24 Page Preview

PUBLICATION NUMBER	AAT NR12983
TITLE	Application and re-use of information and knowledge in managing risks of infrastructure projects
AUTHOR	De Zoysa, Garumuni Niranjan Sanjaya
DEGREE	PhD
SCHOOL	THE UNIVERSITY OF BRITISH COLUMBIA (CANADA)
DATE	2006

APPLICATION AND RE-USE OF INFORMATION AND KNOWLEDGE IN MANAGING RISKS OF INFRASTRUCTURE PROJECTS

by

GARUMUNI NIRANJAN SANJAYA DE ZOYSA

B.Sc., The University of Moratuwa, Sri Lanka, 1996
M.A.Sc., The University of British Columbia, Canada, 2000

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF
THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

in

THE FACULTY OF GRADUATE STUDIES

(Civil Engineering)

THE UNIVERSITY OF BRITISH COLUMBIA

January 2006

Your file Votre référence
ISBN: 0-494-12983-2
Our file Notre référence
ISBN: 0-494-12983-2

Abstract

The management of economic risks is critical for the success of major infrastructure projects. As with other management challenges, the tasks associated with risk management rely heavily on knowledge and experience, and also involve the use of a diverse and sizeable set of information. Thus, computer-based methodologies that can allow the application and re-use of information and knowledge have the potential to be particularly useful to an organization in managing risks. Described in this thesis are the results of an effort to develop such a methodology.

The methodology represents the risks and the context to which they apply by considering five dimensions or views. The five dimensions are the Risks, the Physical components of the project, the Processes required to procure and operate it, the Organizational entities involved, and the Environment in which it is being procured and operated. The methodology facilitates the creation of enterprise-level ontologies or libraries for each of these views. The libraries which can be augmented over time are made up of components relevant to a particular view which are modeled in a project-neutral format. Information and knowledge that is relevant to supporting project risk management is modeled within the components.

In analysing the risks of an individual project, the methodology facilitates the development of project-specific models for each of the five dimensions for that particular project making use of the content of the libraries. The relationship between the context and risks is modeled through a driver-issue relationship and refined using the notion of spatial and temporal gateways. The methodology also allows the user to leverage the representations to derive insights such as the distribution of risks among spatial location and among project participants, and the evolution of risks as project conditions change. It is anticipated that the functionality provided for re-using information and knowledge and for leveraging available information will assist an organization in identifying a more complete set of risks, in providing more refined input to economic models used in decision making, and in deciding on appropriate risk assignments, thus bringing an organization closer to achieving success on the projects they undertake.

Table of Contents

List of Tables

List of Figures

Abbreviations

COSEWIC	Committee On Status of Endangered Wildlife In Canada
CPI	Consumer Price Index
DBFO	Design Build Finance Operate
DSCR	Debt Service Coverage Ratio
EBS	Environmental Breakdown Structure
EIA	Environmental Impact Assessment
FDBOM	Finance Design Build Operate and Maintain
HM	Her Majesty's
IRR	Internal Rate of Return
IT	Information Technology
KM	Knowledge Management
KRIS	information and Knowledge application and re-use in RISk management
LCC	Life Cycle Cost
MCS	Monte Carlo Simulation
MEBS	Master Environmental Breakdown Structure
NPC	Net Present Cost
NPV	Net Present Value
OLB	Okanagan Lake Bridge
P3	Public Private Partnership
PBC	Partnerships British Columbia
PFI	Private Finance Initiative
PMI	Project Management Institute
PRIME	Project RIsk knowledge Management Environment
PRR	Project Risk Register
PSC	Public Sector Comparator
RAMP	Risk Analysis and Management for Projects
REOI	Request for Expressions Of Interest
RFP	Request For Proposals
ROI	Registration Of Interest
SEL	Standard Environmental Library
SRR	Standard Risk Register
TRIMS	Technical Risk Identification and Mitigation System

Acknowledgements

Foremost, I would like to express my sincere gratitude to Prof. Alan Russell whose ability to achieve the perfect balance between being demanding and empathetic towards his students continuously amazes me. I am immensely grateful for his guidance and encouragement throughout my life as a graduate student. My thanks also go out to Professors Thomas Froese, Barbara Lence, and Scott Dunbar for serving on my Ph.D. committee and for their comments that helped make my thesis a much better one.

I would like to thank Prof. Roger Flanagan for a very thoughtful review of the thesis in his role as the external examiner, and also to the university examiners Prof. Tim McDaniels and Prof. Sigi Stiemer for their constructive review of my work.

The pursuit of graduate studies has its ups and downs and having a set of great friends to share both its rewards and frustrations helps immensely. A big thank you to Heli, Arezou, Tanzy, Paul, Justin, Ming En, Kehui, Min, Dinesh, Arthur, Marina, Asad and David for all the fun times. I really think we contributed greatly to the success of the coffee industry irrespective of how we may have helped science along. I am also indebted to Professors Malik Ranasinghe and Sam Hettiarachchi of the University of Moratuwa and to Dr. Ziad Shawwash of BC Hydro for their encouragement and advice at various stages of my studies.

Finally, words could never do full justice to the gratitude I feel towards my mother and late father and my wife Missara for all the sacrifices they made and for their unfailing support and belief in me.

Dedicated to the memory of my father and to the hope and joy that someone due later this year brings.

1 Introduction

1.1 Managing the Economic Risks of Infrastructure Projects

Presently, governments on a worldwide basis are faced with an insatiable demand for public infrastructure such as roads, bridges, transit systems, water supply systems, and wastewater treatment plants. They wrestle with how to construct these facilities in the face of tight budgets and pressing needs for other services such as health and education. As a result, governments are exploring a greater range of procurement modes in an effort to meet some of the demands for new or improved infrastructure in a timely manner. Many of these modes can be grouped under the rubric of public-private partnerships, or P3's. Of particular interest are those modes (e.g., Finance, Design, Build, Operate, and Maintain – FDBOM) that maximize the involvement of the private sector and which result in the greatest transfer of risk to this sector. Major design and construction firms are embracing the challenge of such procurement modes, as they provide the opportunity to deliver value-added services and create new business opportunities.

The recent emphasis on considering alternative modes of procurement for public infrastructure has resulted in governments taking a more disciplined approach to risk management, especially for major projects. For example, it is said that the rigour of the risk assessment and contractual risk allocation processes undertaken for P3 projects in Victoria, Australia exceeds any risk evaluation process ever undertaken by an Australian government (Fitzgerald 2004). Private sector firms now find themselves assuming responsibility for all facets of the total life cycle of a project, including financing, regulatory processes, design, construction, commissioning, revenue generation, operation and maintenance, and debt servicing. As a result, they must identify and manage a much larger spectrum of risks – in fact it is this extended risk transfer that has special appeal to government.

Effective management of project risks has the potential to bring about cost savings and other benefits. Andersen (2001) draws attention to a study carried out in Denmark which suggests that savings in the range of 800 million euro could be achieved annually in the Danish construction industry through the introduction of formal project risk

management. 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 descoped[1].

However, the scale and complexity of infrastructure projects can present significant difficulties for risk management. The lengthy time spans of the pre-financial close phase and the operational phase, the multitude of stakeholders involved, coupled with requirements to carry out environmental studies and adopt protective measures, complicate an already complex task of designing, constructing, and operating a facility that typically contains a vast number of components and an equally large number of technical and administrative processes (Flanagan and Norman 1993). Therefore, the task of identifying the risks associated with all facets of the project lifecycle, assessing their magnitude, and the development of response strategies is non-trivial. In some instances the number of categories of risks such as design risk, project scope risk, native title, construction risk, commissioning risk, industrial relations risk etc. can run into over 100 (Fitzgerald 2004) with each category consisting of several individual risk events.

As with other management functions, knowledge and experience are invaluable assets in successfully dealing with the risks of a project. Recognizing the risks that are relevant to a particular project, identifying their impact on project performance measures, and devising appropriate risk mitigation measures are all tasks which rely heavily on past exposure to similar situations. However, knowledge within organizations that resides primarily in the minds of experienced personnel is seldom documented in a consistent and accessible manner (Rezgui 2001), and can easily be lost through resignations, downsizing, and retirements. Computer-based methodologies that make use of advances in Information Technology (IT) have the potential to play a significant role in facilitating the capture of knowledge gained on past projects in a manner suitable for re-use. As

[1] A word that is yet to reach most dictionaries, "descope" refers to the reduction or elimination of elements of a project that can be accomplished, while still permitting the project to meet the critical project objectives. Source: NASA (http://appl.nasa.gov/resources/crm/glossary.html)

identified by Fitzgerald (2004) in a study of P3 projects undertaken in Victoria, Australia, "*the expertise of the risk evaluators and the comprehensiveness of the risk schedule does not substitute for the lack of an empirical database of what risk events major projects of this nature face and with what frequency and cost should they be expected*". Such methodologies also have the potential to assist users in exploiting project information and archived knowledge in effectively tackling project risks. Their use can help reduce the burden on the project team in identifying and managing all significant risks, and assist in avoiding costly omissions that could undermine project success.

To date, a methodology that can deliver on this promise does not exist, although a number of researchers have sought to develop risk management tools using various IT approaches, (e.g., Niwa 1989, Tah and Carr 2001). While progress has been made in treating subsets of the risk management process, further success depends on developing an approach that treats several issues comprehensively and in unison. Among such issues is the need to explicitly consider the context under which risks occur and need to be managed, i.e., to treat the project context, and allow facility to users for capturing their knowledge in a reusable and editable format, features that are not fully addressed by current approaches.

An integration of risk information with information describing the project context will allow the user to identify and focus on context-specific risks as opposed to perusing a generic listing of risks made available by tools such as prompt lists. It could also assist in identifying changes in the risk profile that could accompany changes in other project information, especially when design changes are made, or as more project information is obtained. A matching of risks to project context information could also facilitate knowledge re-use on future projects by allowing the identification of recurring project conditions that act as drivers of risks. A methodology also needs to be cognizant of the realities of full-scale projects for it to be practical. These include the need to work at different levels of granularity of project definition as the project life cycle unfolds, the need to cope with vast amounts of information, and the need to work with incomplete information. This thesis documents the development of a methodology that meets these broad requirements. The methodology is termed KRIS (an acronym for 'information and **K**nowledge application and re-use in **RIS**k management'). In the following section a

summary of the specific research objectives is presented, followed by a commentary on the scope of the research endeavour.

1.2 Objectives and Contributions of the Research

The management of risks necessarily involves their identification, quantification of their impact upon performance measures, and the development and implementation of risk response measures (Chapman and Ward 1997; Construction Industry Research and Information Association 1996). These risk management functions require the use of a diverse set of information such as the conditions under which particular risk events occur, probability and consequence values of the risks, details of the mitigation measures that are applicable, and information regarding the project stakeholders affected by the risk. The broad objective of the research was to develop a methodology that facilitates the modeling and application of information and knowledge in managing the risks of an infrastructure project and which facilitates the re-use of such content on future projects. The specific research objectives that relate to this task are:

- Identifying the core set of information and knowledge groups used in managing economic risks as well as the concepts that are applied in the process;
- Developing a set of constructs that can be used within a computerized environment to model the information and knowledge related to risks as well as the aspects of the project context that are of relevance to risk management; and,
- Formalizing a methodology that allows representations of the risk-related information and knowledge to be generalized and stored in a project neutral format, and facilitates the extraction and use of the project-neutral representations in developing a model of the risk profile on future projects.

KRIS meets these objectives, and if applied correctly would move an organization closer to its prime goals in risk management, which are to minimize exposure to downside risks and maximize exposure to upside risks, or to minimize risk altogether. Whilst the ultimate contribution of KRIS to risk management practice is in facilitating an organization to better achieve these goals, its research contribution arises as a result of

answering a series of questions and challenges that relate to both the intellectual and practical aspects of the risk management domain. Broadly, the questions that need to be addressed by a computer-based methodology that aims to allow an organization to manage risk-related information and knowledge fall under several topics. They are:

(i) Questions as to the most appropriate role(s) for the machine and for the system users in developing a computer-based methodology;

(ii) Questions related to the representation of risks;

(iii) Questions related to representing the project context-risk relationship and the representation of the project context;

(iv) Issues dealing with leveraging such representations to maximize the assistance that can be provided to users to derive meaning from the models. For example, to support diagnosis such as the work activities that are most risk prone and the change in the risk profile that occurs as alternative activities are considered; and,

(v) Questions relating the content that can be re-used for other projects and the means by which re-use can be facilitated.

Each topic is made up of a series of questions and they are elaborated upon in Chapter 3. Current approaches have either implicitly or explicitly dealt with some of these questions. However, the treatment has been incomplete with regard to individual questions and no approach has attempted to deal with them in totality. The contribution of KRIS therefore is that it provides a means of addressing each of these questions individually and more importantly of addressing them in unison, a feature that provides users with unmatched capability of modeling, re-using, and deriving meaning from the risk-related information and knowledge on infrastructure projects.

1.3 Research Scope and Anticipated User Audience

The focus is on supporting the risk management function in civil infrastructure projects, with the emphasis being on risks with economic consequences, i.e., risks that ultimately impact economic performance measures of a project such as total project cost and duration, Net Present Value (NPV), Debt Service Coverage Ratio (DSCR), and Internal

Rate of Return (IRR). While projects procured using alternate modes such as P3s are of particular interest due to the greater emphasis placed on risk analysis, the application of KRIS is not restricted to projects procured as P3s. It could also be utilized on projects procured using a traditional design-bid-build approach, albeit to model and manage information and knowledge related to a narrower realm of risks, particularly in the case of private sector users whose role is limited in traditional delivery. The use of examples that have been drawn from P3 project scenarios in illustrating the research concepts does not therefore reflect limitations in applicability. In a similar vein, the application of KRIS does not assume the use of a particular risk management approach. As will be elaborated in Chapter 2, several approaches towards the risk management process have been proposed by various authors. A core set of information common to many of these approaches are modeled within KRIS making it broadly applicable.

Risk management is a continuous process that is applied in a transforming manner throughout the lifecycle of a project. The approach towards risk management along the timeline of a project requires consideration of the differences between the phases of the project life cycle (Chapman and Ward 2003). The phases of a FDBOM project from both public sector and private sector perspectives are shown in Figure 1. During the initial planning phase of a project, risk management is geared towards supporting the government's go / no-go decision and decisions as to the scope of the project, as well as providing input to validating the use of P3 as the preferred mode of delivery. Alternatively, from a private sector perspective the primary role of risk management during the early stages is to provide input to the private sector bids. In the succeeding contracting phase, the focus of both the public and private sector is more on the use of contractual risk transfer as a means of risk mitigation. The project execution phases are characterized by implementation of risk mitigation measures to control the occurrence and the impact of risk events. KRIS is aimed primarily towards supporting the planning, procurement, and the contracting phases of a project, as these are the phases during which strategic decisions are made by both the public and private sector with critical input from the risk management process. Having said this, extensions can be readily made to the methodology to allow for the tracking of risks during the course of a project.

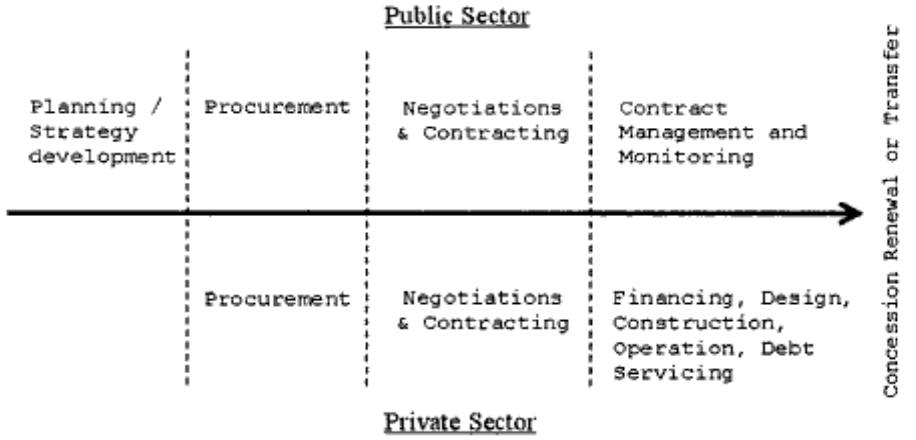

Figure 1. Project Phases of a FDBOM Project - The Viewpoint of the Public and Private Sectors

Data, information, and knowledge regarding the risks of a project are treated with varying degrees of confidentiality throughout the project lifecycle. In a P3 project, the government will treat values assigned to various project risks in its financial models as confidential in order to preserve competitive pressure (Partnerships British Columbia 2005b). Making known such value assignments will result in the government being at a disadvantage as it negotiates the intricacies of risk allocation with the private sector. The private sector for its part would strive to keep the mitigation strategies that could affect its risk profile and the value of their bid confidential in order to achieve success during the bidding process, and in the event of success, in negotiating a favourable apportionment of risks during the Best and Final Offer process (Akintoye et al. 2003). From a methodology development perspective, the implication of such practices is that support for managing risk-related knowledge is best provided at the enterprise level, an assertion further strengthened when risk perception is taken into account.

Different organizations and individuals tend to have different perceptions of the risks associated with a project (Gallimore et al. 1997). This can hold true in a comparison of the private sector and the government sector, as well as in comparing different private

sector entities involved in the project delivery process such as general contractors, financiers, and facility operators. The difference between the risk perceptions of different parties can be as far apart as one party seeing an opportunity in an instance where another believes a downside risk to exist. Therefore, taking into account the issues of confidentiality of information and the potential differences in risk perceptions, KRIS has been developed for use within a single organization. Enterprises that serve as candidates for users include the government represented by individual ministries, and entities such as Partnerships British Columbia which is responsible for bringing together ministries, agencies and the private sector to develop projects through P3s (Partnerships British Columbia 2005a). Private sector entities such as engineering firms and lending institutions also stand to gain by utilizing a methodology such as KRIS that allows the re-use of risk-related information and knowledge on the different projects they undertake, especially P3 ventures in which they are faced with the task of managing a much larger spectrum of risks.

1.4 The Research Path

The author's thoughts first turned towards research on information and knowledge re-use in risk management as a result of discussions between the author and his research supervisor during a period in which the author was completing a Masters thesis on environmental risks. During that research, it became obvious that while the topic of risk management has seen extensive research interest over a period of time, much work remains to be done in managing[2] the knowledge and information associated with the process. Also moulding the focus of the research was a renewed interest within the province of British Columbia, Canada in alternative modes of infrastructure delivery. Whilst the arguments as to the pros and cons of such modes persist within the province and elsewhere, several such projects have got off the ground in recent years. As stated

[2] As will be discussed in Chapter 2, a multitude of definitions exist for terms such as 'knowledge management'. In the context of the research described, 'managing information and knowledge' is used to collectively refer to the tasks of developing the information and knowledge assets as an organization undertakes projects and applying such content in managing the risks of individual projects.