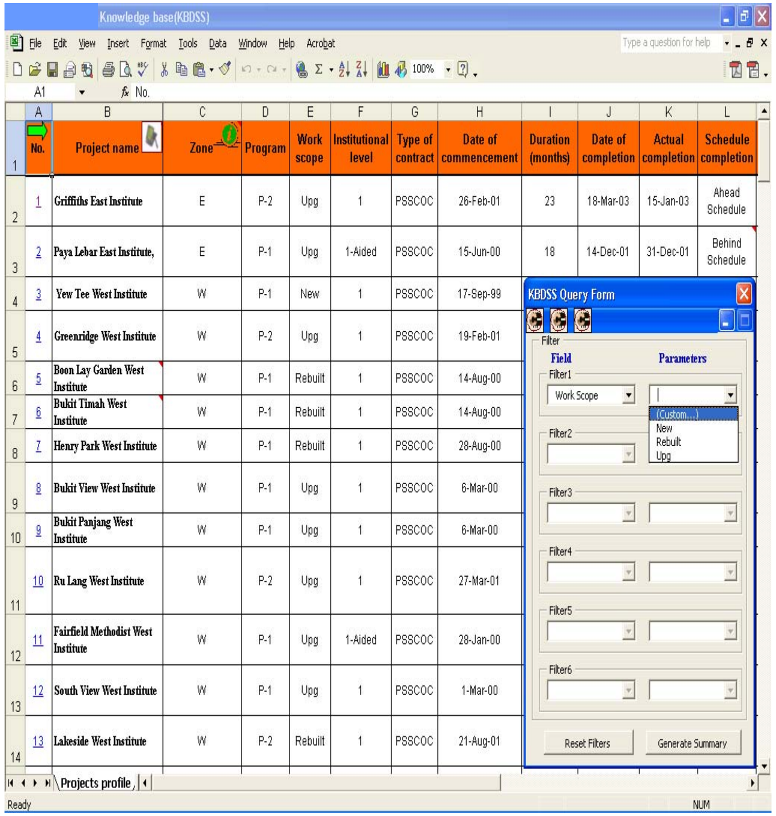


Figure 2b. Macro Layer of the Knowledge Base (cont'd)



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				

Figure 2c. Macro Layer of the Knowledge Base (cont'd)

A variety of filters are provided on the macro layer that assists in sieving information by certain rules. The user would be able to apply multiple filters to analyse the information by certain rules; for instance, the user would be able to view the information about the educational projects that were completed behind schedule and, among these projects, the projects with the highest frequency of variation orders, highest used contingency sum, highest number of variations, etc. This analysis assists the user in identifying the nature and frequency of variations in certain types of educational projects.

The inference engine provides a comprehensive summary of the information that is available on the macro layer. As shown in Figure 3, the inference engine computes the total number of projects, subtotal (that assists in identifying the projects when multiple filters are applied), total number of projects based on the program phases, subtotal of projects based on the program phases, total number of projects that are categorised according to the work's scope, subtotal of projects that are categorised according to the work's scope, total number of projects that are categorised based on institutional levels, subtotal of projects that are categorised based on institutional levels, total number of projects based on completion schedule status (ahead of schedule, on schedule, behind schedule), subtotal of projects based on completion schedule status, total number of projects based on three levels of contingency sum usage, subtotal of projects based on three levels of contingency sum usage, total number of projects that are categorised based on time implications and subtotal of projects based on time implications. Furthermore, the inference engine also computes the percentages for each category that is mentioned above and shown in Figure 3. This assists the user in analysing and identifying the nature and frequency of variation orders in certain types of educational projects.

The information that is available on the macro layer would assist the designers in identifying the potential tendency of encountering more variations in certain types of educational projects. By applying multiple filters that are provided on the macro layer, the professionals would be able to evaluate the overall project variance performance. Furthermore, the wealth of knowledge that is available on the macro layer may assist in reducing the design variations; for instance, if the designers are developing a design for a Level-1 institute, they may evaluate the project's performance based on the information that is available on the macro layer: project cost, total number of variations, contingency sum usage, frequency of variations and variation orders in the Level-1 institutes. These analyses at the design stage would assist the professionals in developing better designs with due diligence.

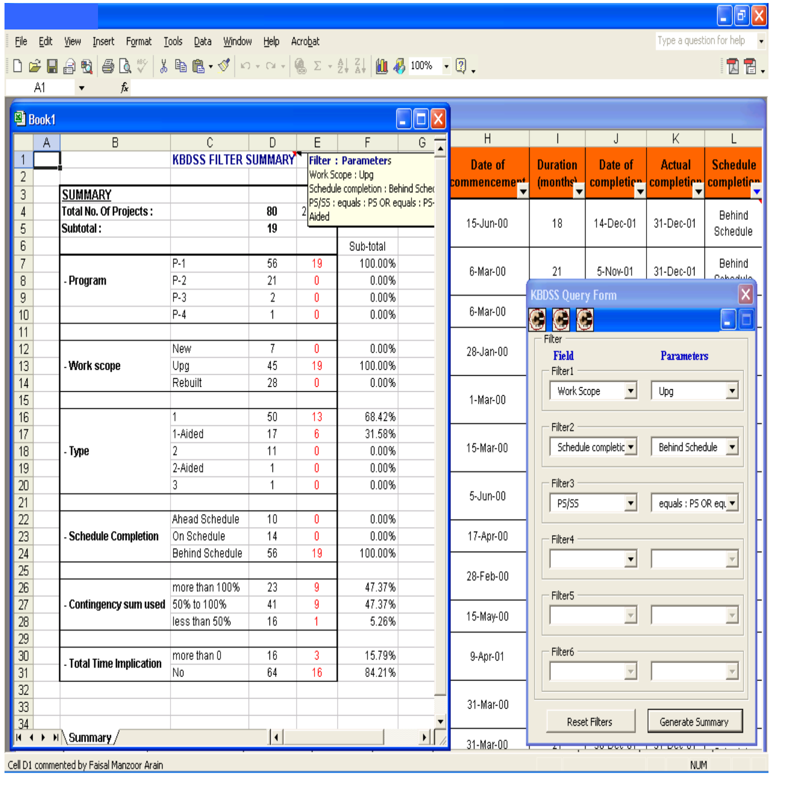


Figure 3. Summary Section that Displays the Results of the Applied Filters

INFORMATION AVAILABLE ON THE MICRO LAYER

The micro layer is the second segment of the knowledge base that contains 80 sub-layers that are based on the 80 educational projects, respectively. As shown in Figures 4a and 4b, the micro layer contains detailed information regarding variations and variation orders for the educational project. The detailed information includes the variation order code that assists in sieving information, detailed descriptions of the particular variation that have been collected from source documents, the reason for carrying out the particular variation (which has been provided by the consultant), the root cause of the variation, the type of variation, cost implications, time implications, approving authority and endorsing authority. In this case, the information regarding the description of a particular variation, reason, type of variation, cost implication, time implication, approving authority and endorsing authority were obtained from the source documents of the 80 educational projects. The root causes were determined based on the description of variations, reasons given by the consultants and the project source documents. They were later verified through in-depth interview sessions with the professionals who were involved with the projects.

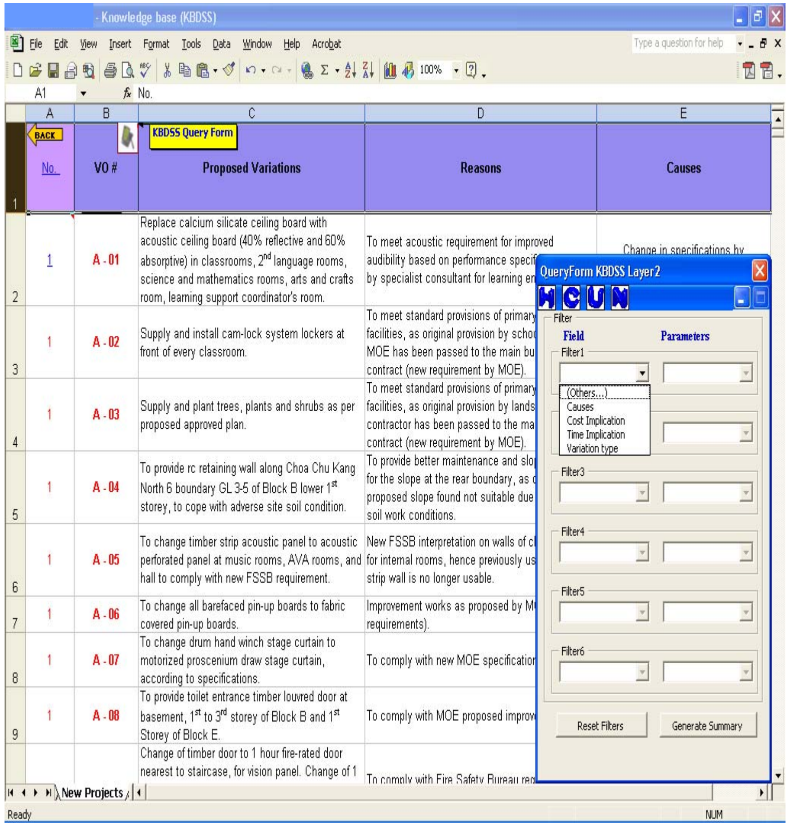


Figure 4a. Micro Layer of the Knowledge Base on the Macro Layer

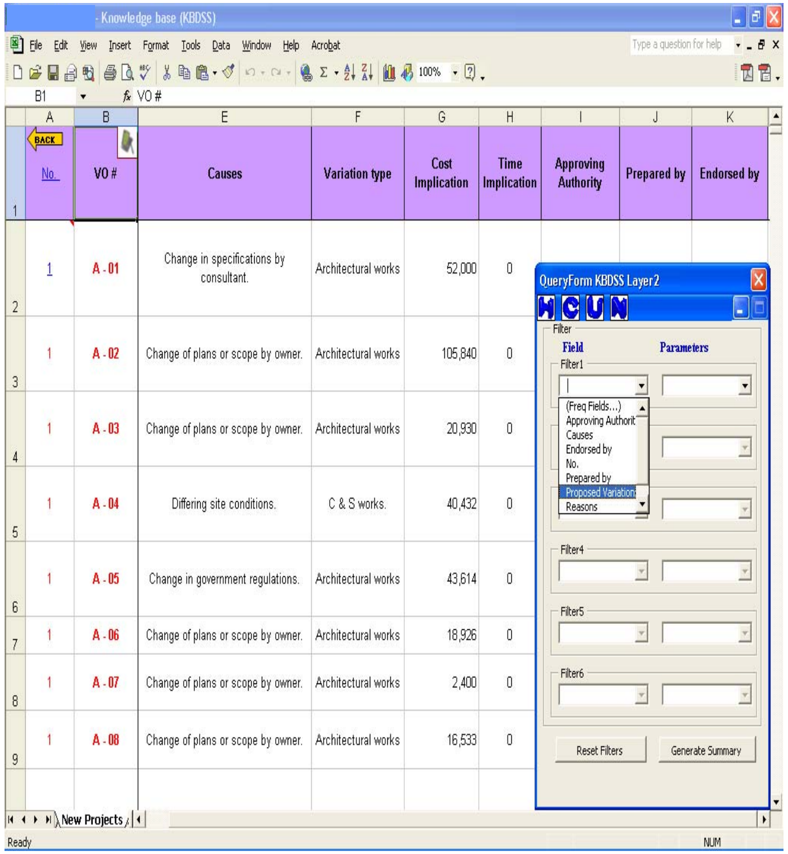


Figure 4b. Micro Layer of the Knowledge Base (cont'd)

In addition to compute the aforementioned information, the inference engine also computes and enumerates the number of variations according to various types of variations, as shown in Figure 5. The inference engine also assists in computing the actual contingency sum by deducting the cost of variations that are requested and funded by the institution or other sources. This may assist in identifying the actual usage of the contingency sum based on the project's cost.

The information can be sieved by certain rules through a variety of filters that are provided in the micro layer. The professionals would be able to apply multiple filters to find out the most frequent causes of variations, the most frequent types of variations and the variations with both the most significant cost and time implications. The multiple summaries that can be generated by applying filters and using the query form are presented in Figure 5. The summary section of the micro layer can be saved for future reference. This feature of the KBS assists in carrying out comparative analyses of the information that is provided in all of the layers of the KBS. The inference engine integrates the summary section with the filter applications that assist in indicating the multiple filters' application results in the summary section. The results in the summary section assist the user in determining the most important causes of variations in each project. However, the micro layer also provides detailed information (as mentioned above) about all of the 80 educational projects for a comprehensive analysis.

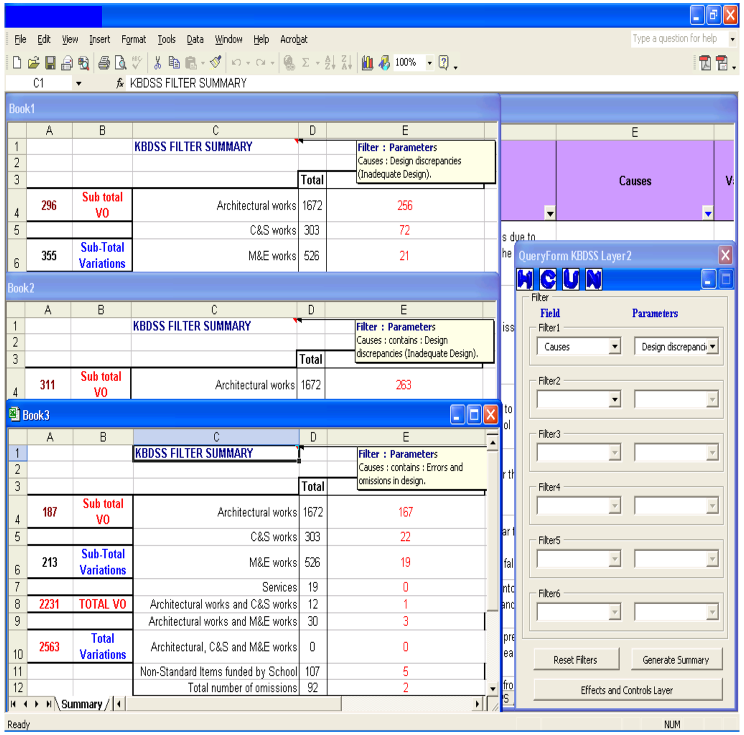


Figure 5. Multiple Summary Sections that Display the Results of the Applied Filters on the Micro Layer

The professionals would be able to analyse the most potential variations in educational building projects. The information that is available on the micro layers would assist in pinpointing the design errors and discrepancies in the past educational projects. As shown in Figure 5, the KBS provides comprehensive summaries that are based on the applied filters; for instance, the professionals would be able to evaluate variations that are categorised according to the cause of variations. These analyses assist in identifying the potential areas on which to focus in order to reduce variations in future projects. Furthermore, the KBS provides a brief description about each variation that is implemented in the past documented educational projects. This may assist in finding the actual variations and the reasons for carrying out these variations. Based on these analyses, the professionals would be able to pinpoint the major variations that were initiated due to design errors, design discrepancies, non-compliance of the design with certain regulations, etc. Hence, during the early stages of construction projects (i.e., the design stage), the KBS would assist in improving designs by identifying the potential frequent errors and discrepancies in the designs.

When the professionals select any specific cause of variations (see Figure 6), they select design discrepancies. The effect and control tab appears in the query form that creates the interface between the micro layers and the effect and control layers of the KBS. Furthermore, the information that is available on the micro layer will also be filtered according to the applied filter. The layers and the query forms are dynamic; therefore, the user may interact or browse the layers that are activated. This assists in a thorough analysis of the information. The professionals may apply custom filters, i.e., the filter can be defined in order to retrieve a particular set of information that is available on the micro layer. This feature of the KBS is very useful and user friendly because the professionals can define any combination of information that is required. During the design stage, the professionals may retrieve all of the design-related information that is available in the micro layer that could assist them in improving the design and accommodating the potential variations, which can adversely affect the projects, at an early stage where the impact of the variations would be less severe than during the construction phase.

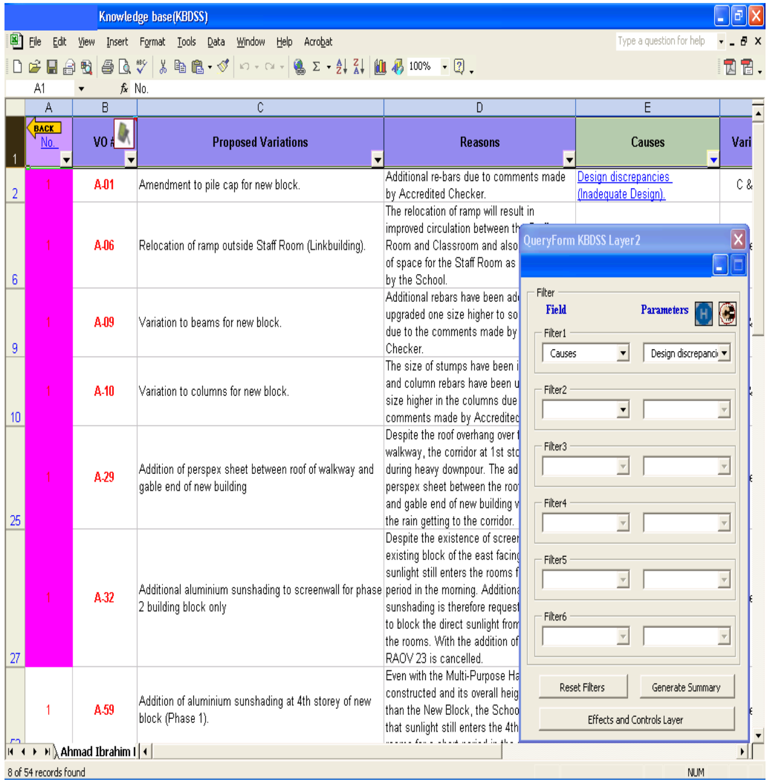


Figure 6. Query Form that Shows the Effects and Controls Layer Tab that Connects the Micro Layer with the Effect and Controls Layer of the Knowledge Base

EFFECTS AND CONTROLS FOR THE POTENTIAL CAUSE OF VARIATIONS

The third layer of the KBS contains a combination of 53 sub-layers that are based on the potential causes of variations and 10 sub-layers of the most important causes (note: the 53 causes were identified from the literature review, analysis of information given in the source documents and in-depth interviews with the developers, consultants and contractors (Arain and Low, 2005a). The 53 causes can be modified in the event that new ones are discovered or emerge over time. The numerous filters that are provided in the macro, micro and effects and controls layers will be updated automatically with every new project that is added. As shown in Figure 7, the graphical presentation of the five most important effects and the five most effective controls for the cause of variations was presented. The upper part of the graphical presentation displays the potential effects of the cause of variations. The lower part presents the most effective controls for the cause of variations. Here, the effects and controls for variation orders were tabulated according to the survey results. As shown in Figure 7, the CDP form is provided in the effects and controls layer, which enables the user to switch among the effects and controls layer, micro layer and the macro layer, which contains the major information about all of the 80 projects. The names of the projects can be selected in the CDP form that links with the corresponding micro layers.

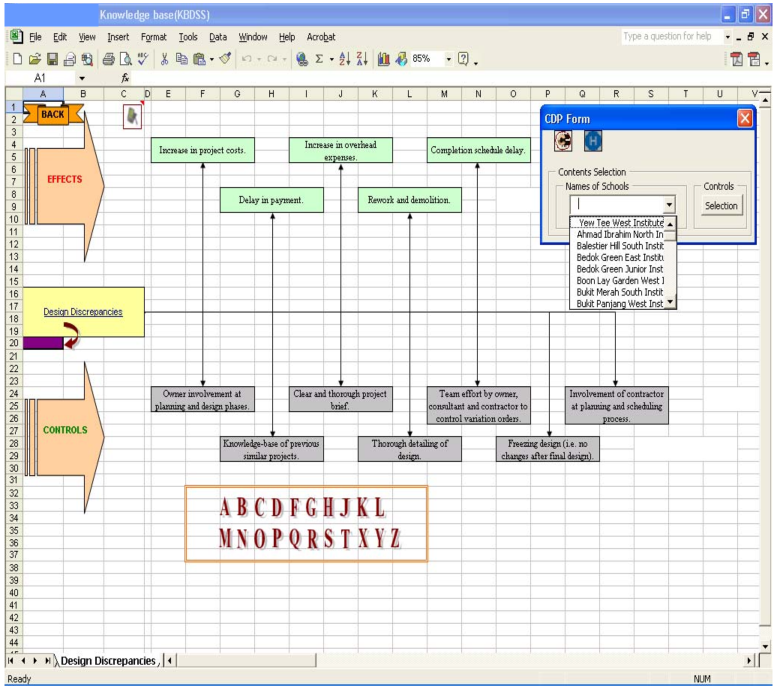


Figure 7. The Most Important Effects and Controls for the Cause (Design Discrepancies) of Variations, Which is Displayed in the Effects and Controls Layer of the Knowledge Base

THE WEALTH OF KNOWLEDGE IN THE KBS FOR TEACHING CONSTRUCTION LAW

The knowledge consolidation process of the past experience generates a wealth of knowledge that is pertinent to construction law and that impacts the documented projects. The system also captures the information that is pertinent to the design of building projects and documents the changes to the design based on various categories that are related to the cause of the change, where construction law is one of the most significant cause categories. The system displays the verified information with the design changes based on what is built and the law. For example, the system helps identify the building codes that contribute to the most frequent changes in design, by highlighting the frequency of such changes in design. Interestingly, it is revealed that the designers and building code officials approached interpretations from quite different perspectives. The designers were trying to make a functional or formal design code that was compliant while satisfying project requirements in an aesthetic, economical and practical way. The Authorities Having Jurisdiction (AHJ) examined the completed drawings for compliance with the building code requirements and were charged first and foremost with protecting the health, safety and welfare of the public. The KBS presents the related building code and detailed information about incidents in which the designs were significantly changed in order to make the design compliant with the building codes. The system would therefore facilitate a deeper understanding of the detailed requirements that are common to educational building projects.

The intended use of a building is a fundamental consideration for building law. The desired use of the facility determines the occupancy group to which it is assigned under the construction law. As mentioned earlier, the KBS was developed based on educational building projects that were carried out in Singapore. The building codes separate uses into broad groups called occupancies. The KBS highlights the group under which the educational buildings fall. It would be beneficial for construction law students to learn to determine the flow of occupancy types in almost every case from the number of occupants and the hazards to their safety from external and internal factors. The system shows that the major considerations for occupancy classification are the following: the number of people that will be using a facility; whether there are assembly areas; whether people will be awake or asleep in the building, such as students in hostels; and whether there are hazardous materials or processes, such as labs and workshops. The system highlights all of the pertinent categories in the checklist that is imbedded in the system.

Singapore's dynamic culture and architecture were the driving force for developing unique designs for the educational building projects. The KBS would help students to explore and learn about the impact of Building Heights and Area (BHA) regulations on the design of the educational building projects. The system revealed that an iterative design process was used to maximise the economic efficiency of the educational building projects, where the goal was to achieve the maximum area with a minimum investment in construction materials while still meeting or exceeding the code that mandated the requirements to protect public health, safety and welfare. As mentioned earlier, the KBS presents the pertinent codes and the information that is pertinent to the changes that were initiated for developing design alternatives in order to achieve the best possible design in conformance with the building law.

Singapore's building codes include the Fire Protection and the means of egress codes, which are the most emphasised and integral requirements of any building design. The fundamental purpose for the means of egress is to get all of the occupants out of a building in a safe and expeditious manner during a fire of other emergency. The KBS assists in pinpointing the changes that occur during the design and construction phases due to non-compliance with these codes. The students would learn the details of these building laws and the impact on the design and execution of the educational building projects.

The KBS reveals all of the decisions that management makes in response to a specific construction law change, for example, the provision of handicapped facilities in all educational building projects. The system presents detailed information on scenarios that occurred when the new building law that provides handicapped facilities in all educational buildings was approved; eventually, all of the projects that were in the design and construction phase were affected. The built environment students would learn how project teams responded to the new building accessibility law and how the projects were re-shaped to accommodate the handicapped facilities in the campuses.

It is important for the built environment students to understand the essential elements of a contract. The KBS presents documented information and essential contract elements that are pertinent to the contract documents. Contracts consist of benefits to and the obligations of the contracting parties. The law will enforce the provisions of a valid contract; the law will not intervene to impose contract terms that are more favourable than those negotiated between the parties. The KBS presents the documented contractual information that, in some cases, interestingly revealed that parties alter an existing contractual arrangement by mutual agreement since the amendment was effected within the framework of the essential contract elements.

It is important for project managers to take time to read all of the contract documents that are pertinent to their projects, including any general, supplementary and special conditions. These important contract documents define various situations that may arise during the life of a project and specify how they are handled within the defining limits of construction law. The KBS highlights the contract clauses, especially the ones that initiated changes in the projects or were the cause of disputes. The built environment student would learn the potential clauses in general construction contracts that may initiate changes in construction projects. The system presents scenarios of disputes and the measures taken to resolve the disputes within the domain of construction law.

Numerous delays and interference claims were documented in the KBS that establish an excellent resource for students to explore in order to find out the root causes of the delays and interference claims. The system not only presents the delays and interference claims but also management's decisions that were taken to handle these situations. Further, the system suggests the potential clauses that may initiate changes and result in claims and delays in the construction projects.

The KBS presents important information about the contract types, contract documents and approval procedures. Learning about the approval processes that are affiliated with different types of construction contracts would be of interest to the students of construction law. The system presents how construction contracts impact projects since similar analyses could easily be generated based on the knowledge base that was developed from past projects. The students would be able to explore the system and analyse information in the context of contractual changes and newly imposed construction laws.

PSSCOC CLAUSES ON PROJECT CHANGES: AN EXAMPLE

The KBS presents useful analyses and information about contractual clauses that may initiate changes in the educational building projects. The Public Sector Standard Conditions of Contract (PSSCOC) for Construction Works is the de facto standard form for building contracts that is used by public agencies in Singapore. First introduced in 1995, it is now in its fourth edition since it was re-published in 2005 by the Building and Construction Authority (BCA, 2005). Clause 19.1 of the PSSCOC, which deals with "Variations to the Works," defines the term "variation" to mean any change in the original contract's intention as deduced from the contract as a whole that describes or defines the work to be carried out; it shall include but is not restricted to the following:

(1) An increase or decrease in the quantity of any part of the work;
(2) An addition to or omission from the work;
(3) A change in the character, quality or nature of any part of the work;
(4) A change in the levels, lines, positions and dimensions of any part of the work;
(5) The demolition of or removal of any part of the work that is no longer desired by the Employer or the Superintending Officer (SO);
(6) A requirement to complete the work or any phase or part by a date earlier than the relevant time for completion.

To avoid any doubt, Clause 19.1 also provides that the term "variation" include any change as aforesaid that may be designed to alter the use to which the work will be put but shall exclude any instruction (which would otherwise be a variation) that has arisen due to or is necessitated by or is intended to cure any default of or breach of contract by the contractor. The power to order variations is provided for in Clause 19.2 of the PSSCOC, wherein the SO may at any time issue an instruction in writing that requires a variation. However, as provided for in Clause 19.3 of the PSSCOC, the SO may, before issuing an instruction for any variation, require the contractor to submit a quotation for any proposed variation and the contractor shall be obliged to submit such a quotation in writing at his own costs. Nonetheless, Clause 19.3 specifies that an instruction that requires a variation shall not be treated as an acceptance of any quotation.

All variations shall be valued using the following valuation methods, which are specified in Clause 20.1 of the PSSCOC: (1) where the varied work is of a similar character to, is executed under similar conditions as and does not significantly change the quantity of work described in the contract, the rates for the work, as set out in the contract, shall determine the valuation; or (2) where the varied work is of a similar character to the work that is described in the contract but is not executed under similar conditions or involves significant changes in the quantity, the rates for the work, as set out in the contract, shall be the basis for determining the valuation but with a fair allowance for any differences in such conditions and/or quantity; or (3) where (a) and (b) do not apply, the varied work should be measured and valued at fair market rates and prices; (4) where none of the above methods are applicable or appropriate in the circumstances of the particular varied work, then the valuation shall be based on the cost of necessary plant, materials or goods, labour and any additional equipment that is necessary for the execution of the varied work plus 15%. This percentage shall be deemed to adequately compensate the contractor with respect to all supervision, the use of construction equipment, overheads, profit and all other costs or damages that are incurred in or connected with the execution of the varied work; (5) the rates for the work, as set out in the contract, shall determine the valuation of the omitted items, provided that if the omissions vary, the conditions under which any remaining items of work are carried out, the values for such remaining items shall be determined under Clauses 20.1(b) or (d) as the case may be.

Clause 20.2(1) of the PSSCOC provides that the contractor shall carry out all of the variations that are instructed by the SO, pending the valuation of the variations by the SO. When the contractor considers that the respective variation work has been substantially completed, he may give notice in writing to that effect to the SO as provided for under Clause 20.2(2)(b). The SO shall either (i) certify in writing that the variation work in his opinion was substantially completed or (ii) give instructions in writing to specify the work that in his opinion is required to be done. Thereafter, Clause 20.2(2)(c) specifies that the contractor shall, within 30 days from the day of the SO's certification, submit to the SO a valuation of the aforementioned variations (with such details and particulars including invoices and receipts that the SO may require for the purpose of valuing the aforementioned variations) based on the completed variation work. The contractor shall thereafter include his claim for the aforementioned valuations in the next payment claim that is submitted by the contractor under Clause 32.1.

The SO shall also, within 60 days from the date of his certification, value the total amount due for the aforementioned variation based on the completed variation work and shall notify the contractor in writing of the value of the variation as provided for under Clause 20.2(2)(d) of the PSSCOC. Thereafter, the SO shall certify the amount due to the contractor for the aforementioned variations in the next payment certificate to be issued by the SO under Clause 32.2.

There are also provisions that are provided in Clauses 20.2(2) (e)-(g) of the PSSCOC for the contractor to give notice of his disagreement with the valuation of the SO within 30 days of receipt of the SO's valuation and for the SO to take appropriate actions, as the case may be, upon receipt of the contractor's disagreement.

The above review suggests that there is already ample provision for judicious variation management and valuation in the PSSCOC. Variations may be caused by the owner (e.g., change of plans or scope), the consultant (e.g., design discrepancies), the contractor (e.g., unavailability of equipment) or others (e.g., change in government regulations). The PSSCOC, however, does not distinguish if a variation is caused by the owner, consultants, contractor or other factors that are not within the control of the parties in the contract. However, an evaluation of Clause 19.1(a)-(f) of the PSSCOC, which defines the meaning of the term "variation," appears to suggest that a majority of the provision therein deals with variations that are related to the consultants (Arain and Low, 2005b). While this may be the case, it is also unclear what exactly these consultant-related variations entail. For example, Clause 19.1(b) includes "an addition to or omission from the Works" as part of the variations. As part of the consultant-related variations, this addition or omission may be caused by a change in the design by the consultant, errors and omissions in the design, design complexity, ambiguous design details and so on.

It is therefore desirable to expand upon the variation-related provisions in the PSSCOC in order to obtain a better understanding of what the exact cause is of the consultant-related variations. The KBS presents in-depth analysis of the information that is documented in the knowledge base. It is recommended, based on an analysis of the available information in the KBS, that the consultant and, in particular, the Superintending Officer pay close attention to the more frequent and expensive causes of variations in the context of Clauses 19 and 20 of the PSSCOC. While the provisions for managing and valuing variations judiciously are in the PSSCOC, it is worthwhile for consultants and the Superintending Officer to pay heed to some of the more common and costly CRV, which have been identified in this study, in order to avoid their pitfalls. This should then pave the way for smoother progress and better working relationships among all parties in the building project. The KBS prompts the project managers and the professionals that are involved with educational building projects of these potential clauses in the contract in order for them to take proactive measures for successful completion of the projects.

The built environment students would learn about various types of construction contracts and their impact on projects based on the knowledge base that has been developed with past projects. The students would be able to interact with the system through the user interface. The user interface would allow the students to access, analyse, edit, modify, add and view the information that is displayed on the KBS. The inference engine would allow students to create hypothetical projects and carry out analyses based on the information that is shared in the KBS (Arain and Low, 2006b). The KBS provides useful information pertaining to the contract types, contract documents and approval procedures. The built environment students would be able to explore the system and analyse information in the context of contractual changes and the newly imposed construction law. Furthermore, the KBS systematically consolidates all of the decisions that have been made for numerous projects over time so that individuals, especially new staff, would be able to learn from the collective experience and knowledge of everyone.

CONCLUSION

This paper discussed potential utilisation of a knowledge-based system that has been developed by Arain and Low (2006a) for teaching construction law to built environment students. Although every construction project has its own specific condition, professionals and students can still obtain useful information from past experiences. This information will enable students to better understand construction law and its implications and how to carry out construction projects smoothly without making unwarranted mistakes; it should also be helpful when improving the performance of the project.

The KBS was developed based on information that was gathered from the source documents of the completed educational projects and in-depth interviews with the professionals. It would help decision makers to take proactive measures for reducing potential variations. The system provides detailed information about variations in completed educational building projects. This may assist the students in identifying the potential variations during the early stage of the construction projects. The KBS provides designers with information on how changes in construction law can cause variations. It can extend from inception right up to the building stage. The KBS provides such information so that designers will know what to address and what to avoid based on changes in construction law. Furthermore, the system assists in pinpointing the suggested controls that can ideally be implemented during the early stages of the building projects. Hence, the system would assist in improving the designs for educational building projects because the most likely areas on which to focus can be identified during the design stage of the educational building projects. In short, the KBS is able to assist project managers by providing accurate and timely information for decision making and a user-friendly tool for analysing and selecting the suggested controls for variations in educational buildings.

For the students, the KBS provides an excellent opportunity to learn from past experiences. It is important to note that this system, for the management of variations, 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 and judgments. Although this system does not try to take over the role of human experts or force them to accept the output of the system, it provides more relevant evidence and facts in order to facilitate the human experts in making well-informed final decisions. The KBS presents real data that has been trawled from construction projects and assists in analysing the information. By providing a systematic way to manage variations through the KBS, the efficiency of the building project and the likelihood of the project's success can be enhanced.

The knowledge consolidation process of past experiences will allow students to learn from past projects. Students would be able to explore the system and analyse information in the context of contractual changes and newly imposed construction law. Furthermore, the KBS systematically consolidates all of the decisions that have been made for numerous projects over time so that individuals, especially new staff, would be able to learn from the collective experience and knowledge of everyone.

The KBS should be used during the early stages of the construction projects in order to achieve optimal results (Arain and Low, 2006a). The students will be able to explore the details of all of the previous actions and decisions that have been taken by other staff who were involved with the educational projects. This would assist them in learning from past decisions in order to make better-informed decisions for the effective management of variations in the future. Eventually, this assists them in developing improved designs with fewer discrepancies and errors that may increase the overall level of the project's performance.

The KBS presents cases studies that have already been developed and analysed in the system. This is an excellent opportunity for faculty members that teach construction law to analyse information and to reveal the various impacts of contraction contract clauses on a project's success. The system assists in analysing information and presenting trend analysis and impacts on a project's cost and time. In addition, the system is dynamic and designed to accommodate information that is pertinent to ongoing projects and recent changes in construction law.

The KBS is primarily designed for building professionals to learn from similar past projects. The KBS is able to assist professionals by providing accurate and timely information for decision making and a user-friendly tool for analysing and selecting the suggested controls for variations in educational buildings. It is recommended that the wealth of knowledge that is available in the KBS can be very helpful in teaching construction law to built environment students. The system would present real case studies and scenarios to students for them to analyse and learn. The KBS would be useful to the students as a more general research tool since students could populate it with their own data and use the reported educational projects. With further generic modification, the KBS will also be useful for learning project management of building projects; thus, it will raise the overall level of professional understanding and, eventually, productivity in the construction industry.

REFERENCES

Arain, F.M., Assaf, S. and Low, S.P. (2004). Causes of discrepancies between design and construction. *Architectural Science Review*, 47(3): 237—249.

Arain, F.M. and Low, S.P. (2005a). How design consultants perceive potential causes of variation orders for institutional buildings in Singapore. *Architectural Engineering and Design Management*, 1(3): 163—178.

Arain, F.M. and Low, S.P. (2005b). The nature and frequency of occurrence of variation orders for educational building projects in Singapore. *International Journal of Construction Management*, 5(2): 79—91.

Arain, F.M. and Low, S.P. (2006a). Knowledge-based decision support system for management of variation orders for institutional building projects. *Automation in Construction*, 15(1): 272—291.

Arain, F.M. and Low, S.P. (2006b). A knowledge-based system as a decision making tool for effective management of variations and design improvement: Leveraging on information technology applications. *International Journal of IT in Architecture, Engineering and Construction (ITAEC + ITCon), Special Issue Architectural informatics*, 11(1): 373—392.

Arain, F.M. and Low, S.P. (2007a). PSSCOC and variations: An analysis of consultant related variations in school building projects. *The International Construction Law Review*, 24(3): 366—381.

Arain, F.M. and Low, S.P. (2007b). Leveraging on information technology for effective management of variations in educational building projects: A KBDSS approach. *Centre for Education in the Built Environment*, Working paper 10: 1—88.

Barrie, D.S. and Paulson, B.C. (1992). *Professional Construction Management: Including CM, Design-Construct, and General Contracting.* New York: McGraw Hill.

BCA, (2005). *Public Sector Standard Conditions of Contract for Construction Works*. (4th ed). Singapore: Building and Construction Authority.

Brooker, P. (2002). Construction lawyers' attitudes and experience with ADR. *Construction Law Journal*, 18 (2): 97—116.

Clough, R.H. and Sears, G.A. (1994). *Construction Contracting*, (6th eds.). New York: John Wiley & Sons Inc.

Cox, R.K. (1997). Managing change orders and claims. *Journal of Management in Engineering, ASCE*, 13(1), 24–30.

Ibbs, C.W., Wong, C.K. and Kwak, Y.H. (2001). Project change management system. *Journal of Management in Engineering, ASCE*, 17(3): 159—165.

Miresco, E.T. and Pomerol, J.C. (1995). A knowledge-based decision support system for construction project management. *Proceedings of the Sixth International Conference on Computing in Civil and Building Engineering*, (2), 1501—1507.

Ng, J. (1997). Should Law be Introduced into the engineering curriculum. *International Journal of Engineering Education*, 13(1): 72—78.

O'Brien, J.J. (1998). ***Construction Change Orders***. McGraw Hill: New York.

Oloke, D., Yu, H., and Heesom, D. (2007). Developing practitioner skills in construction health and safety management: An integrated teaching and learning approach. ***Journal for Education in the Built Environment***, 2(01): 3–30.

Yates, D.J. and Hardcastle, C. (2003). The causes of conflicts and disputes in the Hong Kong construction industry. ***RICS Research Paper Series***, 4(22): 1–50.