APPLICATION OF AN INFORMATION AND KNOWLEDGE MANAGEMENT METHODOLOGY IN ANALYZING THE RISKS IN CONSTRUCTION PROJECTS

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ABSTRACT

The multitude and diversity of risks encountered on infrastructure projects necessitates an approach to manage a significantly large body of information regarding risks and their properties. Computer-based methodologies that make use of advances in Information Technology (IT) have the potential to play a significant role in facilitating the management of this body of information and also in assisting the capture of knowledge gained on projects in a manner suitable for re-use in the future. In this paper we describe the development of a methodology for information and **K**nowledge application and re-use in **RIS**k management (KRIS) and its application towards the analysis of risks on a case study building project proposed for construction in the Greater Vancouver Regional District (GVRD). The case study is a unique one-off facility that involves multiple public and private sector stakeholders and a complex program to accommodate over 1800 employees. This case study is used to illustrate concepts addressed in KRIS and in particular how this IT application can assist project personnel address risks in a complicated project.

KEY WORDS

Risk management, infrastructure, information technology, computing.

INTRODUCTION

Risk management is considered an essential task in the management of an infrastructure project to ensure technical, contractual, financial, organizational, operational, and other performance requirements are met. A survey carried out by Voetsch (2003) of more than 150 respondents from various industries such as information and communications, energy, and construction has indicated that a positive relationship exists between the frequency of use of formal risk management practices and the frequency of project management success, as measured by customer satisfaction, on time project delivery, and avoidance of the project being de-scoped. However, the task of identifying the risks associated with all facets of the project lifecycle, assessing their magnitude, and the development of response strategies is

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non-trivial. In some instances the number of categories of risks such as design risks, project scope risk, construction risk, commissioning risk, and industrial relations risk can exceed 100 (Fitzgerald 2004) with each category consisting of several individual risk events. Although risk management is considered a key task to ensure project success, the current tools available, although helpful, are simplistic and unable to integrate identified risks with the multiple dimensions of a project.

The purpose of our research has been to bring more structure to the risk management process performed by practitioners in the construction industry by means of a systematic approach using information technology (IT). The benefits of such an approach enable one to track the history of the risk event and associated properties, reflect project changes in the risk profile, query the source(s) of the risk and what happened in the as-built context and generate insights on the spatial and temporal distribution of the project's risks. The tool also incorporates features that enable an organization to build up a repository of risk-related information and knowledge over time. In this paper we illustrate the knowledge management and querying features of the comprehensive risk management tool, KRIS, on a unique project proposed for construction in the Greater Vancouver Regional District (GVRD).

CURRENT STATE OF THE ART IN MANAGING RISKS WITHIN THE CONSTRUCTION INDUSTRY

In both public and private sector organizations, the use of paper-based or spreadsheet-based risk registers for managing risk information on infrastructure projects is widespread, and provides a mechanism to record the risks that are identified for a particular project and to track them through the project's lifecycle. Contents of registers (Ward 1999) include information about the timing of risks and responses, resources required by alternative responses, information about interdependencies, as well as information on the nature of impacts and risk ownership. A government department with one of the largest and most diverse real property portfolios in Canada has developed a formal risk management framework in a spreadsheet format to help project stakeholders have a clear understanding of the major risk exposures relative to the project objectives. This framework involves the project manager developing a comprehensive list of potential risk events and assigning linguistic values (High, Medium, Low) for the probability of occurrence and consequence for each risk event identified. A risk response in terms of mitigation or reduction measures is identified for each risk event and a dollar value is assigned to cover the risk exposure and residual risk remaining after considering the risk response. This information is documented in the risk register spreadsheet and the project team is required to update and manage its content over the life of the project. Additionally, risk registers have also been implemented as computer databases. Among them are Risk Radar (Integrated Computer Engineering Inc. 2002) and SiteRisk (Andersen 2001). (Hall et al. 2001) describe a spreadsheet-based software tool termed RiskCom that allows the user to record information during the different stages of risk management. Pre-programmed help functions that provide instructions and information on different stages of the risk management process guide the user through the different stages.

All of these approaches are useful for the initial identification of risks and assist in the risk management process. However, they are not dynamic, do not reflect the associations between risks and representations of project context components signifying the drivers of a particular risk, and do not reflect the changes in the project risk profile as new information becomes available. In addition, these approaches do not enable the user to gain insight on risk distribution and properties of risk issues and events. The features of the risk management tool introduced in this paper demonstrate how we have addressed the challenges of risk management in a complex building project with multiple and inter-related dimensions, and how we have responded to the industry need for a tool with knowledge management capabilities.

SUMMARY OF APPROACH USED IN KRIS

Several practical and intellectual issues need to be considered in developing a computer-based methodology that can be used in managing risk information and knowledge for the broad spectrum of project types and sizes encountered in practice. After reviewing the state of the art in the academic literature and observing first hand processes carried out by industry practitioners, we have posed the following questions to guide our research:

1. A fundamental question that needs to be addressed is the identification of the most appropriate role(s) for the machine and the system users in developing a computer-based methodology. Does one attempt to opt for a higher degree of automation at the expense of flexibility in terms of the ability to model a diverse range of project types and the ability of users to add/edit the contents or vice versa?

2. How can the set of risks that pertain to an infrastructure project be represented? What are the properties of individual risks (e.g., the project phase to which the risk pertains, the project stakeholder responsible for the risk), which are important in carrying out the various tasks of risk management (i.e., identifying, quantifying, and developing responses), and how should such properties be modeled?

3. How can the relationship between the project context and the risks of a project be represented? Furthermore, how can the project context be modeled in support of representing that relationship?

4. How can the representations of project risks, their properties, and the relationship with the project context be exploited in order to gain additional insights that can assist in the decision making process? What are the functions (e.g., querying, reporting) and formats, which are of use?

5. What is the information and knowledge content that can be re-used between projects? How can such content be archived in a project neutral format? How can the content from past projects be extracted from the archives and what sort of assistance can be given to the user in deciding the appropriate content to re-use?

The KRIS methodology allows users to develop a model of the project context and integrate the context representation with a representation of the risks of the project detailed in the risk view. We have characterized the project context through four views or dimensions, which are the physical (what will be built), process (how it will be built and operated), organizational / contractual (the organizations involved and the relationships among them), and environmental (the natural and man-made environments in which it is being built) – (yet to be treated in entirety is integration with the project's cost view). Hierarchical representations of these four views are linked to the risk model making use of risk driver –

risk issues associations. The integration of views allows for changes in the project context such as design, regulatory and scope changes to be reflected in the risk profile. Risk events are driven by components in one or more views (e.g. organizational entities, physical aspects of the facility, schedule activities) the presence of which, either singly or in combination with other risk drivers, lead to the potential for a risk event occurring. Since the tool is capable of integrating multiple views of a project, a querying function is supported, which enables the user to gain additional insights into the risk profile such as the spread of risks over time and responsibility domains.

The KRIS approach provides an architecture that allows users to model a categorized listing of risk issues and events, and to model their properties. While the use of risk categorization or a risk breakdown structure in modeling project risks is highly recommended in the literature (e.g., Hillson, 2003), a standard classification scheme does not exist. The KRIS architecture allows an organization to use a risk categorization and nomenclature scheme of their choice, with flexibility being provided in terms of the number of classification levels used in grouping the risk components.

Once the user models a project, the representations of the risks identified, as well as the representations of the project context can be archived in a project neutral format within KRIS. As an organization keeps on undertaking projects, the archive of project neutral representation, herein referred to as standard libraries are augmented allowing the organization to continuously enhance its repository of risk-related information and knowledge. We have also provided the architecture for the development of master lists of entries that can be used in populating the properties of risk events (e.g. mitigation measures). The approach that we have taken in allowing the content of the libraries to be re-used, as well as the approach taken in devising reporting and querying procedures (issues relating to question 4) are discussed in detail later in the paper.

With respect to the first question, our philosophy has been to develop an approach that can facilitate the application and re-use of information and knowledge, as opposed to an answer-based approach, in order to ensure the broadest applicability possible of the approach adopted. Keeping in line with our philosophy of assisting a user as opposed to generating answers, we have incorporated several modes that can be made use of in re-using archived content, thus providing the user with control over how much assistance is to be made of it. In the most rudimentary mode of use, standard libraries (or master lists) are utilized as a mnemonic device. For example, the tool supports a standard risk register (SRR) in which the user manually browses through the listings of potential risk issues and selects ones that are thought to be relevant to the project under consideration, thus building up a risk register for the project. This mode of use is envisaged in instances where the project is of a unique nature or in a unique environment, precluding the use of components from the standards side in describing the project context. It is noted that even though in this mode, the system does not provide assistance in identifying risks, risk properties such as the mitigation measures adopted on past projects, the contractual language used in transferring risks, and the project parties best suited to handle the risk are encoded within the components selected from the SRR and can assist the user in decision making. The mode of use that offers the most assistance involves the semi-automated checking of component attribute values (e.g. endangered species present) and the activation of relevant risks in the project risk register.

CASE STUDY PROJECT

In order to illustrate features of the KRIS approach, we apply it to a unique building infrastructure project proposed for construction by 2011 in the GVRD. One author of this paper was on the project team for over two years and is therefore familiar with all technical and user requirements of the project. The project, a mixed use building(s), is both capital and operationally intensive with a proposed budget in the order of 300 million dollars and a construction period in excess of 2 years. The facility is proposed to accommodate 1800 employees. The volatility in the construction market place, high client involvement in the design because of the uniqueness of the functional program, special technical performance requirements and the multiplicity of stakeholders including all three levels of government are just some of the complexities of the project which make it unique.

It is anticipated that the tenant organization will enter into a lease agreement with the contracting organization who will own the facility. This results in a multiplicity of organizations being involved, which complicates the decision making process to meet the program requirements of the two primary organizations, and brings in risks related to long time lines to reach consensus. The potential for a change in government leadership, or changes in organizational policies (of both organizations) in a government environment that is in flux highlights the need for effective communication between regional and national offices as well as between organizations, and the need for a tool that can track the evolution of decision making over time and the potential risks of exceeding the project completion date, not meeting budget constraints, and failing to deliver on one or more key scope objectives.

Other project stakeholders include government authorities from all three levels of government. Owners of adjacent property facilities are interested in the opportunity for some shared services. In addition, the tenant organization has service delivery responsibilities to the public and to other government agencies. Adjacent to the project site is a municipal park, which is actively used by local public interest groups with specific environmental mandates (e.g. tree conservation). Risks are associated with the heavy involvement of diverse stakeholders both in project planning, design and execution.

It is uncommon for a facility of this size and with the unique program requirements to be constructed in the region. Thus, the pool of design and project management expertise available that is familiar with delivering such a project is scarce. The tenant organization tends to be influenced by world events, and how best they respond to complex domestic or international situations makes it difficult for the scoping of capacities to house personnel and associated technical requirements. In addition, the tenant organization has changing needs which has implications for the flexibility in the building design to accommodate future changes, as well as technical, security, post disaster and environmental design performance requirements. As a result, there is a substantial risk that the project scope will not be responsive to user needs at the time of building occupancy, a primary risk that the project team wishes to ensure is minimized.

Construction costs have increased by over 45% during the period 2000 to 2005 in the lower mainland, driven by the increase in construction volumes, material costs and limited labour resources (BTY Group, 2005). Recent construction cost escalation rates of 8-10% per year in aggregate and up to 20% with respect to some key trades (electrical and mechanical) as compared to the inflation rate represented by the consumer price index of some 2-3% per year have created enormous budget pressures not withstanding the allocation of dollars in the original budget to address expected construction cost escalation. The performance requirements outlined for this project are constrained by budget limitations in this booming construction market and in a risk averse environment of the contracting organization.

Thus the challenge faced by the project manager involves identifying, tracking and managing risks, several of which are interrelated, and which arise from an economic environment at or close to capacity, a complex stakeholder environment, and a technically sophisticated facility for which scope creep is inevitable because of the need to respond to external, uncontrollable events, all within defined budget and time frame constraints.

The project manager developed a risk register, in order to assist in the management of these risks, using the organizational framework in conjunction with two other owner risk frameworks available. Other documents available included the project charter, schedule, building functional program, environmental phase 1 and phase 2 reports, and preliminary engineering reports. The register, in a spreadsheet format, was divided into three risk categories; the first two categories addressed strategic and operational risk events to the programs of both organizations and examined the risk/benefits to the owner proceeding with the project. The third risk category addressed project delivery risks and examined those risk events common to project delivery (e.g. adverse geotechnical conditions, errors and omissions) in addition to those risk events caused by broader government issues and by the two organizations involved in the project. Although helpful, this register does not reflect the dimensionality of the project and since it is a passive document, updating the register to reflect the associated new risks with respect to changes in the project context, assumptions, changes in the regulatory or organizational environment over time has been a challenge. A formal database or record of risks from past projects performed by this organization was not available to the project team; therefore, another challenge faced by the team was to develop a comprehensive list of risk events for this complex, multi-faceted project. Such situations have provided the impetus for the kind of approach captured in KRIS.

APPLICATION OF KRIS APPROACH ON PROJECT

In what follows, we use the case study project to highlight features of our risk management tool. In particular, we demonstrate the knowledge management features, modeling of risk properties, the categorization of risks, and the generation of insights into the risk profile of the project through targeted reporting strategies. We believe each of these features improves the risk management process and assists in the decision making processes in the project planning and execution stages. The actual project risk register, which is considered to conform with the current best practice approach to risk management followed by practitioners involved in infrastructure delivery, was used as the base reference document to assess some of the benefits and limitations of applying KRIS to model the project risks.

KNOWLEDGE MANAGEMENT FEATURES

KRISs' architecture allows the user to model a project and its risk register using a bottom up approach, a top down approach or a combination of the two. For the bottom up approach, the user develops the various views of the project and the associated risk register from scratch. Alternatively, using a knowledge management feature of the tool, the user can draw upon standardized master lists to populate select views of the project with relevant components and their associated properties. These master lists represent the organizations experience accumulated over many previous projects. For example, as shown in figure 1(a), the environment master template or list is shown and enables the user to select applicable environmental components that describe the natural and man made environment in which the project is being built and thus build up an Environmental Breakdown Structure (EBS) for the project at hand. (The left hand side of figure 1(a) indicates an extendable list of user-defined templates. A second concept of templates also supported in the system, but not elaborated upon herein, is complete project templates which are comprised of all views of a project developed in support of a particular project instance – a hospital, a bridge, etc., but stripped of parameter values, thereby allowing their reuse for similar future projects.) Figure 1(a) also illustrate how the interface of KRIS allows users to visualize the entire list of risk components organized into various categories, and expand / collapse parts of the tree in navigating among the entries. In this case, the entity 'Design Earthquake' has been selected and properties of this entity are illustrated in figure 1(b) including attribute descriptions (e.g., Return Period, Near Field Event Magnitude), a description of the unit of measurement (binary, quantitative, linguistic) and the unit itself (e.g., Year, Richter). The user can add, delete or edit each of the entity attributes as project information is updated or made available. Other properties treated deal with links to standard EBS records, links to risk issues in the standard risk register, and the ability to record other relevant information.

A portion of a standardized library, the standard risk register, is shown in figure 1(c) and is a repository of information on risk issues, events and mitigation measures. Information on other properties of the risk event such as a risk description, driver, measures affected (time, cost, revenue, etc.) and values among others can also be recorded in this master list. Furthermore, the tool also allows sources of information such as websites, documents, and media files to be referenced and associated with representations of risk components. Thus, representation of each risk within KRIS allows for the compact documentation of all sources of information that leads to its identification as well as the sources of information that are used in assisting with the quantification and allocation processes. Only one standard risk register is supported, as from first hand experience risk profiles for the same type of project can vary markedly from project to project, and a legitimate fear of project personnel is that important risks could be missed. Hence the single, standard, master risk register.

The development of a comprehensive project risk register often requires input from project participants with diverse specialties (e.g. technical, environmental, and financial among others) because few, if any, of the project stakeholders have a complete understanding of the full spectrum of project risks. The participation time and associated costs for the involvement of multi-disciplinary project participants in the development of a project risk register can be substantial particularly for a project with the scale and complexity as the case study project. Although it is a unique facility, it still has many physical and process components and related risk components that are common to other projects undertaken by the contracting organization in past projects. The use of the knowledge management features of this tool could substantially add value to the project financial bottom line in terms of the time

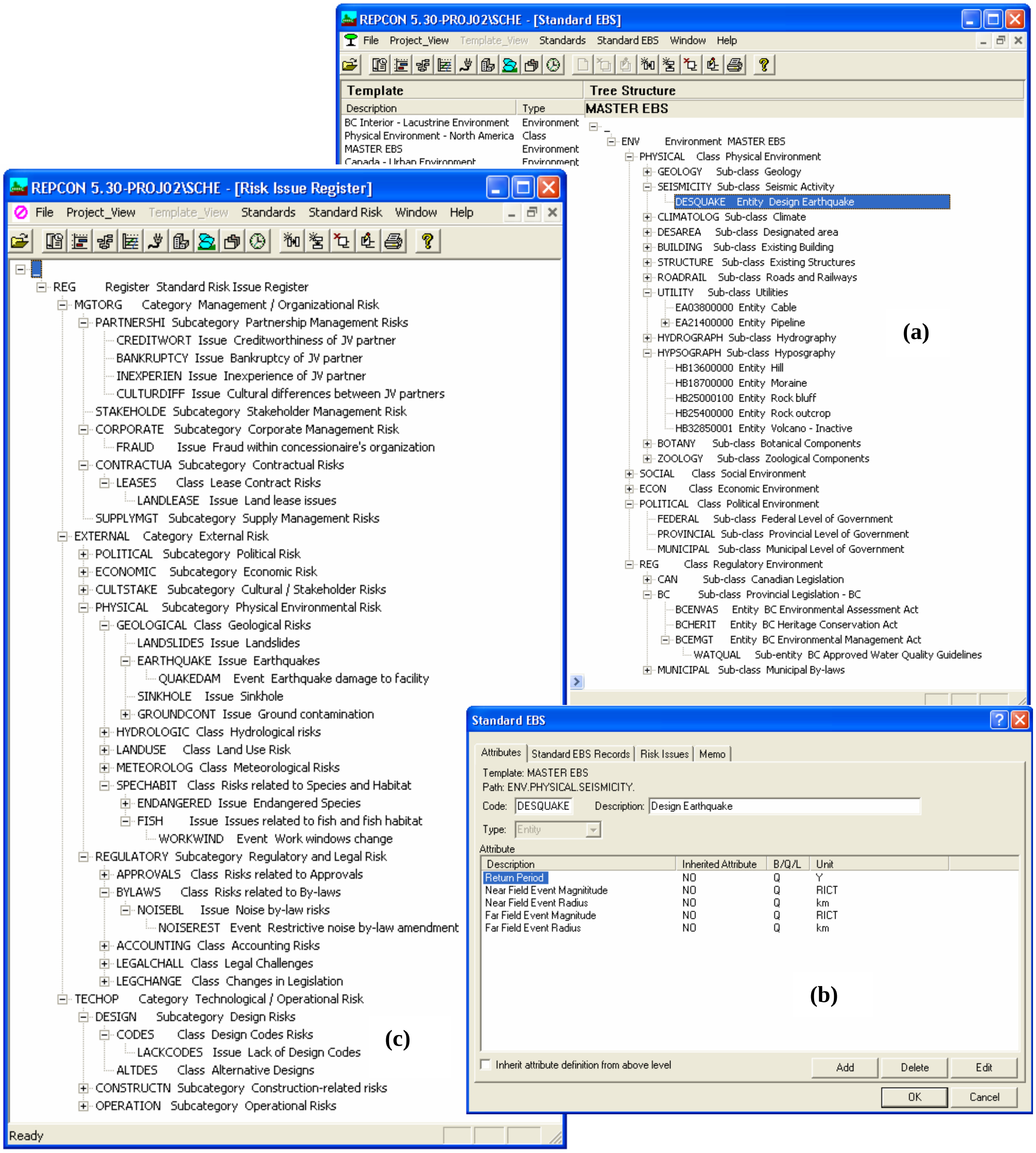

Figure 1 Knowledge Management: (a) Environmental Breakdown Structure (EBS) Templates; (b) Attributes of an EBS Component; (c) Standard Risk Register

and cost saved in developing a comprehensive risk register because as a mnemonic device it enables the user to determine which components in the master lists are applicable, as well as which ones should be added because of the uniqueness of the project (and later incorporated into the standard risk register).

FLEXIBLE REPORTING STRUCTURE

KRIS supports a flexible reporting structure that gives the user control over the reporting content such that targeted reports can be generated once the project context is modeled and the associated risk profile developed. This feature is essential for project management personnel to gain insights into the project risk profile in terms of the most significant drivers, groupings of risks in time and space, the reasonableness of risk assignments, and the magnitude of potential risks, and then communicate findings in a focused and easily understood way to the relevant project participants and stakeholders. Reporting features currently supported include the ability to develop risk data report content profiles, and user specified profiles which allow one to query the system as to specific risk contexts. As shown in figure 2(a), the user first specifies the data they want contained in the report, in this case it includes, risk event drivers, and performance measures affected, along with projected outcome values. They then specify for which risk events they want the foregoing data, by specifying select conditions and select criteria. For our example, it is desired to choose all

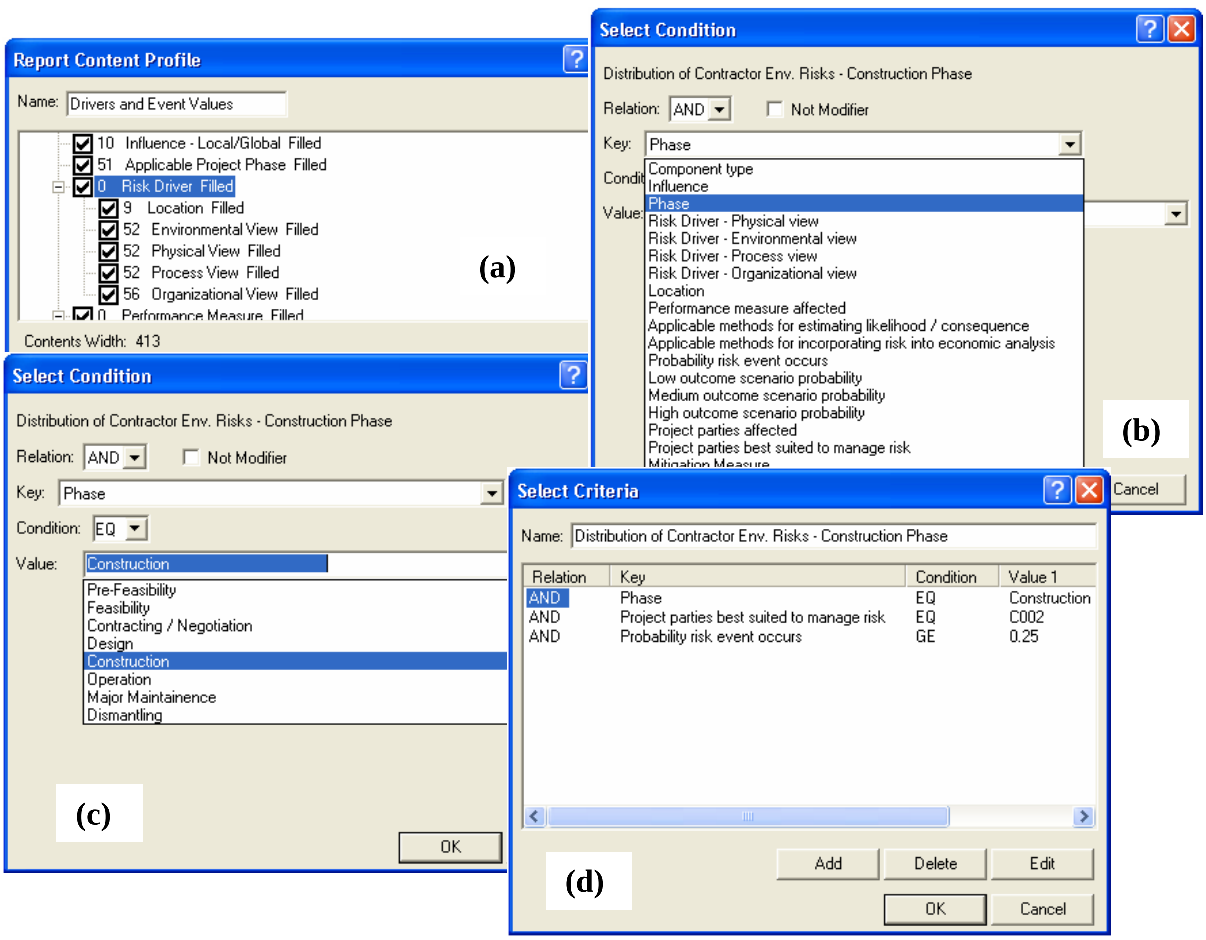

Figure 2 System Reporting: (a) Defining a report content profile; (b) Selecting Phase as a query condition; (c) Selecting the value for a condition; and, (d) The complete select criteria query profile.

risk events in the construction phase for which party C002 is best suited to manage, and for which the probability of the risk event occurring is greater than or equal to 25% (figure 2(d)). In defining these criteria, the user has access to a list of conditions that can be used to form the query – as shown in figure 2(b) Phase is selected, and the value for this condition is assigned in figure 2(c). Figures 2(a) through 2(c) indicate the ease of access to the representation of the project context and the values assigned by the user. Finally, figure 2(d) demonstrates the selection criteria for the risk events of interest to the user.

CONCLUSION

Past research on the topic of risk management has resulted in very useful frameworks for guiding the risk management process. However, the same cannot be said of approaches available for managing the information and knowledge associated with the process. We have described results from an ongoing research effort that attempts to fill this void and demonstrated its features on a case study project. The computer based approach that we have introduced allows an integration of risk information with models of the project context as described by four views – environmental, physical, process, and organizational/contractual. The tool also fosters consistency and knowledge management. On-going work is directed at the development of interfaces for the elicitation of quantitative and linguistic estimates of risk probabilities and consequences from project stakeholders and visualization schema that enable decision makers to examine the interactions between risks, and the distribution of risks in the spatial and temporal domains. Scenario and versioning features are also currently being considered for development such that the user could compare the risk profile that was anticipated during the early stages of the project with an evolved version of the register that depicts the risk events that actually occurred on the project, their impact upon performance measures, and the degree of success of mitigation measures adopted.

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