DEVELOPMENT OF A RISK MANAGEMENT DECISION SUPPORT SYSTEM FOR INTERNATIONAL CONSTRUCTION PROJECTS

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ABSTRACT

DEVELOPMENT OF A RISK MANAGEMENT DECISION SUPPORT SYSTEM FOR INTERNATIONAL CONSTRUCTION PROJECTS

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It is agreed upon by many researchers that, although risk management (RM) is accepted as one of the critical success factors for construction projects, project participants generally do not have sufficient knowledge pertinent to risk management concept and the number of risk management support tools which facilitate the process is rather low. In order to facilitate risk management activities, decision support tools that will enable risk identification, analysis and response strategy formulation should be developed. Decision support tools are necessary for systematic identification of risks, scenario generation, proactive management of risk and integration of risk management activities with other project management functions such as planning, cost estimating and monitoring project success.

The aim of this study is to introduce a conceptual risk management model and a prototype risk management decision support system (DSS) which is applicable to construction projects. The proposed decision support system, namely Integrated Risk Management System (IRMS), is designed to support the user at all phases of the risk management process and to integrate risk management activities with other project management functions in the bid preparation stage of international construction projects. A risk management process model has been developed as well as a risk information model so that IRMS can be used for systematic management of risk by all parties involved in a construction project. Major functions of IRMS include, risk identification by using a built-in Hierarchical Risk Breakdown Structure (HRBS), risk analysis by Monte Carlo (MC) simulation, risk assessment by risk rating, risk re-assessment, response generation, risk monitoring and corporate memory. The applicability of the system has been tested by a real case study and its functionality has been demonstrated using the data associated with the case study.

Keywords: Risk Management, Decision Support Systems, International Construction Projects

ÖZ

ULUSLARARASI İNŞAAT PROJELERİ İÇİN BİR RİSK YÖNETİM KARAR DESTEK SİSTEMİ GELİŞTİRİLMESİ

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Risk yönetimi, bir çok araştırmacı tarafından inşaat projelerindeki kritik başarı faktörlerinden biri olarak gösterilse de, sektör katılımcılarının risk yönetimi konusunda yeteri kadar bilinçli olmadığı ve risk yönetimini kolaylaştıracak karar destek sistemlerinin bulunmadığı, bu sebeplerle de risk yönetiminin çoğunlukla sistematik olarak uygulanamadığı bilinmektedir. Bu bağlamda, risk yönetim uygulamalarını iyileştirmek amacıyla, inşaat projelerinde ortaya çıkabilecek olan risklerin tanımlandığı, risklerin proje üzerindeki etkilerinin analiz edildiği ve risk yönetim stratejilerinin geliştirildiği karar destek araçlarının oluşturulması hedeflenmelidir. Risklerin sistematik olarak incelenmesi, risk senaryoları kurgulanması, proaktif risk yönetim stratejilerinin geliştirilmesi ve risk yönetimi aktivitelerinin planlama, proje başarısı ve maliyet hesaplamaları gibi proje yönetimi fonksiyonları ile entegrasyonunun sağlanması için karar destek sistemleri gerekmektedir.

Bu tezin amacı, risk yönetim aktivitelerini destekleyen, risk yönetiminin diğer proje yönetim fonksiyonları ile bütünleşmesini sağlayacak kavramsal bir risk yönetim modelinin ve modelin inşaat projelerinde kullanılabilirliğini artıracak bir risk yönetim karar destek sisteminin tanıtılmasıdır. Önerilen karar destek sistemi, Integrated Risk Management System (IRMS), uluslararası inşaat projeleri için teklif hazırlama aşamasında kullanılmak üzere, kullanıcıyı risk yönetimi işleminin her aşamasında destekleyecek ve risk yönetim aktiviteleri ile diğer proje yönetimi fonksiyonlarının bütünleşmesini sağlayacak şekilde tasarlanmıştır. Risk bilgi modeli yanında, bir risk yönetim modeli geliştirilmiş ve böylece inşaat projelerinde yer alan katılımcılar tarafından sistematik risk yönetimi uygulamaları için sistemin kullanılmasına olanak tanınmıştır. Hazırlanmış hiyerarşik risk yapılanması kullanılarak risklerin tespit edilmesi, Monte Carlo (MC) benzetimi kullanılarak risk analizi yapılması, risk derecelendirilmesi ile risklerin değerlendirilmesi, risk yönetim stratejilerinin geliştirilmesi, kurumsal bellek kullanımı ve risk görüntüleme işlemi IRMS'in içerdiği başlıca özellikler olarak vurgulanabilir. Sistemin uygulanabilirliği gerçek bir inşaat projesi ile test edilmiş ve işlevselliği proje verileri kullanılarak gösterilmiştir.

Anahtar kelimeler: Risk Yönetimi, Karar Destek Sistemleri, Uluslararası İnşaat Projeleri

Dedicated to my wife and family

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AC	Additional Response Cost
AHP	Analytical Hierarchy Process
BOT	Build Operate Transfer
CBR	Case Based Reasoning
CBT	Computer Based Training
CIA	Cross Impact Analysis
CMCS	Computer-Mediated Communication Systems
DB	Design Build
DBB	Design Bid Build
DBMS	Database Management System
DSS	Decision Support System
EC	Estimated Cost
EIS	Executive Information Systems
EPC	Engineering Procurement Construction
FETA	Fuzzy Event Tree Analysis
FIDIC	Federation Internationale Des Ingenieurs Conseils
GDSS	Group Decision Support Systems
HRBS	Hierarchical Risk Breakdown Structure
HTML	Hypertext Mark-up Language
HTTP	Hypertext Transfer Protocol
IFE	Integrated Facility Engineering
IRMS	Integrated Risk Management System
JV	Joint Venture

LAN	Local Area Network
LCOF	Life Cycle Objective Functions
LCPRM	Life Cycle Project Risk Management
MBMS	Model-Based Management System
MC	Monte Carlo
MCDM	Multi Criteria Decision Making
MMS	Mail Management System
OLAP	On Line Analytical Process
pdf	Probability Density Functions
PERIL	Project Experience Risk Information Library
PM	Project Management
PMBoK	Project Management Body of Knowledge
PMI	Project Management Institute
PRAM	Project Risk Analysis and Management
RAMP	Risk Analysis and Management for Projects Methodology
RC	Risk Carding
RM	Risk Management
RMP	Risk Management Process
RMSS	Risk Management Support Systems
RR	Risk Rating
RS	Rating Score
SMART	Simple Multi Attribute Rating Technique
UML	Unified Modeling Language
WBS	Work Breakdown Structure
www	world-wide web

CHAPTER 1

INTRODUCTION

Significant changes in global economy have resulted in increased business opportunities for engineering and construction companies throughout the world. Nowadays, more companies are positioning to expand their operations in international construction market. However, while realizing the project in the international arena, the construction companies should give necessary importance to risk management concept which simply covers risk identification, analysis and response development stages. The reason to take risk management concept into the consideration is that construction industry is subject to more risk and uncertainty than many other industries due to requirement of multitude of people with different skills and interests, the co-ordination of a wide range of interrelated activities and vulnerability of construction projects to political, economic, social and environmental conditions.

Most researchers agreed that risk plays a crucial role in business decision making. The management of risk in projects is currently one of the main topics of interest for researchers and practitioners. Risk management has been designated as one of the eight main areas of the Project Body of Knowledge (PMBoK) by the Project Management Institute (2000), which is the largest professional organization in the project management field. Starting from early 1970's, lots of studies have been conducted pertinent to risk modeling concept. Some of the researches were related with definition of a systematic risk management process and methodologies in order to eliminate lack of formality. On the other hand, most of the studies have been focused on quantitative risk analysis for time and cost estimation. In recent years, it is noticed by researchers and experts that RM does not mean only risk measurement or quantification processes. On the contrary, as the construction projects have been becoming increasingly complex and dynamic, the significance of soft system approaches which consider human based issues such as experience, knowledge, team work has also considered. This situation leads to the definition of new concepts in RM field such as risk information modeling, risk register data base systems and RM decision support systems which are designed to assist the expert during the decision making process. In other words, although numerous researches exist which deal with the underlying theoretical concepts of risk and with techniques which identify and manage it, there is a gap between the theory and the techniques proposed to manage risk, and what practitioners in practice. Intuition, expert skills and judgment will always influence decision making, but a set of tools is needed which enable RM techniques to be put into practice in the construction industry. Decision support tools that facilitate systematic risk management process have the potential to make proposed methodologies implemented in practice and simplify development of risk models.

In this thesis, it is aimed to develop a fully integrated RM decision support system for construction projects, which can be used during the tender stage. The model is designed to combine soft system approaches with hard systems like risk identification and analysis techniques to increase the efficiency and adoptability of the model. The system is designed to store and re-use of project information, by formation of a corporate memory, and carry out RM processes by using a uniform language in a systematic manner.

Within the context of this study, following concepts will be discussed; In Chapter 2, findings of a detailed literature survey which covers the trends of RM from the early 1970's till today are presented. Also, risk management methodologies proposed by different researchers are discussed together with different subjects most frequently covered in the risk management literature will be discussed.

In Chapter 3, a brief information pertinent to DSS history and logic is given. Furthermore, the details of the proposed RM process model which is called as Integrated Risk Management System (IRMS) are discussed.

In Chapter 4, applicability and functionality of IRMS are demonstrated by a real project application. Accuracy of IRMS is tested and how the IRMS algorithm is carried out in practice is shown by means of a real project, namely Poland Cracow Project.

In Chapter 5, concluding remarks about IRMS methodology and its application are given as well as the expected benefits and potential shortcomings.

CHAPTER 2

LITERATURE SURVEY

2.1 Definition of Risk, Uncertainty and Risk Management

Decision-making takes place in an environment which has three components as certainty, uncertainty and risk (Flanagan and Norman,1993). Certainty can be defined as a situation in which all the factors can be exactly specified and known by the decision-maker which does not happen very often in the construction industry. By contrast, uncertainty can be stated as a situation, in which the decision-maker has no historic data or experience available to realize the decision-making process related with the future. In other words, uncertainty arises as decision-making is oriented towards the future. According to Raftery (1994), the word "uncertainty" is used where it is impossible to describe a situation in terms of probability of occurrence of an event. On the other hand, risk can be stated as a situation where the actual outcome an activity deviates from the estimate or forecast value (Raftery, 1994). Thus, the major difference between risk and uncertainty is related with its quantification. Risky situations have quantifiable attributes, whereas uncertainty does not. If risk arises, it is possible to apply statistical methods to quantify the magnitude of risk by using hard data. On the other hand, uncertainty can not be quantified and is used to describe situations where it is impossible to attach a probability to the likelihood of occurrence of an event; thus, uncertainty tends not to be insurable. A broad definition of risk is the probability that an adverse event occurs during a stated period of time (Royal Society, 1991). This definition considers negative side of risk only. Similar to this definition, Moavenzadeh and Rossow (1976) regarded risk as an exposure to loss only. On the other hand, Porter (1981), and Perry and Hayes (1986) have expressed risk as an exposure to economic loss or gain. Furthermore, Chapman (1990) defined risk as "exposure to possibility of economic and financial loss or gain, physical damage or injury, or delay as a consequence of the uncertainty associated with pursuing a particular course of action". This statement is the explicit definition of risk that arises from significant uncertain situations. Risk exists when a decision is expressed in terms of a range of possible outcomes and when known probabilities can be attached to the outcomes. On the other hand, uncertainty exists when there is more than one possible outcome of a course of action but probability of each outcome is not known.

As the construction industry is complex in nature in terms of parties involved, methods applied and activities executed, it is always dealt with risks. In addition to above risk definitions, project risk can be defined as an event or action which tends to cause a negative impact on project performance achievable, which includes project scope, quality, performance, schedule and cost. From this perspective, risk can be observed as "threats of success". Therefore, a systematic approach is needed for dealing with risks. According to Flanagan and Norman (1993), RM is a discipline for living with the possibility that future events may cause adverse effects. Although this definition correlates the term risk with chance of bad consequences or effects, it can also refer to possibility of opportunities. Chapman and Ward (1997) stated aim of RM as removing or reducing the possibility of underperformance. They declared that fundamental or essential purpose of RM is to improve project performance by systematic identification, appraisal and management of project related risks. This approach does not deal with only "downside" risk which has adverse outcomes, but also they stated the importance of "upside" risk which seeks to exploit opportunities and favorable possibilities. This is a wider perspective of RM to improve project performance. Another explicit definition of RM is done by Dikmen et al. (2004) which defines risk management as definition of objective functions to represent the expected outcomes of a project, measuring the probability of achieving objectives by generating different risk occurrence scenarios to ensure meeting/exceeding the preset objectives.

In most projects, for identification of situations whether it is certain or not, application of formal project management is required. According to Chapman and Ward (1997), the roots of project uncertainty are based on six basic questions (six W's) which define **who** are the parties involved, what do the parties what to achieve (**why**), **what** is it the parties are interested in, how is it to be done (**which way**), what resources are required (**where**) and **when** does it have to be done. Actually, the six W's approach that is shown at Figure 2.1 constitutes the basis for "contingency plans" which are second level plans related with how to respond to threats or opportunities associated with a "base plan" or a target scenario which indicates how well the project will go. Risk management is usually related with the evaluation and development of contingency plans supporting base plans (Chapman and Ward, 1997); however, application of effective risk management should start in the development of project base plans. This means that RM is most valuable early in a project proposal because of the flexibility in design and planning to consider how the serious risks may be avoided. This approach indicates the importance of planning and risk management in this sense. Therefore, the philosophy behind the risk management concept covers identification of proactive strategies before risk events occur by generating risk occurrence scenarios and carrying out formal and systematic tasks instead of intuitional approaches to manage risks.

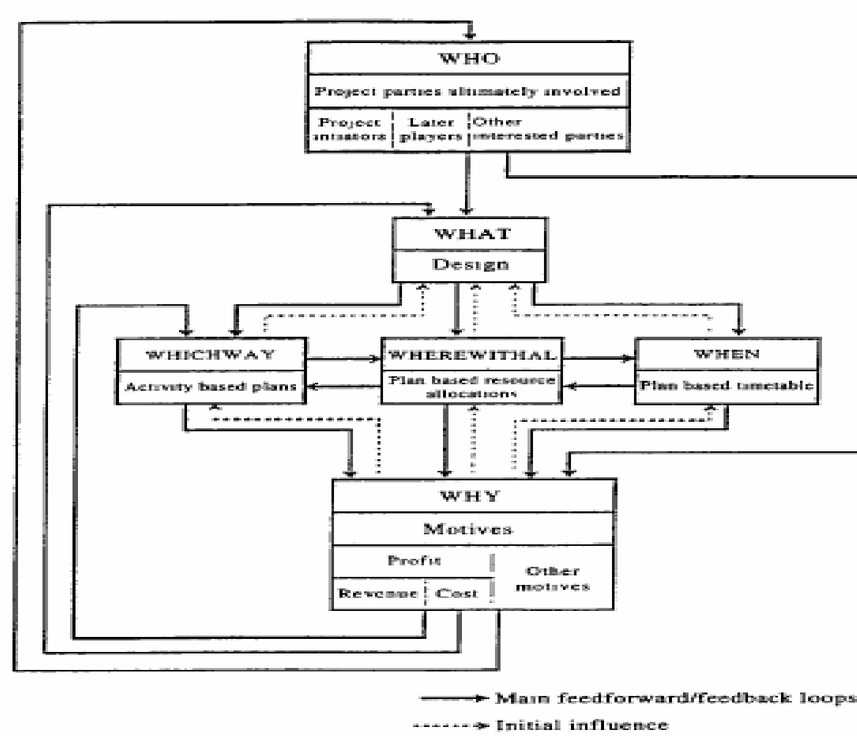

Figure 2.1. The six W's of PRAM methodology (Chapman and Ward, 1997)

2.2 Risk Management in Construction

The concept of RM is not unique to construction industry. Organizations from many industries have noticed the importance of risk management (Akintoye and Macleod, 1997), and many companies have established risk management departments to apply formal risk management to identify, control and monitor risks. RM has an increasing trend in various sectors, in financial sectors like banking industry, in commercial and business sectors like manufacturing industry and in service sectors like health and safety industry etc.

Besides these sectors, the need for application of formal risk management to construction industry has been recognized since two-three decades. As Perry and Hayes (1985) stated, risk and uncertainty do not occur only on large projects but also even small projects need effective risk management. Construction projects involve lots of (sometimes, thousands) interacting activities, where each may have a cost, time, quality or sequence problem. All of the risks, whether they are dynamic risks which can create potential gains as well as causing losses, or static risks which relate only to potential losses, should be managed for effective project management. It is frequently observed that construction projects faced with time and cost overruns. For example, a 1992 worldwide survey reported that the majority of construction projects fail to achieve the objectives of the schedule (Cooper, 1994). In many of these projects a schedule overrun did not seem probable at the beginning of the project. Similar to schedule overrun, the history of construction industry is full of projects that were completed with significant cost overruns. This requires utilization of a systematic approach to RM in the cost estimation stage of the project life cycle.

Since the construction industry is complex in nature, in terms of parties involved, methods applied and activities executed, it is always dealt with risks. In other words, RM is essential for construction projects as the projects contain lots of uncertainties stem from project, country and market, and have numbers project participants. As the construction projects are realized in dynamic environment, the project objectives tend to change during the life cycle of the project. Risks involved in construction projects are numerous as construction activity is a complex process which comprises of many interrelated activities carried out by different parties at different times. Apart from its technical difficulties, project success is highly sensitive to environmental conditions. Macro-economic, political and social factors also have an impact on the construction business. Factors affecting construction business are dynamic creating a high level of uncertainty in the project environment. Project objectives tend to change as well as changes in design, work methods, responsibilities of parties etc which result in an increased vagueness of conditions. Thus, risk management is a critical task, within the context of which lies a whole life cycle approach. Risks should be managed throughout the project by all project participants to ensure project success in the presence of uncertainties associated with macro-environmental factors as well as project-specific factors such as construction-related factors.

2.3 Literature survey on Risk Management in Construction

Risk management has taken its part in project management literature from early 1970's till today and preserved its importance as a research topic. If RM in construction sector is investigated, it will be noticed that the literature is rich enough in terms of conceptual studies. As construction projects contain lots of uncertainties that stem from project, country and market conditions have many project participants resulting in various kinds of risk sharing and management scenarios, and as it is mostly difficult to predict impact of risks, it is hard to simulate risk environment of a construction project. Therefore, the researches have given more importance to development of conceptual frameworks and risk management methodologies specific to construction projects.

When construction risk management literature is examined, it is observed that RM studies can be grouped under four categories (Dikmen et. al, 2004).

(1) Development of conceptual frameworks and process model for systematic RM,
(2) Investigation of risks, risk management trends and perceptions,
(3) Application of risk identification and analysis techniques in specific projects, and

(4) Development of risk management support tools.

This categorization is not a generic one and different researchers may define different headings under which RM studies may be collected. However, for this thesis, this categorization scheme is found applicable and RM literature will be discussed based on this scheme.

2.3.1 Category 1: Development of Conceptual Models

Development of RM methodologies started at early 1980's. Some researchers defined several risk management processes till mid 1990's. From mid 1990's some institutions provided procedural, task-based guides for construction risk management. Starting from late 1990's, researchers proposed different decision support systems and information models to implement the conceptual process models in practice. The details pertinent to development of conceptual models are explained in the forthcoming parts.

2.3.1.1 Early Efforts

One of the earliest efforts to define risk management process belonged to Hertz and Thomas (1983). They proposed a step-wise procedure of risk identification, measurement, evaluation and re- evaluation. Furthermore, Hayes et al. (1986) defined RM as three stages which are risk identification, analysis and response. They suggested that RM is particularly appropriate during three phases which are project appraisal, development of contract strategy and tender preparation. The CRM Manual (1987) provided a procedural, task-based guide to construction risk management. Flanagan and Norman (1993) proposed a RM framework by breaking RM process down to RM system that consists of 5 stages as risk identification, risk classification, risk analysis, risk attitude and risk response. This approach contains identification of the source and type of risks and then considers the type of risk and its effects on the project or organization. At risk analysis stage, consequences associated with the type of risk, or combination of risks, by using analytical techniques are measured and then necessary decisions, depending on the attitude of the person or organization, are taken. Finally, the response strategy is chosen as either transferring it to another party or retaining it. Actually, this framework gives a major idea for the forthcoming researches about RM methodologies.

Raftery (1994) proposed his RM cycle as risk identification, risk analysis and risk response. He emphasized that during risk identification three separate risk factors should be considered. These factors are; risks internal to project which are found by breaking the project down into major work packages, risks external to project with emerge from the business and physical environment and finally risks due to different perspectives of client, project team and poor quality documentation. According to Raftery, risk analysis is not a substitute for professional experience and judgment. On the contrary, “it helps professionals to make use of the full extent of their experience and knowledge by liberating them from the necessity of making simplifying assumptions in order to produce deterministic plans or forecasts” Raftery (1994). Therefore, Raftery’s approach accepts risk analysis not as a substitute but a supplementary tool for professional judgment. After all, risk response is the third part of the RM cycle which is similar to those in other frameworks. Later texts with similar approach include Edwards (1995) and Sawczuk (1996) who proposed frameworks comprising of risk identification, risk analysis, response planning, continuous monitoring and finally feedback for risk learning and action planning. All of these frameworks imply a systematic approach for risk management by following a risk identification-analysis-response-monitoring loop (Dikmen et al., 2004). The researchers agree that risk management frameworks and methodologies propose several benefits to users. For example, RM frameworks encourage the user to make pre-planning which leads to use of pre-evaluated responses to risks. Next, these methodologies facilitate clear definition of specific risks associated with particular projects and force the user full use of his/her experience and skills. Moreover, as the aim of risk identification and risk analysis is to enable the decision maker to take action or response in advance of problem solving, it provides more explicit decision making conditions on the project. RM methodologies give necessary importance to documentation and propose development of a knowledge pool by accumulation of individual’s knowledge which can be further converted to corporate knowledge. Finally, it can be noted that aim of all RM methodologies to minimize overall risk impacts.

In addition to those researches, starting from mid 1990's, several institutions provided procedural, task-based guides for construction risk management. All attempt to eliminate informality of risk management activities. They aim to formalize and systematize risk management process and integrate risk management with other project management functions. Although these methodologies have slight differences in model architectures, number of phases, level of detail, and coverage of project life cycle, all the models and reference frameworks have similar characteristics and common goals.

2.3.1.2 Project Risk Analysis and Management Guide (PRAM)

Project Risk Analysis and Management (PRAM) Guide was drafted by Chapman (1997) for the Association of Project Managers. It aims to provide a formal risk management processes (RMP) for projects in generic terms. Actually, PRAM is conversion of the experience of a large number of organizations, which have used RMP successfully for a number of years. Similar to other methodologies, PRAM suggests that formal risk management process should be applied to all stages of the project life cycle by all project participants. Some of the RMP are described in terms of phases (stages) which are separated into activities or products. PRAM uses more detailed nine phase structure which provides clarification of relative importance and role of aspects of the process which is emphasized in different degrees by other RMP. PRAM is a flexible methodology which gives an opportunity both for making short cuts and developing more sophisticated processes within the framework provided. Figure 2.2 shows nine-phase structure of PRAM methodology.

Nine phases of PRAM methodology starts with define phase and continues with focus, identify, structure, ownership, estimate, evaluate, plan phases and finishes with manage phase. It can be noticed that the phases have start to start precedence sequence. Once started all the phases proceed in parallel, with intermittent activity defined by iterative process interlinking the phases which are associated with broadly defined deliverables. Each deliverable is discussed in terms of its purpose and the tasks required producing it.

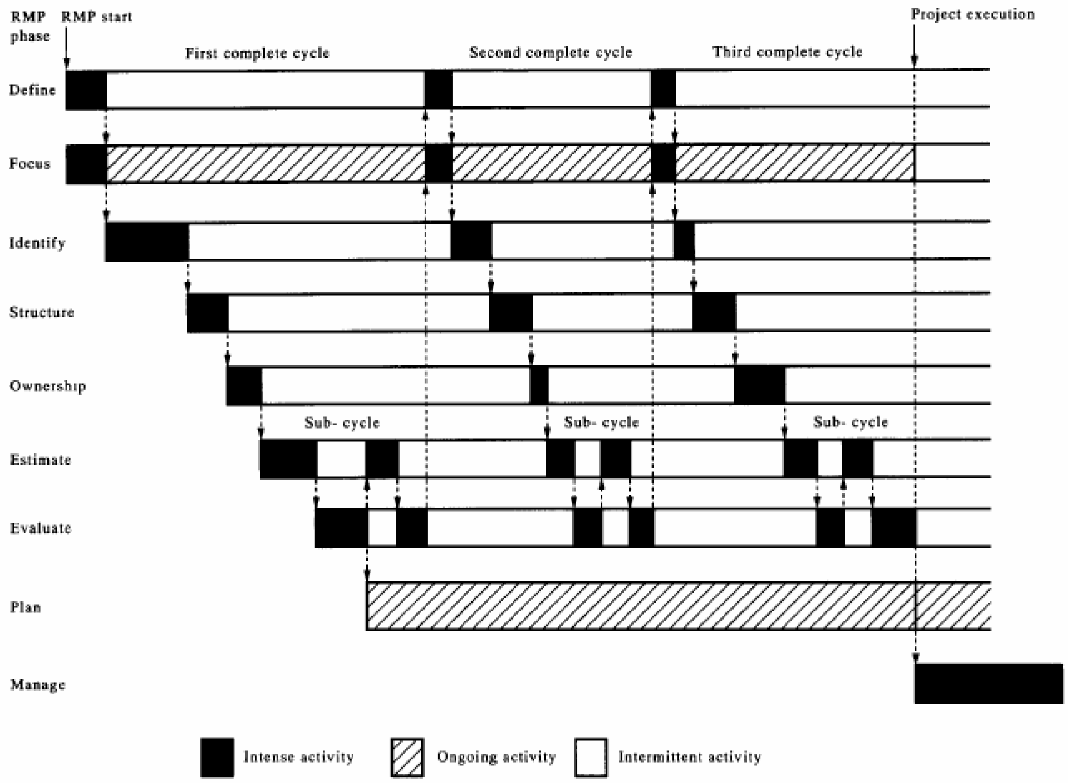

Figure 2.2. Nine phase risk management process of PRAM methodology, Chapman (1997)

The define phase has a purpose of gathering and summarizing (consolidation) of relevant existing information in a suitable form about the project which the RMP address like stating project objectives clearly; defining project scope, activity plans and time frame; and specification of resource usage etc. Furthermore, it is aimed that any gaps uncovered in the consolidation process should be eliminated. On the other hand, the target deliverable of define phase is a clear, unambiguous, shared understanding of all key aspects of the project documented. To provide this deliverable, some tasks should be executed like consolidation, and elaboration of the gathered information, documentation, and verification of the information, assessment of risks and reporting verified documents. Although first two tasks are specific to define phase, other tasks are common to all phases. In most projects, as the key aspects of the project may not clearly be defined at the beginning of the project, important aspects of the define phase may be ongoing. Therefore, more attention should be given to make as much progress as possible with the define phase before going on to forthcoming phases. The reason for that is if the level unfinished business from the define phase is high; it means that lower efficiency and effectiveness of the following phases may be encountered. In define phase six-W approach of Chapman and Ward (1997) facilitates execution of tasks for deliverable.

Second phase of PRAM methodology is focus phase. Actually, all risk management processes have focus strategy with different titles as scope or initiation. The purpose of focus phase is defining scope of RMP and planning the RMP in operational terms as project in its own right. The target deliverable of this phase is clear, unambiguous shared understanding of the RMP. Therefore, scoping and planning the process (who is doing the analysis for whom, what is the scope of relevant risk, what models or methods should be applied and which software should preferred etc.) should be done and four common tasks (document, verify, assess and report) are also involved. Similar to define phase, focus phase may include ongoing activities like updating RMP plans. Therefore, this phase, may be concurrent with the define phase.

All the risk management methodologies stress on a need for identification of risk sources. Some of them give more attention to impact of these risk sources, leaving root causes or root sources. Some of the RMP defer the issue of root causes and also defer the related issue of responses, and then only consider alternatives in relation to major risks. On the other hand, at least one response must be identified and assumed in order to understand the impact of a risk later in the first iteration through the process (Chapman, 1997). According to PRAM methodology, to identify risks and responses two specific tasks should be applied as searching and classification. The sources of risk and responses are searched by carrying out some techniques such as pondering, interviewing, brainstorming and checklists. In addition, the sources of risk and responses are classified by providing a suitable structure for defining risk and responses. The output of identification phase should include a risk register list or log with at least one assumed response.

Fourth phase of PRAM approach is structure phase. Actually, this phase is common for all risk management processes, usually as a part of another phase such as analysis phase. The purpose of the structure phase is testing simplifying assumptions, and providing more sophisticated structure when it is needed which prevents leading to loose of opportunities. Structuring involves the review and development of existing classifications (refine classifications), reviewing and exploring possible interdependencies or links between project activities, risks and responses, and seeking to understand the reasons for these interdependencies (explore interactions), and possible revisions to the precedence relationships for project activities assumed in define phase (develop orderings). The key deliverable of structure phase is a clear understanding of the implications of any important simplifying assumptions about the relationships between risks, responses, base-plan activities.

Clarification of ownership constitutes fifth phase of PRAM as ownership phase. This phase aims to distinguish the risks and associated responses that the client is prepared to own and manage from those the client wants other organizations to own and manage; to allocate responsibility for managing risks and responses owned by the client to named individuals; and to approve ownership-management allocations controlled by contractors and third parties. The products of this phase are clearly definitions of the ownership and allocations of management responsibility. To get these outputs, scoping the policy and planning the allocations should be carried out which answer questions like; what are the objectives of ownership strategy, which parties are being considered, and what kinds of risk require allocation. The details of the approach, the instruments and the timing are also considered. A separate phase for clarification of ownership facilitates treating it as a project in its own right, and providing effective project management application.

Estimate phase is concerned with cost, time and other appropriate performance measures. Its goal is identification of “reference plan” that involves significant uncertainty which need more attention in terms of data acquisition and analysis, and which require careful decisions and judgments by the client team. The deliverables achieved by the estimate phase are estimates of likelihood and impact in terms of cost, duration, or other project criteria for risks identified. From this perspective, the key product of this phase can be stated as the provision of a basis for understanding which risks and responses are important. Next, the importance of uncertainty is scoped based on simple numeric subjective probability estimate and after the impact of risk is estimated under chosen response warrants, the refinement of the initial scope estimation is done.

After finalization of estimation phase, evaluation phase starts. Some of the RMP have combined estimation and evaluation phases together and taken up these phases as a single and broader phase like analysis phase. The purpose of evaluate phase is synthesis and evaluation of the results of the estimation phase, with a perspective to client assessment of decisions and judgments. Evaluate phase should be used to drive the distinction between two purposes of the estimate phase. The deliverables of estimate phase depend on the depth of the preceding phases achieved to this phase. As an example, an important early product of this phase can be prioritized list of risks, while a later deliverable might be diagnosed potential problem associated with a specific aspect of the base plan or contingency plans, and suggested revision of these plans to resolve the problem.

As Chapman (1997) stated plan phase uses all preceding efforts of risk management process to produce a project base plan which is ready for implementation and associated risk management plans for the project management process. Therefore, providing these plans complete and appropriate is the major objective of plan phase. Some of the key specific deliverables of plan phase are base plans in activity terms, at the detailed level required for implementation, with timing, precedence, ownership and associated resource usage and contractual terms where appropriate clearly specified, including milestone initiating payments, other events or processes defining expenditure, and an associated base plan expenditure profile; and recommended proactive and reactive contingency plans in activity terms, with timing, precedence, ownership and associated resource usage and contractual terms where appropriate clearly specified, including trigger points initiating reactive contingency responses, and impact assessment.

Final phase of PRAM methodology is manage phase. All the RMP have a manage phase that is concerned with monitoring actual progress of the project and associated risk management plans, responding to any departures from these plans, and developing more detailed plans for the immediate future. The key products of manage phase is similar to outputs of evaluate and plan phases like regularly prepared short prioritized list of risk-response issues requiring ongoing management attention, measures of achieved performance in relation to planned progress etc.

The combination of all those phases forms PRAM approach, which provides a clearly defined, formal, flexible risk management methodology. PRAM facilitates application of risk management principles to the projects.

2.3.1.3 Risk Analysis and Management for Projects Methodology (RAMP)

Risk Analysis and Management for Projects Methodology (RAMP) promoted by Institution of Civil Engineers (1998) is a comprehensive framework within which risks can be managed effectively and financial values placed upon them. It aims to achieve as much certainty as possible about long term and uncertain future. In the case of a project, RAMP covers entire lifecycle of the project, from initial conception till eventual termination. The process facilitates risk mitigation and supplies a system for the control of residual risks.

The RAMP process consists of four major activities, which are generally carried out at different times in the lifecycle of a project as process launch that is conducted early in the lifecycle; risk review which is applied before key decisions or at intervals; risk management that is carried out between the risk reviews; and process close-down is conducted at the end of the life cycle or on premature termination. Each activity is composed of several phases, each of which is made up of a number of process steps. Although process launch and process close-down activities are performed once only at the start and end of the investment, risk reviews are carried out at crucial stages or time intervals within the project lifecycle. Risk management activities are performed continuously between risks reviews based on the analysis, strategies and plans produced by preceding risk review.

RAMP launch is the first activity of four major activities. Process launch includes preparation for preliminary identification of the objectives, scope and timing of the investment. This should also include the definition of provisional overall strategy for risk reviews and management throughout the investment lifecycle, including purpose of RAMP as the objectives of the RAMP process; level of risk analysis like what level of detail, sophistication and efforts is appropriate for such a project; scope of review as what stages in the investment life cycle are considered; stage/timing as what points or times within each stage are the risk reviews to be carried out; and budget for RAMP as establishing a budget for conducting the RAMP process stage by stage for the life cycle of the project. RAMP proposes that the risk analysis and management strategy is communicated as fully as possible to all concerned. Therefore, the involvement of as many people as possible will make it more effective. As a result, the last stage of the RAMP launch process is to form a team, who will act as risk analysts.

Risk management approach of RAMP includes risk identification, risk analysis, risk mitigation and risk monitoring phases. In the risk identification phase, it is aimed that all significant types and sources of risk and uncertainty associated with each of the project objectives and key parameters relating to these objectives are identified. Furthermore, the causes of each risk are determined and assessment is done for designation of how risks are related to other risks and how risks should be classified and grouped for evaluation. The identification phase starts with listing the risks associated with each objective, key parameter, or major deliverable. The first attempt should be from first principles without the use of checklists or prompts, to avoid constraining the process of discovery. Next, the resulting risks are listed in the risk register for subsequent review and analysis, with a tentative indication of significance of each risk and inter-relationships between risks. It is suggested that the risk register is extended and revised by applying brainstorming sessions. After all, having identified as many risks as practicable, it is necessary to classify and group risks, to assist in the evaluation. After identification of risk, risk analysis phase starts which covers assessment of likelihood/frequency of the risk occurring per unit of time or some other convenient unit, potential consequences if risk occurs, the most likely frequency of risk occurring during the whole lifetime of the project, the likely timing of risk impacts, and the acceptance score, by combining the likelihood with the consequence, using risk assessment tables. If a risk is related to one or more other risks, in the sense that they are common causes or for other reasons, the occurrence of one affects the likelihood of another, the related risks should be evaluated together. The resulting assessment of each risk or group of related risks should be entered in the risk register. After all, by using the model and parameter estimates, the overall impact of the risks on the whole lifecycle of the project is determined. Then, a preliminary assessment will be made of the extent to which the major risks can be mitigated and the results will be recorded in the risk register. The aim at this stage will be limited to establishing whether optional courses of action exist which, may reduce the major risks to acceptable levels. Next phase of risk management process is risk mitigation, or lessening the adverse impacts of risks, which is at the heart of the effective risk management. If implemented correctly, a successful risk mitigation strategy should reduce any adverse variations in the financial returns from a project. However, risk mitigation itself, because it involves direct costs like increased capital expenditure or the payment of insurance premiums, might reduce the average overall financial returns from a project; this is often a perfectly acceptable outcome, given the risk aversion of many investors and lenders. Therefore, risk mitigation should cover all phases of a project from inception to close-down. According to RAMP, there are four main ways in which risk can be dealt with within the context of a risk management strategy which are; risk reduction or elimination, risk transfer, risk avoiding, and risk absorbing and pooling. These four ways constitute the mitigation alternatives of RAMP framework. After finalization of the mitigation phase, go/no-go decision should be taken based on the description of the project and its baseline, description of most significant risks and how it is proposed to mitigate them. If it is decided to keep on the project, the key task at this stage of RAMP is the monitoring of risks included in the residual risk analysis, risk mitigation strategy and the risk response plan. Other risks also need to be monitored regularly including those in the remaining stages of the investment life cycle-not only the risks occurring in the present stage. Any significant changes in risk or new risks should be reported and assessed immediately. Regular monitoring of risks can be undertaken by studying events, situations or changes (sometimes called 'trends'), which could potentially affect risks during the normal management and progress of an investment. These trends must be systematically identified, analyzed and monitored on a regular basis by scrutinizing reports, letters, and notes on visits, meetings and telephone conversations. The results are entered in trend schedules. Ideally, these should be considered at regular progress meetings involving key members of the management team.

After application of risk review and risk management activities, RAMP close-down activity is executed at the end of the project lifecycle, or on prior termination of the project. At this point, a retrospective review analysis is carried out to measure the effectiveness of the RAMP process. The results of the review are recorded in a RAMP close-down report, which can be easily referred to for future projects.

2.3.1.4 Project Management Body of Knowledge (PMBoK)

Project Management Institute (PMI), which is the largest professional organization with over 100,000 professional members representing 125 countries, is dedicated to project management field. PMI proposed a risk management methodology to eliminate informality of risk management application by the sector participants which is called as Project Management Body of Knowledge (PMBoK). The Project Management Body of Knowledge (PMBoK) is an inclusive term that describes the sum of the knowledge within the profession of project management. This document is intended to provide a common lexicon within the profession for talking about project management. According to PMBoK, risk management forms one of the so-called nine functions of project management. Modifications regarding risk management methodology is still being carried out and the revised version of PMBoK is published in 2000 which includes minor revisions regarding project risk management. According to PMBoK (2000), project risk management includes the processes concerned with identifying, analyzing and responding to project risk. It includes maximizing the results of positive events and minimizing the consequences of adverse effects. The processes should interact with each other. Each process may involve effort from one or more individuals or groups of individuals based on the needs of the project. Each process generally occurs at least once in every project phase.

Similar to other methodologies, PMBoK declares explicitly, which inputs are required for that phase, which tools or techniques can be used for assessment of inputs, and which deliverables should be provided at the end of the phase. First process of four major processes of PMBoK is risk identification. According to PMBoK, risk identification consists of determining which risks are likely to affect the project and documenting the characteristics of each. Risk identification is not a one time event; it should be performed on a regular basis throughout the project. Furthermore, risk identification should address both internal risks which are factors that the project team can control or influence like cost estimates, labor productivity etc.; and external risks are factors beyond the control or influence of the project team like government actions, macro economic issues etc. Similar to PRAM approach, PMBoK also mentioned that risk identification is also concerned with opportunities which have positive outcomes as well as threats. In risk identification phase, by using checklists, flowcharts or interviews as tools for identification; sources of risks, potential risk events, risk symptoms and inputs for the forthcoming processes are provided as deliverables of identification phase.

Next process of PMBoK is risk quantification. Risk quantification involves evaluating risks and risk interactions to assess the range of possible project outcomes. It is primarily concerned with determining risk events that warrant response. Various factors such as interaction of opportunities and threats in an unanticipated way, multiple effects of a single risk event, or false impression of precision and reliability of the mathematical techniques etc make risk quantification process complicated. The inputs that will be used in this phase are the combination of deliverables from risk identification and project constraints like cost estimates, schedules estimates. For risk assessment, several mathematical techniques can be carried out. Expected monetary value which is product of risk event probability and risk event value, statistical sums that can be used to calculate a range of total project costs from the cost estimates for individual work items can be given as examples for risk quantification methods. In addition, simulation can be applied for risk quantification which uses a representation or model of a system to analyze behavior or performance of the system. For example, Monte Carlo analysis which is a widely used simulation technique in risk management; is applied to assess the range of both cost outcomes and schedule outcomes. Furthermore, decision trees method which is a diagram that depicts key interactions among decisions and associated chance events can be applied as risk quantification techniques to quantify risks. The outputs of this phase are clarification of opportunities to pursue or ignore and threats to respond or accept. Risk response development is the third process in PMBoK RM methodology. Risk response development deals with defining enhancement steps for opportunities and responses to threats. Responses to threats can be in terms risk avoidance by eliminating specific threats, risk mitigation by reducing the expected monetary value of a risk event either by reducing the probability of occurrence or the risk event value or both, and risk acceptance by accepting the consequences. In this phase, the inputs are the ones that are the deliverables of risk quantification process. The tools and techniques for risk response development may be development of effective procurement strategy, development of contingency plans that involve defining action steps to be taken if an identified risk event occurs, developing alternative strategies and insurance. The outputs of this phase are risk management plans which are the documents that explain the procedure that will be used to manage risk throughout the project, contingency plans, reserves that are the provisions in the project plan to mitigate cost and/or schedule risk, and contractual arrangements. Figure 2.3 summarizes risk management methodology of PMBoK.

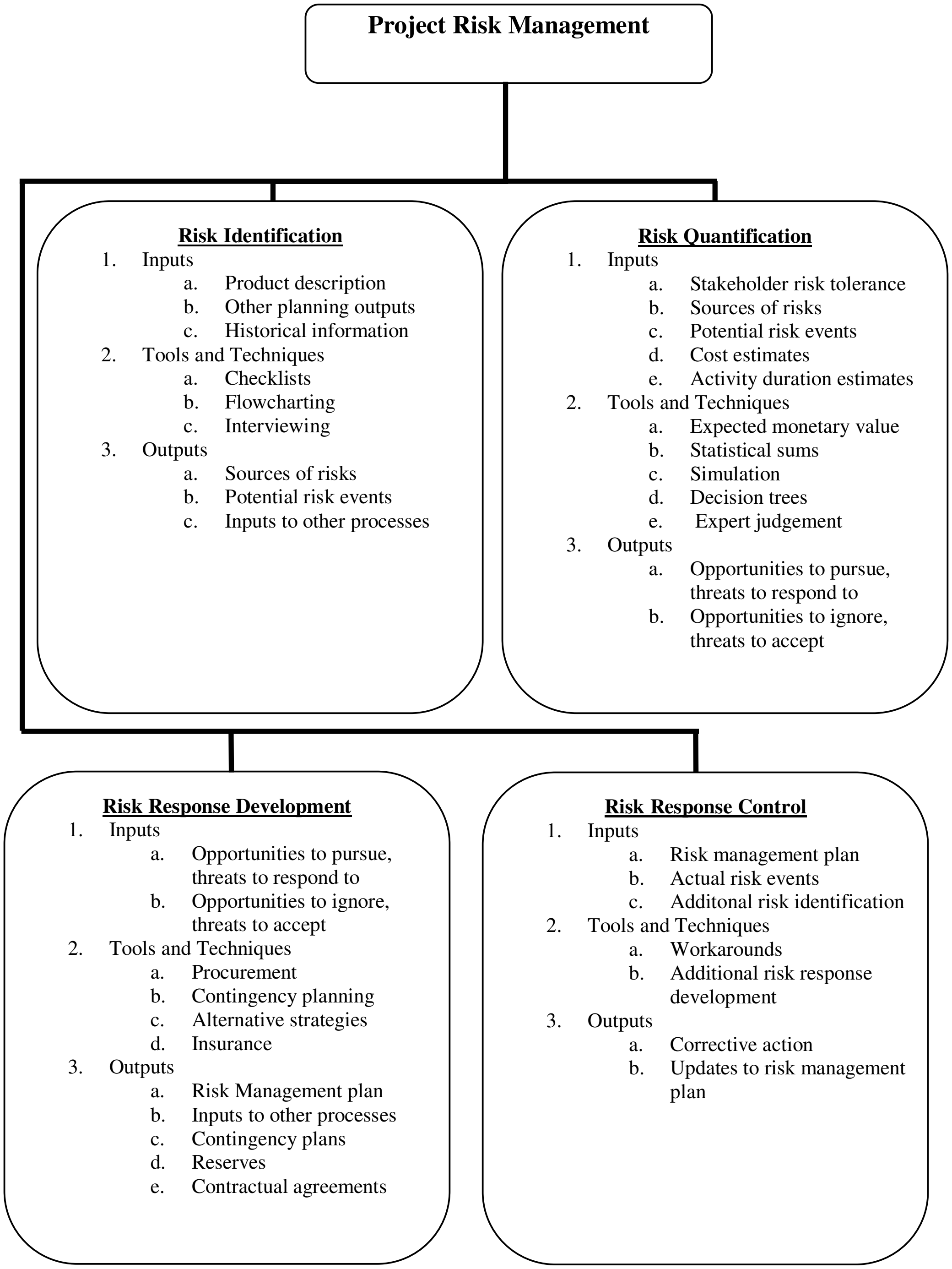

Figure 2.3. Project Risk Management overview of PMBoK

Final process of PMBoK RM approach is risk response control. Risk response control involves executing the risk management plan in order to respond to risk events over the course of the project. When changes occur, the basic cycle of identify, quantify and respond is repeated. Actually, one of the outputs of the each phase is inputs to other processes, which provides feedback to necessary process. It is important to understand that even the most comprehensive analysis cannot identify all risks and probabilities correctly. Therefore, risk monitoring and control is required. The inputs of this phase are risk management plan, actual risk events and additional risk identification which is checked by workarounds those are unplanned responses to negative risk events and additional risk response development. Necessary corrective actions and updates to risk management plans are provided as outputs of risk response control phase.

From the framework of PMBoK RM process, it is observed that each phase is a complementary process of the forthcoming one. Furthermore, outputs are the inputs for other processes, which facilitates making feedback and updating the RMP. This enables application of risk management process throughout the lifecycle of the project.

2.3.1.5 Recent Efforts

The implementation of these process models is as important as development of these models. Therefore, a more recent research theme is discussion of critical success factors for implementation of process models. Researchers proposed different decision support systems and information models for implementation of developed conceptual process models in practice. For example, one of the recent researches is carried out by Tah and Carr (2000), which focuses on vital role of common language and an information model for the risk management process. According to Tah and Carr (2000), due to lack of a common language and common process model in which risks and responses are identified, analyzed and dealt with in a defined way, individuals use different methodologies as well as terminologies leading to informality of the RM process. For this reason, a common language describing risk and remedial measures within in the construction supply chain throughout the project lifecycle is required. Based on these arguments, they developed a Hierarchical Risk Breakdown Structure (HRBS) which provides the basis for classifying risk within a project and a risk catalogue that is collection of risks that have been defined using common language and the HRBS. Figure 2.4 shows the hierarchical risk breakdown structure proposed by Tah and Carr (2000).

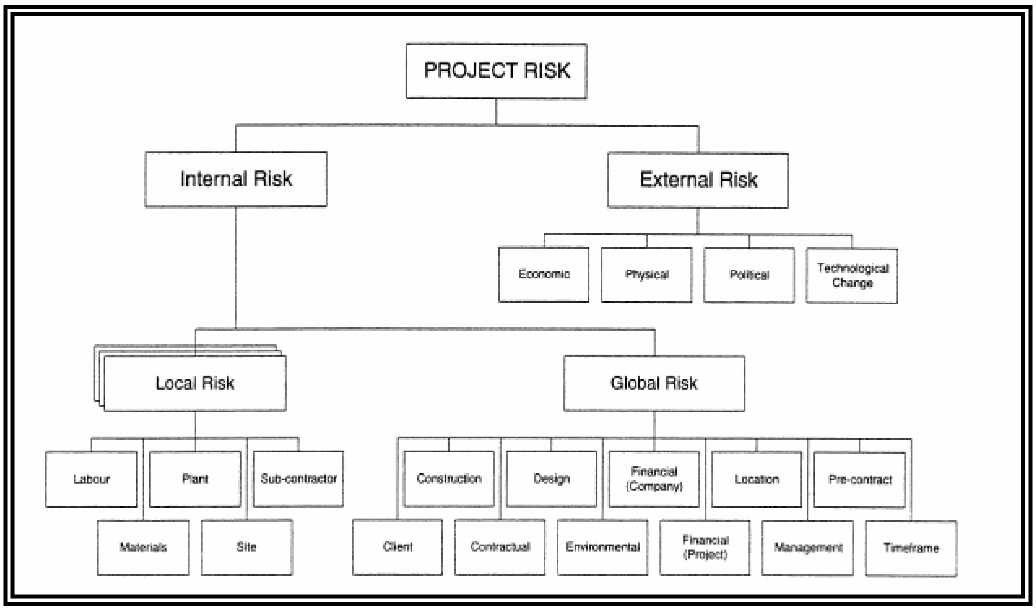

Figure 2. 4. The hierarchical risk breakdown structure, Tah and Carr (2000)

The HRBS allows the separation of risks as risks related with them management of internal resources and those related to external environment. According to this classification, external risks are the ones which are uncontrollable and internal risks are relatively more controllable. Furthermore, a common typology for describing risks, is developed which allows risks to be defined using five terms: type, scope, centre, risk and risk factor. Table 2.1 shows a part of the risk catalogue developed by Tah and Carr (2000).

Furthermore, by using IDEF0 and UML (unified modeling language) modeling techniques, they developed a risk management process model that consists of identification, assessment, analysis, handling, and monitoring processes. As a result, a prototype software tool is developed for implementation of the information model.

Table 2.1 Part of risk catalogue, Tah and Carr (2000)

HRBS code	Risk type	Risk scope	Risk centre	Risk	Risk factor
R.1.1.01.003.007	Internal	Local	Labour	Availability	Availability of labour
R.1.1.01.061.004	Internal	Local	Labour	Productivity	Accidents
R.1.1.01.061.065	Internal	Local	Labour	Productivity	Fatigue
R.1.1.01.061.076	Internal	Local	Labour	Productivity	Industrial relations
R.1.1.01.061.108	Internal	Local	Labour	Productivity	Morale
R.1.1.01.061.109	Internal	Local	Labour	Productivity	Motivation
R.1.1.01.061.124	Internal	Local	Labour	Productivity	Productivity of labour
R.1.1.01.061.144	Internal	Local	Labour	Productivity	Safety
R.1.1.01.061.147	Internal	Local	Labour	Productivity	Sickness
R.1.1.01.064.130	Internal	Local	Labour	Quality	Quality of labour
R.1.1.02.003.010	Internal	Local	Plant	Availability	Availability of plant
R.1.1.02.061.125	Internal	Local	Plant	Productivity	Productivity of plant
R.1.1.02.072.018	Internal	Local	Plant	Suitability	Breakdown
R.1.1.02.072.155	Internal	Local	Plant	Suitability	Suitability
R.1.1.03.003.008	Internal	Local	Material	Availability	Availability of material
R.1.1.03.072.156	Internal	Local	Material	Suitability	Suitability of material
R.1.1.03.073.040	Internal	Local	Material	Supply	Damage in storage
R.1.1.03.073.041	Internal	Local	Material	Supply	Damage in transportation
R.1.1.03.073.157	Internal	Local	Material	Supply	Material supply
R.1.1.03.073.171	Internal	Local	Material	Supply	Wastage

Similar to Tah and Carr, Jaafari (2001) who argued that there is still scant attention to proper modeling and quantification of risks, proposed a risk management philosophy and framework. According to Jaafari's new approach, project risk assessment must not be based on a collection of individual assessment of project risks, but be based on assessing the likelihood of achieving project's strategic objectives. Furthermore, similar to other approaches, risk analysis should not be viewed as a stand alone activity; rather, it should be seen as a component of all decisions made continually to respond to project dynamics. In addition, the business objectives, scope, and method of execution should be clearly understood to reduce uncertainties associated with the project. Furthermore, Jaafari states that life cycle objective functions (LCOF) must be formulated as the vehicle for analysis and management of risks. All those principles form the basic structure of life cycle project risk management (LCPRM). Jaafari's approach to risk management as life cycle project risk management has several distinct differences from conventional approach. For example, this approach is a strategy based approach therefore, all the risks and rewards are defined considering strategic objectives and corporate functions. Next, according to this approach, all project decisions are based on all project life cycle information which is generated, integrated, shared and accessed by teams throughout the project life cycle. Then, soft systems integration, in other words, integration of human experience as pooling of expertise of project participants is provided. Finally, a holistic approach to project management is supplied by combination of decisions on soft variables with decisions on the core technical and financial objectives. All these principles and issues form The Integrated Facility Engineering (IFE), which provides a consistent and efficient platform throughout the project. This system supports scenario analysis and offers an integrated environment to effectively and interactively apply “What-if” planning; and integrates the management of the processes of planning, engineering, documentation, procurement, and construction management throughout the project lifecycle. Figure 2.5 shows the IFE architecture.

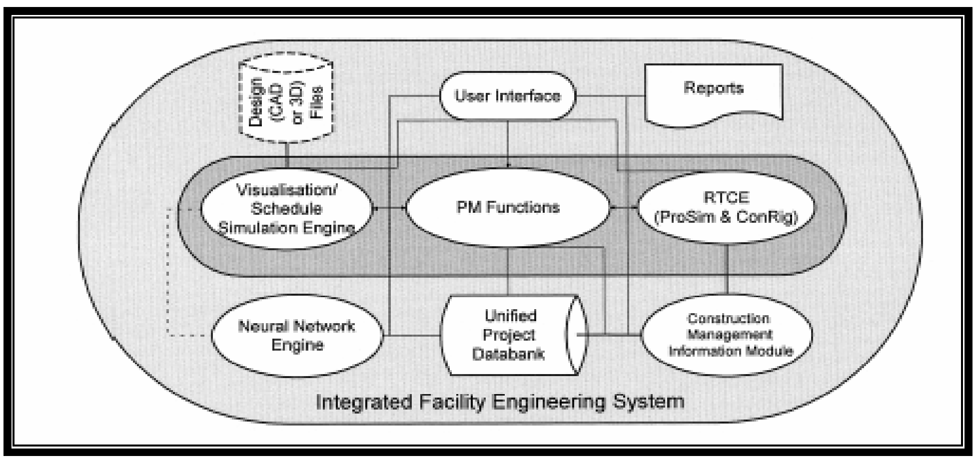

Figure 2.5 The IFE architecture, Jaafari (2001)

The IFE system will enable the project manager to estimate the probability that LCOF will fail to reach or exceed their target values. According to Jaafari, concurrent project management is the right organizational structure for strategy based project management. Therefore, integration of project participants is ensured by information module and unified project databank in the system. In short, Jaafari (2001) mentioned the importance of management information and decision support systems that can integrate all aspects on a real time basis.

2.3.2 Category 2: Investigation of Risks, RM Trends and Perceptions

Second category of the RM literature is investigation of risks, RM trends and perceptions. This category contains researches related with identification of risk factors specific to different projects, project delivery systems, international markets and investigation of risk perception of people within the construction industry. In this category, questionnaire, interview, and case study are mostly preferred by the researchers as a research method. As there is no single categorization of risk which is agreed upon by all researchers, different typologies are proposed serving different purposes, and numerous questionnaires have been conducted using different typologies (Dikmen et al., 2004). Ashley and Bonner (1987) studied political risks in international construction projects and aimed to identify political risk sources and their impacts on project cash flow elements. Dingle (1991) and Swierczek (1994) made a research on cultural issues regarding risks in major international projects. Similar to Dingle and Swierczek, Levitt et al. (2004) carried out a study regarding cultural risks. Cooper and Chapman (1987) conducted a research about social risks such as criminal acts, and sabotage etc. Chicken (1994) described social and political risks as human based factors in risk management for major projects, and stressed the largely because of difficulty of dealing with them quantitatively.

Some researchers investigated risks in specific projects. Tiong (1995) reviewed risks and guarantees in Build Operate Transfer (BOT) projects and investigated risks in specific projects by referring to questionnaire findings. Wang et al. (2000) made a research related to political risks in China's BOT projects, which aimed to identify and manage the unique and critical risks associated with investments in China's infrastructure projects. Charoenngam and Yeh (1999) investigated contractual risk sources and liability sharing in hydropower construction. They identified typical construction risks and described the comparison between FIDIC (Federation Internationale Des Ingenieurs Conseils) and Taiwanese government Conditions of Contract for hydropower construction projects. Lam (1999) reviewed risks associated with major infrastructure developments in sectors such as power, transportation and telecommunication.

As an example for research on risk perceptions, Kangari (1995) investigated risk management perceptions and trends in United States construction industry by a questionnaire study. Akintoye and Macleod (1997) made a research pertinent to the construction industry's perception of risk associated with activities extent to which the industry uses risk analysis and management techniques. Thevendran and Mawdesley (2003) described how human risk factors in construction projects are perceived by the practitioners by conducting a questionnaire survey. Furthermore, Simister (1994) conducted a study about risk management trends and found that checklists are the most frequently adopted method for risk identification and that Monte Carlo simulation is the technique most often used for risk analysis. Similar to Simister, Raz and Michael (2001) studied use and benefits of the project risk management tools and investigated the tools which are more likely to be used in the organizations that report better project risk management performance. Recently, Han et. al (2005) carried out a study about contractor's risk attitudes in selection of international construction projects and aimed to illustrate some of the errors and biases due to risk attitude that commonly exist in bid decisions in construction area.

2.3.3 Category 3: Application of Risk Identification and Analysis Techniques

Third category is composed of application of various risk identification and analysis techniques in construction projects. There exist plenty of research studies about how the RMP can be carried out in a systematic way by the use of different techniques. Some of researchers like Chapman (2001), stated that risk identification should be considered as a part of risk analysis process. In other words, risk analysis should be evaluated as both qualitative risk analysis including knowledge acquisition and risk identification, and quantitative analysis that covers quantification and evaluation of identified risks by carrying out various risk analysis techniques.

2.3.3.1 Qualitative Risk Analysis

Qualitative risk analysis deals mainly with identification of risk events and sources. However, this stage includes knowledge acquisition, probability and impact estimation, initial response statement and secondary risk identification, too. According to Al-tabtabai and Diekmann (1992), the primary basis for identification of risks is historical data, experience and intuition. The most known method for risk identification is risk checklists. Toakley and Ling (1991) stated that risk checklists which are simple catalogues to prevent risk being overlooked, have been compiled by many construction firms.

Similar to Al-tabtabai and Diekmann (1992), Akintoye and Macleod (1997) declared that based on the intuitions, experience and judgments, almost all the project managers know and use risk checklists as a RM technique. In addition to risk checklists, various methods like semi-structured interviews and working group techniques such as brainstorming technique, nominal group technique and Delphi technique are used for identification of project risks. Chapman (1998) conducted a research about the effectiveness of different risk identification and assessment techniques and compared methods of brainstorming, the nominal group technique and Delphi method based on the Handy's (1983) determinates of the group effectiveness model. Günhan and Arditi (2005) conducted a study about factors affecting international construction by using Delphi method. Furthermore, applicability of various risk assessment techniques has been demonstrated by many researchers. Ashley and Bonner (1987) used influence diagramming technique for construction political risk analysis and stated that systematic analysis of construction political risks requires firstly a uniform language for communication. According to Ashley and Bonner, influence diagramming technique (Ashley and Avots, 1984) serves adequately for that language and illustrates the interrelations among the variables. It is obvious that in this research, influence diagrams are the first step in quantitative risk analysis and using subjective probability and value estimates, the quantitative measure of the outcome can be obtained. Similar to Ashley and Bonner, Akıncı and Fischer (1998) investigated uncontrollable risk sources that affect the contractor's risk of cost overburden by using influence diagramming method for mapping interrelations of risk sources. Han and Diekmann (2001) carried out a study pertinent to international risk assessment for construction projects by applying cross impact analysis (CIA). This method maps the interrelations among the variables based on the decision strategies and country conditions and provides a computational basis for decision making. According to CIA model, country conditions and decision strategies affect controllable variables;

and both uncontrollable and controllable variables impact successors variables like project outcomes and corporate outcomes those significantly impact outcome variables of project profitability, other benefits of firm and overall project outcome. Hadipriono et al. (1986) introduced fuzzy event tree analysis (FETA) to explore the events that result in failures of temporary structures and to prevent their failures during construction. Similar to Hadipriono et al. (1986), Choi et al. (2004) applied FETA to identify events that may cause failures in underground construction projects. According to this methodology, construction project is divided into four major phases as contract, planning and design, construction, and operation and maintenance and risk identification is classified into two categories as critical risk events/risk scenarios and completion of the detailed check sheets.

As Uher (1993) stated, for accurate and effective risk quantification, risk identification or qualitative risk analysis is very important. In fact, it is argued that the main benefits of risk management approach come from the identification rather than the analysis stage.

2.3.3.2 Quantitative Risk Analysis

Risk assessment covers quantitative risk analysis based on qualitative risk analysis. Therefore, risks identified in qualitative part should be quantified and evaluated by carrying out several analysis techniques. Quantitative risk analysis techniques may be grouped as sensitivity analysis, probabilistic analysis, decision analysis, fuzzy sets and multi-attribute rating technique.

Sensitivity analysis is the simplest form of risk analysis. It seeks to illustrate the effect of change of a single variable on the whole project. The effect of change of each variable on final cost or time outcome is assessed across the assumed ranges. If several variables are changed, critical variables are illustrated by graphical representation called spider diagram. One weakness of sensitivity analysis is that the variables are treated one by one and possibility that many variables may change at the same time is ignored. Several authors used sensitivity analysis as a risk management tool. For example, Raftery (1994) applied sensitivity analysis on a rehabilitation and redevelopment project in London. Although sensitivity analysis is usually used as a simple technique for risk analysis, a study is conducted by Porter (1981) demonstrates how major project risks can be identified by sensitivity analysis.

As stated above, sensitivity analysis is inadequate for evaluation and assessment of risk combinations in a project. Therefore, probabilistic analysis aims to overcome the limitations of sensitivity analysis by assessing probabilities for each risk and then considering changes in the risks in combination. The result of the analysis is a range of outcomes over which the final outcome lies. Applications of probabilistic techniques, particularly Monte Carlo (MC) simulation, are widely seen in literature. Monte Carlo simulation is based on experimentation and simulation, and is used in situations where a solution in the form of an equation would be difficult or impossible. It is a form of stochastic simulation and requires a set of random numbers to be generated for use in testing various options. The range values for identified risks are assessed together with the probability distribution most suited for each risk and then a value for each risk within its specified range is selected. This value should be randomly chosen and must take account of probability distribution. After all, the outcome of the project is calculated using combination of values selected for each one of the risks. The calculation is repeated a number of times which depends on degree of confidence required, to obtain the probability distribution of the project outcome. One of the earliest efforts regarding the application of probabilistic techniques was carried out by Poliquen (1970). Poliquen applied MC simulation for risk assessment of a port project in Somalia; researched the effectiveness of MC as risk management tool and attracted the attention to difficulties in detection of correlations. Beeston (1986) carried out a research to demonstrate a practical way of achieving a calculated probability of an estimate being exceeded without recourse to complex statistical processes. In this research, it is recommended to use MC simulation as an analytical tool by pointing out the shortcomings and difficulties of MC simulation implementation. Furthermore, the researchers like Dressler (1974), Crandall (1976) and Bennett and Ormerod (1984) declared the pitfalls of deterministic approaches and agreed that the use of MC simulation facilitates risk quantification effectively. Tummala and Burchett (1999) developed a risk management process to manage cost risk for an EHV transmission line project and applied simulation technique for risk measurement by the help of @risk software. The software is used to simulate all possible outcomes in order to determine the cumulative probability distribution of project cost. Zhao et al. (1999) developed a multistage stochastic model for decision making in highway development, operation, expansion and rehabilitation and proposed a solution algorithm based on MC simulation and least-squares regression analysis. Özdogan and Birgonul (2000) carried out a study to develop a decision support framework for project sponsors in the planning stage of BOT projects and applied MC simulation technique in order to examine the effects of cost overrun and completion delays on the tariff rate. Nasir et al. (2003) developed a method to assist in determination of lower and upper construction activity duration values for schedule risk analysis by MC simulation.

As Flanagan and Norman (1993) stated decision analysis deals with the process of making decisions. Decision analysis is both an approach to decision making and a set of techniques to guide decisions like long-term, strategic or short-term decisions under risky and uncertain conditions. Algorithms, means-end chain, decision matrix, decision trees and stochastic decision tree analysis are the examples for decision analysis to be applied to RM process. Algorithms mean a sequence of instructions for problem solving and have often been used as prelude to computer programs as they are logical and easy to follow. Mean-end chain constitutes a chain of objectives and identifies a series of decision points which has hierarchical nature presenting the chain in a step-wise fashion to indicate that means operates at lower level to achieve a higher end. Decision matrix is a representation of options that are open to the decision-maker, the factors that are relevant and the outcomes. Decision matrix is constituted by integrating the alternatives and factors with subjective probabilities of each alternative. Therefore, the final decision is in part subjective but using the decision matrix, final decision taken may be based on objective criteria. Among these techniques, decision tree analysis which is a means of setting out problems that are characterized by a series of either/or decisions, is the most preferred technique by the researchers. Furthermore, according to Akintoye and Macleod (1997), decision tree analysis is one of the most known after sensitivity analysis by contractors and project managers in United Kingdom, too. In most of the major projects, as there exist various routes that may be followed to reach project goals, decision trees analysis illustrates the possible courses of action and all future possible outcomes. Each outcome must be given a probability value indicating its likelihood of occurrence.

It can be noticed that the experience and knowledge of construction project participants are vital issues for assessment of level of uncertainty. Therefore, the opinion obtained from experts with many years of experience in construction projects serve as the major input for risk analysis when historical data is not sufficient or unavailable. However, it is not an easy task to quantify the experience and knowledge of experts for risk assessment. Fuzzy set theory (Zadeh, 1965) is the only mathematical tool that can process linguistic terms usually associated experience and knowledge. Thus, there have been a number of attempts to exploit fuzzy logic within the construction risk management domain. Kangari (1988) proposed an integrated knowledge-based system for construction risk management which performs risk analysis by using fuzzy sets before and during the construction phases. Kangari and Riggs (1989) developed a model to test risk assessment using linguistic variables by identifying the problems and benefits of linguistic variables. Eldukair (1990) made a research and developed a method as fuzzy bidding decision method assuming that the experts are capable of measuring a factor on a scale. Chun and Ahn (1992) conducted a research by using fuzzy event trees to quantify the imprecision and judgmental uncertainties of accident progression event trees. Peak et al. (1993) and Lin and Chen (2004) proposed the use of fuzzy sets for the assessment of bidding prices for construction projects. Ross and Donald (1996) used fuzzy fault trees and event trees in risk assessment problems. Wirba et al. (1996) proposed a method in which the likelihood of a risk event occurring, the level of dependence between risks and severity of risk event, are quantified using fuzzy linguistic approach. Tah and Carr (2001) proposed a knowledge-based construction project risk management methodology including a generic process model underlying information model, common language for describing risks and remedial actions by implementation of fuzzy knowledge representation model to conduct quantitative risk analysis. Fuzzy approach is applied to identify relationships between risk sources and the consequences for project performance. Choi et al. (2004) developed a fuzzy-based uncertainty model for risk assessment of underground construction projects.

There are also multi criteria decision making techniques (MCDM) like Simple Multi Attribute Rating Technique (SMART) and analytical hierarchy process (AHP) for risk quantification. Sometimes, Utility theory is utilized with MCDM methods so that overall utility can be calculated by considering objectives and risk factors. As Flanagan and Norman (1993) stated the major objective of MCDM using utility theory is to obtain overall utility function which yields a utility index or measure of worth for a given set of alternatives. Ahmad and Minkarah (1988) applied utility theory to construction bidding to acquire a markup for a competitive bidding environment. Similar to Ahmad and Minkarah, Dozzi et al. (1996) developed a utility theory model for bid markup decisions.

Analytic Hierarchy Process (AHP) which is developed by Saaty (1980) is widely used as a risk assessment tool. AHP enables experts to make decisions related with many factors including planning, setting priorities, selecting best among the alternatives and allocating resources. AHP is conducted in three steps such as, performing pair-wise comparison, assessing consistency of pair-wise judgments and computing relative weights. Several researchers conducted studies related with implementation of AHP to construction projects. Russel (1991) analyzed contractor failure in US. By using AHP, he suggested that an owner can avoid or minimize contractor failure by analyzing the contractor's qualification prior to contract award and by monitoring the performance of contractor after awarding the contract. On the other hand, Cheung and Suen (2002) applied AHP for dispute resolution strategy. They developed a decision making model composed of four parts like selection criteria, dispute resolution strategies, collection of utility factors and selection criteria weightings. Hastak and Shaked (2000) carried out a study regarding international construction risk assessment by using AHP technique. They developed a international construction risk assessment model which is used for evaluating the risk indicators involved in an international construction operation and is designed to examine attractiveness of a specific project in foreign country. Dikmen and

Birgönül (2005) conducted a study pertinent to risk and opportunity modeling for assessment of international construction projects by using AHP technique. The model uses AHP process for calculation of risk and opportunity ratings and ranking of project options is made according to opportunity and risk ratings calculated based on judgments of the experts.

Besides these risk management techniques, based on the SMART philosophy, risk rating by multiplying the probability with severity/impact of each identified risk factors and adding them up to find an overall risk score is utilized by many researchers, too. Jannadi and Almishari (2003) developed a risk assessor model to determine value of risk associated with a particular activity by using risk rating technique. Baccarini and Archer (2001) described the use of risk ranking methodology which aims to rank and prioritize risks in projects. Similarly, Abourizk and Er (2004) applied risk rating technique for the implementation of a structured risk analysis process.

2.3.4. Category 4: Integrated Risk Management Support Tools

It can be noticed that construction risk management literature is very rich in conceptual frameworks and models to overcome the informality of risk management efforts. As Dikmen et al. (2004) stated risk management paradigms exist as methodologies rather than systems which can fully support RM process. Up to recent years, it has been thought that computer software to conduct RM activities may not be very helpful as the major success factor of RM is data input in the form of human judgment, experience etc. However, in the recent years, it is accepted that RM tools will not substitute human judgment, rather than they will be used to support decision making by systemizing the process. Moreover, it is agreed by many researchers that risk management support tools should be integrated with other project management functions and be used during the whole project life cycle that support all phases of RM. Most of the existing support tools are designed to be used for quantitative risk assessment. Therefore, although there are numerous models/software that support individual phases of RM, the need for development of fully integrated support tools is crucial.

Several researchers tried to develop risk management support systems (RMSS) for implementation of proposed models to construction practices. Alesin (2001) developed a RMSS which may be used for international projects in Russia. In this study, RMSS consists of two parts as computer based training (CBT) system and DSS. CBT can be evaluated as a knowledge management directory which provides information regarding projects in Russia, risk management, and risk analysis. CBT is used for advising the user about what kinds of tools and techniques can be used to make the process of project implementation more successful. On the other hand, DSS provides advices and recommendations to make decision making process better. Furthermore, Alesin stated the importance of risk management database element in RMSS which supplies storage and reuse of information which is updated and grown constantly, for the forthcoming projects.

Another RMSS prototype is developed by Tah and Carr (2001) which is based on a consistent methodology for construction project risk management, including a generic process model and underlying information model. The prototype risk management system follows risk identification, risk assessment, risk analysis, risk handle and risk monitoring processes. Similar to Alesin (2001), the vital role of the risk and action databases are declared by the researchers and the database module which will grow over time, is added to the main system. Although the improvement of databases is provided by the system, the validation of the information produced and stored within the databases is left to the users.

Similar to Tah and Carr (2001), another generic model called IFE (Integrated Facility Engineering) is proposed by Jaafari (2001). IFE consists of various modules and engines like information module, neural network and simulation engines and reporting feature. The main objective of IFE is to provide to the user a consistent and an efficient platform to integrate RM with other project management functions through the whole life cycle of the project. For this reason, IFE model seeks to facilitate non-stop value addition throughout the project lifecycle. One main difference of IFE from other RMSS's is that IFE system gives necessary importance to soft system approach which seeks the collaboration of human aspects for the performance of the project. Beside these researches, several authors conducted studies to developed specific RMSS. For example, Jannadi and Almishari (2003) proposed a risk assessor model and developed a software regarding risk quantification for allocation of safety precautions.

Although several researchers have conducted studies for development of RMSS for years, the number of studies is very limited. In Table 2.2, some of the software used to support risk management process are listed. It is evident from Table 2.2 that there are also a limited number of software which may provide a full support for an integrated risk management system. Therefore, it can be claimed that the literature is very rich in conceptual frameworks; however, risk management paradigms exist as methodologies rather than systems which can fully support the RM process.

Table 2.2 Some of the software tools for risk management

Tool	Developer	Where it can be used	Which risk analysis techniques are used	Which risk management activities are supported
TDRM	HVR Consulting Services	Risk identification in the conceptual planning and bidding stages		Risk identification
Predict!Risk Controller	Risk Decisions	Construction of risk registers, integration of risk info with WBS, monitoring with automatic reminders		Risk identification and monitoring
Risk Radar	Software Program Managers Network	Risk identification and prioritization	Risk rating	Risk identification and monitoring
RiskID Pro	KLCI	Risk identification, monitoring impact of different mitigation plans, risk reporting		Risk identification and monitoring
@Risk	Palisade Europe	Project cost/schedule risk estimation	Monte Carlo Simulation	Risk assessment/analysis
ACE/RI$K	ACEIT	Cost/schedule risk analysis and technical risk assessment	Latin Hypercube sampling	Risk assessment/analysis
CRIMS	Expert choice	Comparison of alternatives according to preset criteria	Analytical Hierarchy Process	Risk assessment/analysis
Decision Pro	Vanguard Software	Setting up a project model for scenario building	Monte Carlo Simulation, Decision Tree Analysis	Risk assessment/analysis
Crystal Ball	Decisioneering	Probabilistic modeling of project variables, estimation of cost, time etc.	Monte Carlo Simulation, sensitivity testing	Risk assessment/analysis
iDecide	Decisive tools	Construction of project models, risk assessment	Monte Carlo Simulation, influence diagramming method	Risk assessment/analysis
Monte Carlo	Primavera	Modeling project variables with probability distributions, integrated with various planning software	Monte Carlo simulation	Risk assessment/analysis

Table 2.2 (cont'd) Some of the software tools for risk management				
Pertmaster prof.+Risk	Pertmaster	Modeling project variables with probability distributions, integrated with various planning software	Sensitivity testing, probabilistic branching	Risk assessment/analysis
Precision Tree	Palisade Europe	Decision analysis	Decision tree analysis, influence diagrams	Risk assessment/analysis
REMIS	HVR Consulting Services	Structured support for all risk management phases, integrated with other support tools (e.g. @Risk), construction of WBS, risk register, mitigation plans	Monte Carlo simulation	Risk identification, analysis, response and monitor
Ris3 RisGen	Line International	Risk identification, construction of risk registers, modeling project variables mitigation plans.	Monte Carlo simulation	Risk identification, analysis, response and monitor
Predict!Risk Analyser	Risk Decisions	Modeling project variables with probability distributions, integrated with various planning software	Monte Carlo simulation	Risk assessment/analysis
Risk+	Project Gear	Integrated with Ms project Planner, modeling of project variables with probability functions, development of risk Gantt chart	Monte Carlo simulation	Risk analysis/assessment
Risksafe	Dyadem	Qualitative risk assessment	Risk rating	Risk analysis/assessment
Risk Tools	Carma	Risk modeling where qualitative data exists, scenario analysis	Fuzzy sets, neuro-nets	Risk analysis/assessment
SCRAM	SCRAM Software	Stochastic risk analysis and generation of PERT and Gantt charts	Monte Carlo simulation	Risk analysis/assessment
RiskTrak	Risk Services and Technology	Risk analysis and reporting (Windows-based tool)		Risk assessment and monitoring
OpenPlan Professional	Welcom Software Technology	Project Management Information Systems	Monte Carlo simulation	Risk analysis and monitoring
SRE	Software Engineering Institute	Decision modeling with risk identification, analysis and response planning		Risk identification, analysis and response
Nickleby KIT	Nickleby HFE	Development of corporate memory, incorporation of experience, intuition, subjective judgments into decision models		Risk identification, analysis, response and monitor
Q2 Risk	Q2 Planning and Consultancy Services	Risk identification, cost/schedule risk assessment, preparation of mitigation plans	Monte Carlo simulation	Risk identification, analysis, response and monitor

2.3.5. Shortcomings of existing RMSS

Before proposing a fully integrated risk management support system, the pitfalls or shortcomings of the existent systems should be clearly stated. For this reason, the literature regarding risk management concept and decision support systems should be critically examined.

When the literature is investigated, it is clear that there are numbers of risk breakdown structures or risk checklists proposed by different researchers. As risk may be used in different meanings such as source, consequence or probability of occurrence of negative event; there exists inconsistency among these breakdowns or checklists. Although it is hard to develop a generic risk checklist or breakdown applicable to all project settings, experience-based databases would be very useful for RM process. An example to these databases is PERIL (Project Experience Risk Information Library) proposed by Kendrick (2003). Such libraries may be constructed for different kinds of projects. Although the PERIL database contains a few unusual situations that are unlikely to recur, nearly all the data represent situations that are typical of technical projects. As a result, it is obvious that experience-based databases like PERIL also provide a template for identifying risk situations that might otherwise fall into “unknown risk” category.

Second pitfall is pertinent to vagueness of the expectations from risk management concept. The literature is full of models built to help the decision maker to determine the contingency value that reflects risk level of the project. Construction risk models based on only quantitative risk assessment do not reflect potential of fully integrated risk management systems. On the contrary, this static approach may only be used for better contingency planning. As Chapman and Ward (1997) stated besides the evaluation and development of contingency plans, an effective risk management should be a dynamic process throughout which the base plans like cost/time plans are developed and better response plans and what-if scenarios are built. Furthermore, effective monitoring of risks and project life cycle objectives in order to revise plans, communication of risk between project participants and construction of corporate memory to introduce experience-based solutions expand the scope of RM process and put forward a dynamic and more effective nature to risk management implementation philosophy, which is squeezed between identification and quantification phases. Thus, more research on these issues, demonstrating potential benefits of RM philosophy is necessary as well as mathematical models built for better estimation and forecasting.

Application of simplistic risk analysis techniques is another pitfall of the existing risk management support tools. None of the risk analysis techniques alone is fully capable of quantification and assessment of risk impacts on project success. Widely used risk rating technique based on multiplication of probability with impact or severity can be given as an example for over-simplistic approach because of the assumption of independent relations of the risk factors. Although in this approach the risk factors are assumed independent from each other, this is not the case in reality. There are usually correlations between risks as they may be affected from similar underlying sources such as macro economical factors. Therefore, the correlation among the risk factors should be considered for a more realistic risk assessment. Moreover, there may be significant differences between values those are assigned as ratings, by using some scales like Likert scale, which are attached by various decision-makers. The reason for assigning different rating values is that the perception of risk factors may differ from one decision-maker to another. In other words, the risk perception is not same for each decision maker while assigning the ratings as well as the underlying assumptions. For example, some of the decision-makers may not consider controllability feature of the risk factor whereas some of the decision-makers may assign the risk the rating assuming that necessary precautions will be taken to avoid risk. For this reason, it is hard to ensure that the rating is done by making the same assumptions about possible responses, capabilities, project success criteria, considering probability and impact independently and having the same risk attitude. It is known that poor risk analysis affects the success of risk response stage and contract strategy. The assumptions made in the risk analysis stage determine the overall success of the risk management process.

It is stated by many researchers that the major problem of risk management support tools is lack of integration. Actually, the problem of integration covers integration of risk management with other project management fields (scope, time, cost, quality, human resource, communication and procurement management); integration of hard systems with soft or human based systems; integration of structured information with unstructured information; integration of project objectives (short-term) with strategic (long-term) objectives; integration of risk management processes with each other; and finally integration of RM activities in one company with those in other project participants. Instead of a traditional linear approach which is a stepwise approach, a cyclic and continuous procedure should be preferred which may be applied to whole project lifecycle. As stated above, the integration of risk management processes can be facilitated by developing support tools based on a continuous procedure by which the phases of RM are overlapped with each other instead of being disjointed activities. Furthermore, the support tools should guide the users for carrying out experience-based computations by providing user-friendly platforms which enable storage and re-use of the experience-based knowledge in RM applications. Thus, the aim of this thesis is to propose a methodology as well as a RMSS which can integrate all RM activities and help decision makers to carry out RM process systematically in construction projects. In the next chapter, model development steps and essentials are given.

CHAPTER 3

MODEL DEVELOPMENT

The aim of this study is to develop a risk management decision support system for international construction projects that will be implemented at the bidding stage. Before giving information related with model development steps, general information related with a Decision Support System (DSS) development will be presented.

3.1 Development of Decision Support Systems

A Decision Support System can assist a decision maker in processing, assessing, categorizing and organizing information in a useful fashion that can be easily retrieved in different forms. In other words, a DSS is a computer technology solution that can be used to support complex decision making and problem solving. DSS facilitates to bring together information from variety of sources, assists in organization and analysis of information and facilitates the evaluation of underlying assumptions. As Bhatt and Zaveri (2002) stated, DSS has the ability to facilitate problem recognition, realize model formation, assist in gathering, integrating, organizing and presenting relevant information, select an appropriate problem solving strategy, evaluate the different solutions and finally choose the best solution. Actually, DSS helps decision-makers uses and manipulates data; applies checklists and heuristics; and builds and uses mathematical models.

DSS studies have evolved in two main areas of research, which are the theoretical studies of organizational decision making and classic DSS tool design. As Shim et al. (2002) stated classic DSS tool design is comprised of components for sophisticated database management capabilities with access to internal and external information and knowledge, powerful modeling functions accessed by a model management system and powerful and simple user interface designs that enable interactive queries, reporting and graphing functions. Starting from early 1970's, development and application of DSS to different kinds of areas have become more popular. The studies pertinent to development of DSS have mainly focused on how information technology can improve the efficiency with which a user makes a decision, and can improve the effectiveness of that decision.

The original DSS concept was most clearly defined by Gorry and Morton (1971) who combined categories of management activities developed by Anthony (1965) with description of decision types proposed by Simon (1960) using the terms structured, semi-structured and unstructured rather than programmed and non-programmed. For their DSS framework, they used Simon's intelligence, design and choice description of decision making process. In this framework, intelligence symbolized the search for problems, design involves the development of alternatives and choice consists of analyzing the alternatives and choosing one for implementation. As indicated above, DSS deals with a problem which covers both structured and semi or unstructured stages. Therefore, a computer system should be developed to deal with the structured portion of DSS problem, but the judgment of the decision maker is brought to bear on the unstructured part, hence constituting a human-machine problem solving system. As DSS has to cope with the sophisticated and complex real world problems, the need for proper information is vital for effectiveness of decision improvement. Therefore, the ill-defined nature of information needs in DSS situations leads to requirement for different kinds of database systems. For this reason, relational databases and flexible query languages are needed.

A DSS is typically composed of four components, which are a database management system (DBMS) providing access to data and control programs to get the data into appropriate forms for analysis; a model-based management system (MBMS) that keeps track of all models running during an analysis and provides the user with a facility to question the assumptions of models; a user interface that provides the mechanism whereby information is presented to the user; and recently a new component, mail management system (MMS) which incorporates mail and other online data into decision support models. The basic approach for decision making process in DSS environment which is adopted from Shim et. al (2002) can be illustrated as in Figure 3.1.

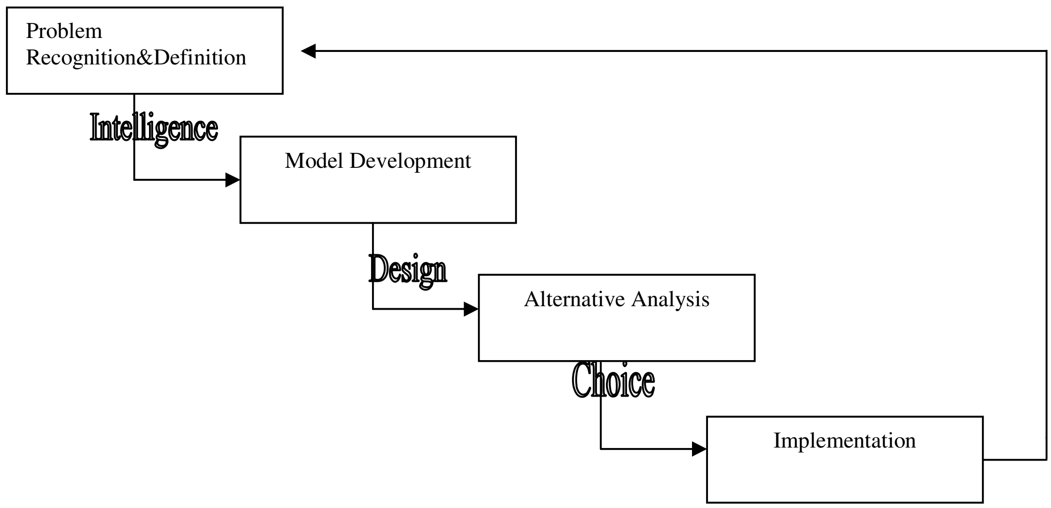

Fig 3.1: Basic DSS decision-making process, Shim et. al (2002)

Starting from early 1980's DSS research has evolved several additional concepts like group decision support systems (GDSS), executive information systems (EIS), model management systems and knowledge based decision support systems. GDSS aim to create greater decision-making effectiveness by providing an effective communication platform either synchronously or asynchronously. In other words, GDSS and computer-mediated communication systems (CMCS) provide support for either spontaneous meetings (synchronous), like face-to-face meetings, phone calls, desktop conferencing and web based chat rooms, or more structured (asynchronous) and document oriented meetings. Furthermore, EIS have extended the scope of DSS from personal or small group use to the corporate level. Model management systems and knowledge-based decision support systems have used techniques from artificial intelligence and expert systems to provide smarter support for decision maker. As Shim et al. (2002) stated, starting from these perspectives on, DSS researchers should embrace more comprehensive view of decision making and develop decision support systems capable of handling much softer information and much broader concerns that mathematical models and knowledge-based systems have been capable of handling in the past. This approach necessitates modifications at the design stage of existing DSS decision making processes. Mitroff and Linstone (1993) suggested some perspectives like organizational, technical and personal should be developed and integrated into problem formulation phase. Furthermore, they proposed that ethical and aesthetic factors should also be evaluated during problem formulation phase which creates a perspective synthesis.

Starting from late 1980's, some powerful tools were used for constituting DSS such as data warehouses, on-line analytical processing (OLAP), data mining and worldwide web (www). These tools have increased the efficiency and capability of DSS and facilitated building decision support systems. Data warehouses were seen as a solution for integrating data from diverse operational databases to support management decision making and thus, can be defined as a subject-oriented, integrated, time-variant, and nonvolatile collection of data. Building large data warehouses often leads to an increased interest in analyzing and using accumulated historical DSS data. One way of analyzing historical DSS data in a data warehouse is using OLAP. Actually, OLAP is a category of a software technology that enables the users gain a perspective into data through fast, consistent, and interactive access to a wide variety of possible views of information that has been transformed from raw data to reflect the real dimensionality of the enterprise. Although OLAP tools have become popular in recent years, a set of artificial intelligence and statistical tools called data mining tools have been proposed for more sophisticated data analysis. Data mining is also called database exploration, or information and knowledge discovery. In addition to these DSS tools, www has become the center of activity in developing DSS for a decade. Web-based DSS means that a computerized system that delivers decision support information or decision support tools using a web browser. The primary web tools are web servers using hypertext transfer protocol (HTTP) containing web pages created with hypertext mark-up language (HTML) and JavaScript accessed by client machines running client software known as browser.

In addition to DSS building tools, one of the more significant trends over the past 20 years has been evolution from individual stand-alone computers to highly interconnected telecommunication network environment of today. Local area networks (LAN) provide a platform in which the computers within the firm are connected, and allow teams and workgroups to share decision making information more easily. Furthermore, firms connect their networks in wide area networks to facilitate sharing of information across organizational boundaries. This system widens the scope of DSS and leads to execution of group processes supporting decision making called as group support systems or collaboration support systems. The communication and coordination activities of team members are facilitated by technologies that use time, space and cost efficiency.

3.2. Proposed Risk Management Support System

The aim of this study is to propose a risk management decision support system which is applicable to international construction project at the bidding stage. The proposed model is designed to overcome pitfalls or shortcomings pertinent to risk management support systems stated in part 2.3.5. This model takes up risk management concept not in traditional form which assumes RM as a disjointed, static, stepwise and somewhat linear approach. On the contrary, the proposed model maintains application of risk management approach at the bidding stage of the project at which the processes overlap each other and proactive risk management perspectives are dictated. As stated already, risk management literature tends to deal with risk analysis and management as separated segments. In other words, some approaches aim to model risk quantification only to represent risk management. In recent studies regarding soft system approach and integration of strategic management to risk management, it is clearly understood that only risk quantification cannot represent risk management process i.e. only quantification models may be impractical for implementation of RM. Therefore, the proposed model is designed to cover soft system approaches like utilization of previous experiences with RM attitudes.

Integrated Risk Management System (IRMS) is a decision support system which has been designed to assist decision makers at the bidding stage of the project and is applicable to all kinds of construction projects. This system supports contribution of soft systems like knowledge and experience based issues to hard systems such as identification and analysis techniques and takes strategic perspectives of the organization into consideration while carrying out risk management process. In addition, the system provides integration of RM with other project management functions like cost planning. The system is designed to aid the risk management process controlling all aspects by using multi user option which increases the efficiency of the process. One of the vital features of the IRMS system is utilization of previous projects knowledge for the forthcoming projects. The system includes a corporate memory which will be formed by previous project data used in IRMS. The system is designed to prepare kinds of reports, charts and maps for the convenience of experts to evaluate current status and decide on the development of mitigation strategies necessary for the project performance. All of these features of IRMS are explained in the forthcoming parts of the chapter.

3.2.1. IRMS risk management process model

IRMS risk management process model consists of following four jointed phases (Figure 3.2):

- risk identification,
- risk classification and rating,
- risk analysis and response development, and
- risk revising.

As IRMS approach is based on the principle of separating the project into work packages and assigning risks to specified work packages, it enables the definition of relationship between hierarchical risk breakdown structure (HRBS) and work breakdown structure (WBS), and supports the integration of risk management with cost estimation function.

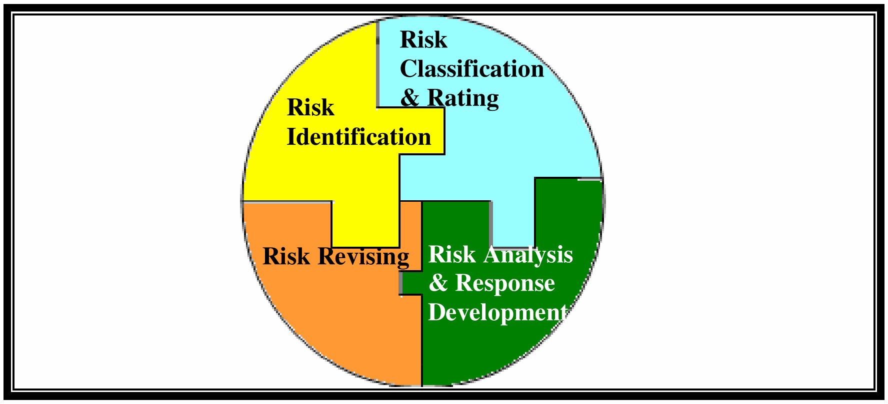

Fig 3.2. IRMS risk management process model

First phase of IRMS process model is risk identification. Risk identification is a process to acknowledge risk events and to identify characteristics of risk sources. Although risk identification seems a simple process compared to other risk management processes, it is the most complex and vague process for a decision maker due to nature and definition of risk. As risk may be used to imply source, consequence or probability of occurrence of a negative event, it leads to a major inconsistency and wrong formulation of the risk model. IRMS handles risk as a source which should be defined for each work packages and prevents the possibility of definition of risk as event or consequence providing a consistent platform for the decision maker. The process must involve an investigation into all potential sources of project risks. Therefore, this phase should be carried out very carefully for the sake of effectiveness of RM, which constitutes a basis for risk analysis and response strategies which may only be performed by referring to the identified potential risk sources. Without the identification of risks, there is nothing to evaluate, to control or manage, or to insure against. Worst important aspects of all, unidentified risks tend to be most disastrous and catastrophic. For this reason, a detailed scanning of project specific and global risk sources should be carried out.

One of the features of the IRMS model is the assistance capability to the decision maker during the risk identification phase by using a template HRBS which incorporates a predefined coding system to establish a common language. In IRMS, the risk sources are handled as project specific risks which can be assigned to project work packages and global risk sources those affect the whole project.

The template HRBS is constituted by taking into account the contract clauses, project participants, project country conditions, construction and design related issues etc which may affect performance of projects. Template HRBS consists of five level breakdown. The major headings are local risk, which are project based risk sources, and global risk defined as country risk and force majeure risk sources. Local risks are the ones which are pertinent to project specific issues. Project specific risks are divided into six subgroups covering 20 risk sources at the fourth level. On the other hand, global risks are the ones which exist outside of project and effect whole project in terms of country related risks and force majeure risks. Country risks consist of four groups as political, economical, social and legal risk sources. Although there exists a template HRBS to assist the decision maker during the identification process, the expert is capable of making modifications on the HRBS and add new sources. However, the decision maker should use at least this template to carry out a proper RM process. First four level HRBS is given in Figure 3.3.

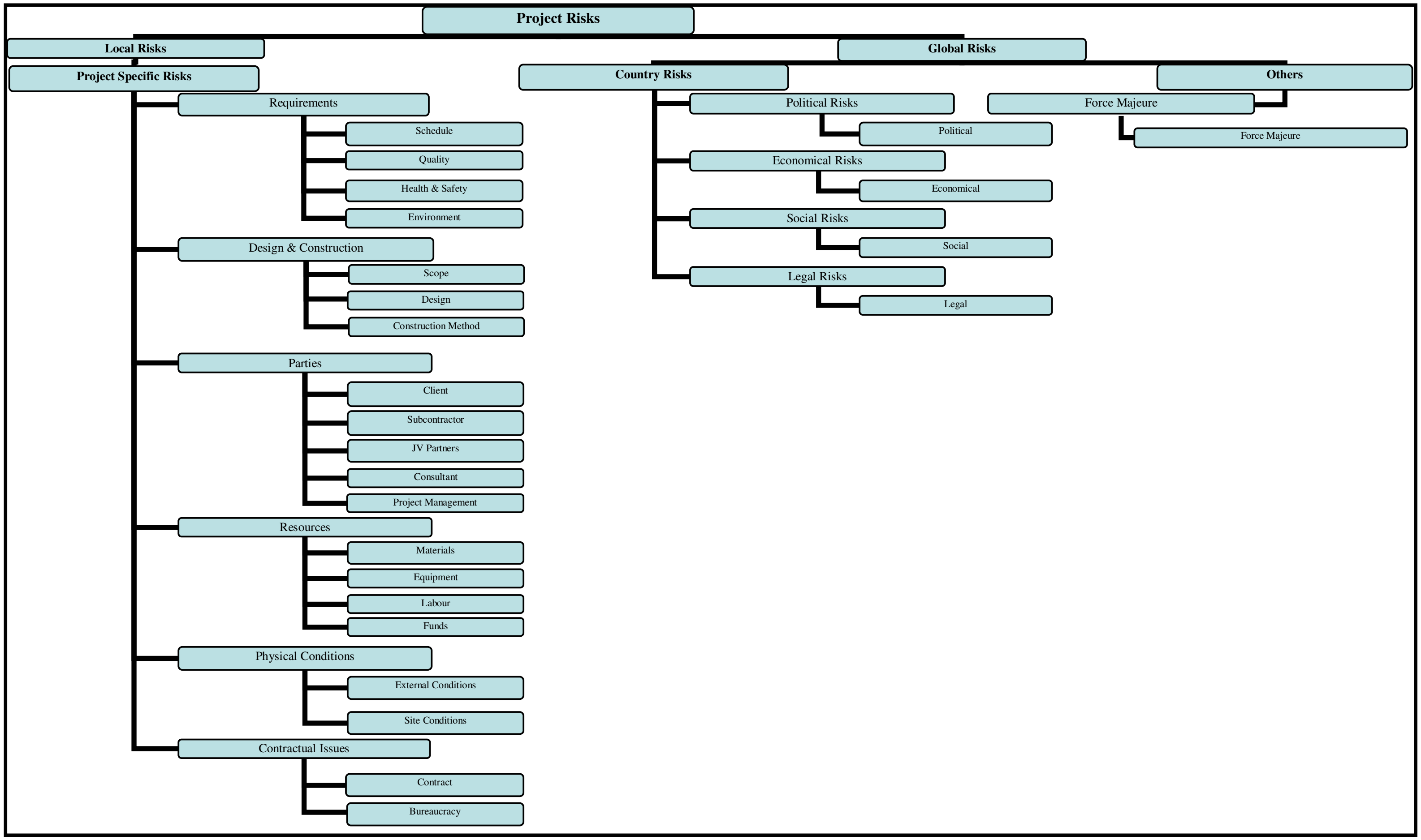

Figure 3.3. Hierarchical Risk Breakdown Structure of IRMS

According to IRMS approach, the project should be split into specified work packages in order to assign risk sources to each package by using proposed HRBS. Formation of a common language will facilitate the processes, increase the speed of computations and prevent confusion of experts while constructing the link between HRBS and WBS. On the other hand, same approach is true for the global risk sources which affect the whole project performance. For this reason, a pre-defined coding system is developed to increase the effectiveness of computations while applying IRMS RM methodology.

The coding system is constituted by using initial letters of the specified risk sources. If there are more than one risk sources with identical initial letters at the same level, the system assigns a number next to the initial letter like R1 and R2 for requirements risks and resources risks at the third risk level. The coding system of risk source of labor strikes is illustrated at Figure 3.4 and HRBS coding for Local Risk sources is shown in Table 3.1.

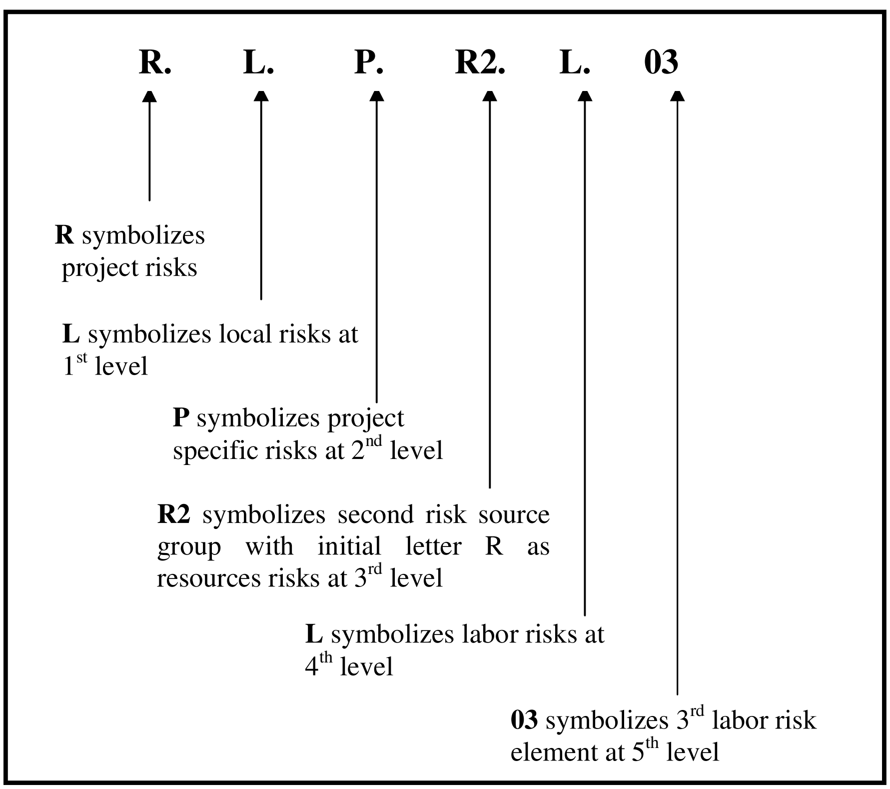

Figure 3.4. Illustration of IRMS coding system

Table 3.1 HRBS coding for Local Risk Sources			
	PROJECT SPECIFIC (R.L.P)		
SCHEDULE (R.L.P.R1.S)	**QUALITY (R.L.P.R1.Q)**	**HEALTH & SAFETY (R.L.P.R1.H)**	**ENVIRONMENT (R.L.P.R1.E)**
.01 inappropriate schedule estimate	.01 strict requirements	.01 strict requirements	.01 strict requirements
.02 unrealistic milestones	.02 vagueness in specs./standards	.02 vagueness in standards	.02 vagueness in regulations
.03 working hour restrictions		.03 accidents	
SCOPE (R.L.P.D1.S)	**DESIGN (R.L.P.D1.D)**	**CONSTRUCTION METHOD (R.L.P.D1.C)**	**CLIENT (R.L.P.P1.C1)**
.01 changes in scope	.01 vagueness in design	.01 complexity	.01 negative attitude towards foreign contractors
.02 vagueness in scope	.02 defective design	.02 vagueness in construction method	.02 poor performance
	.03 delay in design	.03 novelty	.03 lack of enough qualified personnel
	.04 complexity	.04 improper construction method	.04 vagueness of req./client expectation
	.05 poor performance of designer		.05 change in requirements
	.06 poor constructability		
SUBCONTRACTOR (R.L.P.P1.S)	**JV PARTNER (R.L.P.P1.J)**	**CONSULTANT (R.L.P.P1.C2)**	**PROJECT MANAGEMENT (R.L.P.P1.P)**
.01 unavailability	.01 poor performance	.01 poor performance	.01 strict documentation requirements
.02 poor performance	.02 conflicts	.02 conflicts	.02 organizational complexity
.03 conflicts	.03 vagueness of responsibilities		.03 poor performance of PM staff
	.04 unavailability		.04 poor communication between parties
			.05 lack of experience of PM staff
MATERIALS (R.L.P.R2.M)	**EQUIPMENT (R.L.P.R2.E)**	**LABOUR (R.L.P.R2.L)**	**FUNDS (R.L.P.R2.F)**
.01 defective material	.01 unavailability	.01 unavailability of domestic workers	.01 inappropriateness of budget estimate
.02 increase in prices	.02 increase in prices	.02 poor productivity	.02 unavailability of funds
.03 unavailability	.03 delay in delivery	.03 strikes	.03 unavailability of extra funds for additional works
.04 delay in delivery	.04 breakdown/accidents	.04 restrictions on foreign workers	
.05 restrictions on imports	.05 poor productivity	.05 increase in labor costs	
.06 improper material definition	.06 restriction on imports		
	.07 impr[illegible]ent definition		
EXTERNAL CONDITIONS (R.L.P.P2.E)	**SITE C[illegible]ONS (R.L.P.P2.S)**	**CONTRACT (R.L.P.C1.C)**	**BUREAUCRACY (R.L.P.C1.B)**
.01 vagueness of ground conditions	.01 phys[illegible]nts	.01 vagueness of clauses	.01 delay in site hand-over
.02 unfavorable ground conditions	.02 poor [illegible]te	.02 missing clauses	.02 delay in expropriation
.03 unfavorable weather conditions	.03 poor security around site	.03 contradictory clauses	.03 delay in permits/approvals
		.04 lack of major contract clauses	.04 delay in progress payments
		.05 dispute resolution clauses	

Second phase of IRMS is risk classification and rating which covers grouping of risk sources and assigning ratings to each identified risk, based on the expert judgments. In other words, probability and impact values of risk sources are determined. These values are symbolized by linguistic variables, such as low, medium, moderate and high.

First part of this phase is risk classification. As IRMS process model uses a template HRBS for computing the processes, it already provides a classified platform of risk sources and thus risk classification is done spontaneously while doing risk identification process. This feature increases the speed of IRMS process model and effectiveness of risk classification and rating phase. If one risk source is picked up from HRBS for assigning to a work package, it definitely corresponds to a pre-classified group with a risk code. Therefore, risk identification and risk classification is done in parallel in IRMS model, although they seem to be different processes.

According to identified and classified risk sources assigned to work packages, risk assessment should start. In this model, risk rating (RR) aims to indicate the risk level of work packages and the project, although the rating shows not an absolute but a relative value. Risk rating covers assessment of probability of occurrence of corresponding risk sources for the work packages and their impacts on work packages if they occur. The rating of each risk source is calculated by simple multiplication of probability of occurrence of risk sources with their impacts. For the probability and impact values, Likert (1 to 5) scale is used, at which each number symbolizes different magnitudes which are shown in Table 3.2.

Table 3.2. Rating Scale and corresponding linguistic variables

Value	Probability Term	Impact Term
1	Very Low	Very Low
2	Low	Low
3	Medium	Medium
4	High	High
5	Very High	Very High

This phase allows the decision maker to form the link between risk management and other project management functions through constitution of the platform of HRBS with WBS as work packages. As stated before, for each work packages risk sources are assigned, and for each risk elements probability and impact values are assessed to calculate corresponding risk rating of the risk source so that the risk level of work packages can be determined. However, one important aspect of the IRMS model is that the model takes strategic objectives into consideration and provides a consistent platform for risk response development. While completing the risk assessment process, it is needed to develop strategies to mitigate undesirable risks. When the strategies are implemented, the value of RR may change which should decrease to acceptable ranges. The main consideration at this point is to minimize the effect of risk sources, but not necessarily to eliminate them. From this point on, rating should be done as pre-response and post-response ratings depending on the risk response strategy developed by the decision maker. Pre-response means that the rating value at which risk response alternatives are not applied; on the other hand, post-response rating value illustrates the effect of risk response or controlling strategy on the risk source compared to "do nothing" case.

As risk response content covers mitigation and controlling strategies to risk factors, a risk response breakdown should be developed. Risk response breakdown is composed of risk transfer and risk retention strategies, which is shown in Figure 3.5.

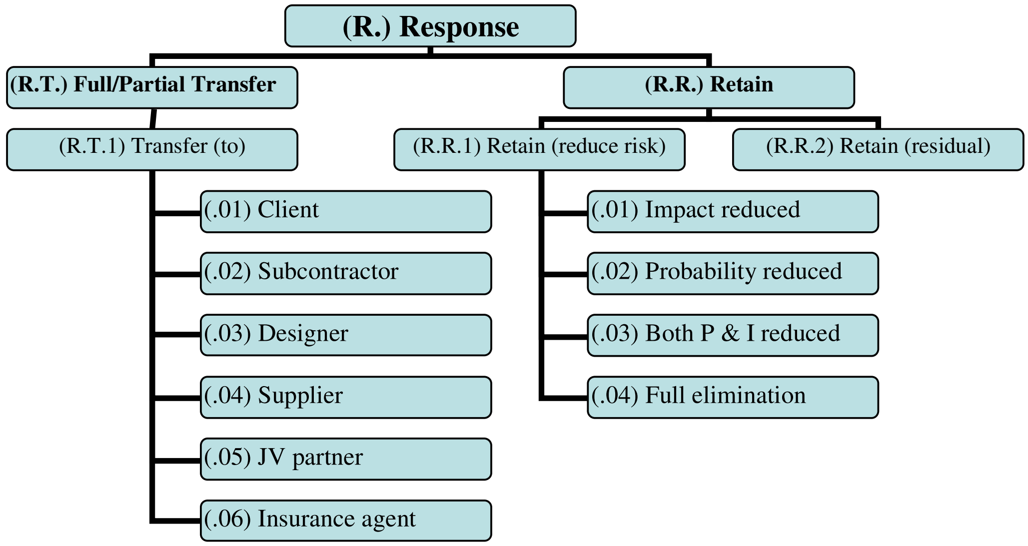

Figure 3.5. Risk response breakdown of IRMS model

IRMS model integrates and systematize all explained tasks such as risk source identification, risk classification and rating, and response development etc in order to facilitate the decision making process and increase the efficiency of the model. Systematic and formal RM process of IRMS is called as Risk Carding (RC) process and constitutes one major component of the IRMS approach. RC process covers risk identification, risk register, risk classification and rating, and finally risk response development tasks. As stated earlier, IRMS does not contain disjointed phases or tasks. Therefore, while applying one phase of IRMS process model, the predecessor and successor phases are also carried out spontaneously and necessary modifications and re-evaluations are considered, too. For this reason, although RC process seems as a step wise approach, it has got rather cyclic nature.

RC process starts with the identification task. If one risk source is identified, it should be described clearly by the expert to prevent confusion of the term. The system calls automatically risk code of the risk source while describing the risk source. On the other hand, the system supports identification of risk source by using pre-defined risk code. After risk source is described, the process continues with contract evaluation in order to determine the ownership of the identified risk source. It is clear that there exist number of participants to realize a construction project which leads to more sophisticated relationships and legal arrangements. The party can be a client, contractor, joint venture (JV) partner, subcontractor, designer, supplier etc. Among all parties, legally enforceable contract arrangements should be formed. This situation illustrates that in a construction project, there are tens of contract arrangements which have specific clauses. For this reason, in order to determine the ownership of an identified risk source corresponding parties and pertinent contract clauses should be analyzed. Therefore, ownership determination necessitates labeling the contracts as project information and definition of the corresponding contract parties. In other words, after identification of a risk source, corresponding parties of the risk source should be identified. Taking the content of risk source into consideration, major clauses are scanned and related contract clause is found. Afterwards, the contract clause is examined and risk owner is determined based on the specified clause explanations. While doing all these tasks, RC provides a platform to register clause code and related clause for a re-evaluation process.

Risk rating process starts with the determination of the ownership of the risk. As stated before, risk rating should be applied in parallel with risk response development process so that model supports integration of the strategic objectives based on the expert judgments. This situation leads to two level risk rating process as pre-response rating and post response rating. Depending on the rating values and response cost, the expert has the ability to continue to apply response strategy, alter response strategy and re-rate or cancel application of the response strategy for the corresponding risk source, which provides a flexible environment to the decision maker. Pre-response rating is calculated by multiplying probability of occurrence of risk source with impact of the corresponding risk source. While calculating pre-response RR, the rates are considered for the “no response” case. Same procedure is applied for post-response RR by choosing an appropriate risk response strategy from the risk response breakdown and corresponding probability of occurrence and impact values are assigned based on the developed response strategy. Applying a response strategy means additional cost for the assigned work package in terms of response cost. As stated earlier, carrying out of post-response RR does not necessarily mean that the chosen response has to be applied. Based on the comparison of response rating values and additional response cost amount, the expert may apply the response or cancel the response and continue with the "no response" values. The general framework of RC process is given in Figure 3.6.

The risk level of the work packages are determined based on the rating values. Normally, RC framework supports to reach one rating value which symbolizes the risk level of the specified risk source for the corresponding work package. However, the system provides to the decision maker three rating values to facilitate the decision making process of the expert:

(I). Final pre-response rating value with no additional response cost,

(II). Final post-response rating value with an additional response cost for each risk source,

(III). Final rating value with an additional response cost corresponds to chosen the response strategy.

Furthermore, each work package has an estimated cost (EC) value. This cost value varies depending on what work package covers or how many percent of the whole project is executed through this work package. For this reason, it can be thought that each work package has its own budget. The additional cost value stated as response cost can be correlated with the estimated cost of the work package to understand the amount of the response cost value. For some cases, the additional response cost value seems a lot if only the numbers are evaluated. However, considering the budget of the work package, it would be a reasonable percent of the estimated cost value of the work package. Similarly, some cost values gives the idea that these cost values are very reasonable if the rating values are considered, but these cost values may correspond to very high percentages and would not be reasonable. Therefore, while evaluating the risk rating and cost values, it would be better to use additional response cost with the percentages of the estimated cost values of the work packages. At the end of the RC process, rating and corresponding additional response cost values are stated for each work package.

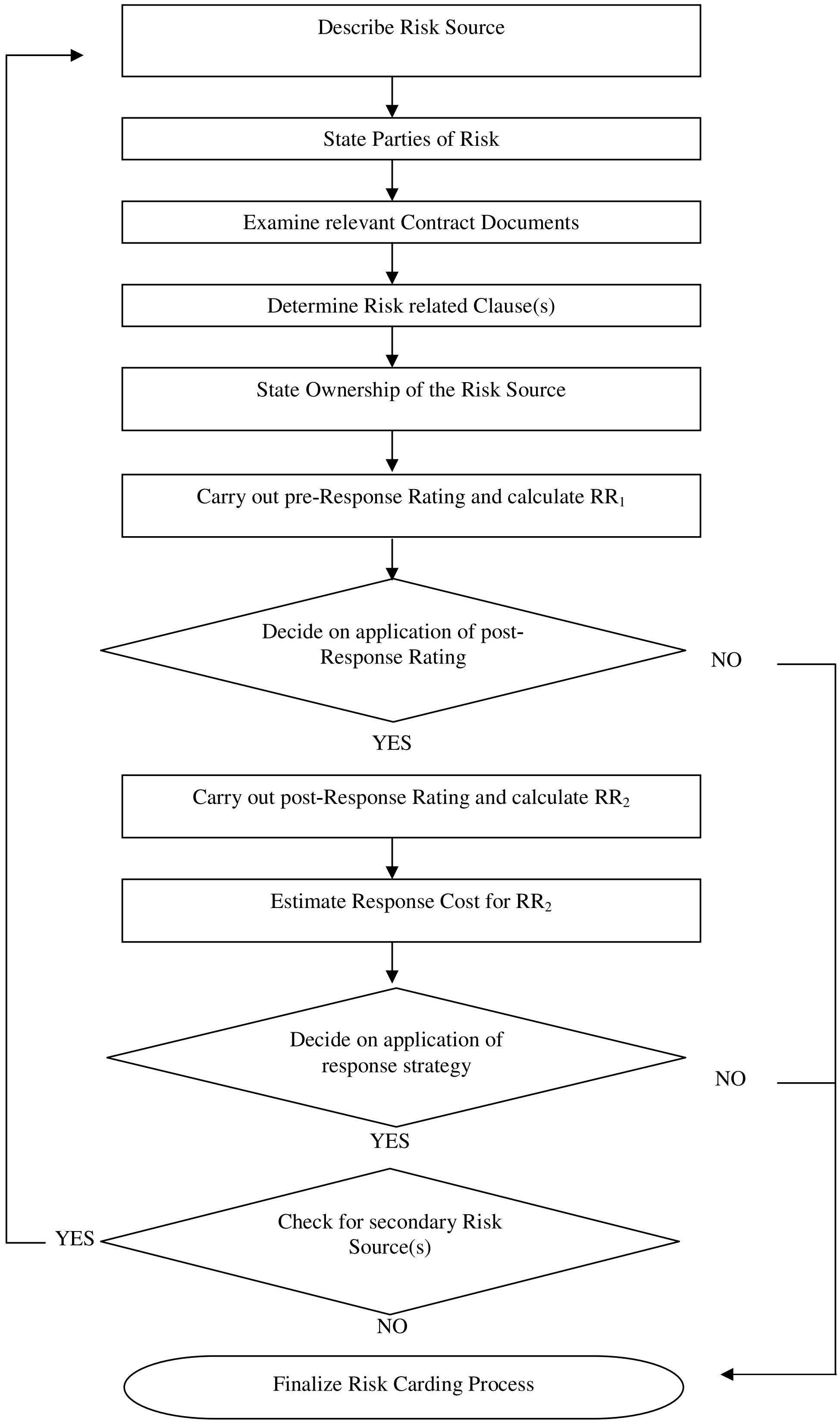

Figure 3.6. Risk Carding Process Framework

As RC process is a semi-quantitative approach, the risk level categorization of the work packages at the end of the process should be declared by using a probability vs impact curves which define the risk level of the work packages by using pre-stated curves as y=K/X. Actually, as the K value represents multiplication of probability of occurrence of the risk source (x) with the impact of the risk source (y), it symbolizes limit values of the categories. K value may depend on the perception of the risk level by the expert. For example, y=10/x curve may define the upper limit of the moderate category; on the contrary, same curve may represent upper limit of low category which indicates that second expert has a risk lover attitude compared to the first one. Therefore, although default values of the risk level categories are supplied by IRMS, the system provides a flexible platform to the experts to alter the limits of the categories or K values while carrying out RC process. The ranges of the rating scores (RS) and corresponding rating curves are given in Table 3.3.

Table 3.3. Rating score ranges and corresponding rating curves

Rating score range (K)	Risk rating curve	Risk category
1-5	<y=5/X	Low
5-10	y=5/X < RS <y=10/X	Moderate
10-15	y=10/X <RS<y=15/X	Significant
15-25	y=15/X< RS	High

It can be observed from Table 3.3; three rating curves constitute the lower and upper limits of rating score ranges. K value of the rating curves can be modified, and categorization can be altered. For each work package; the pre-response, post response and final rating values can be seen through these sets of curves as a summary report in graphical format (Figure 3.7).

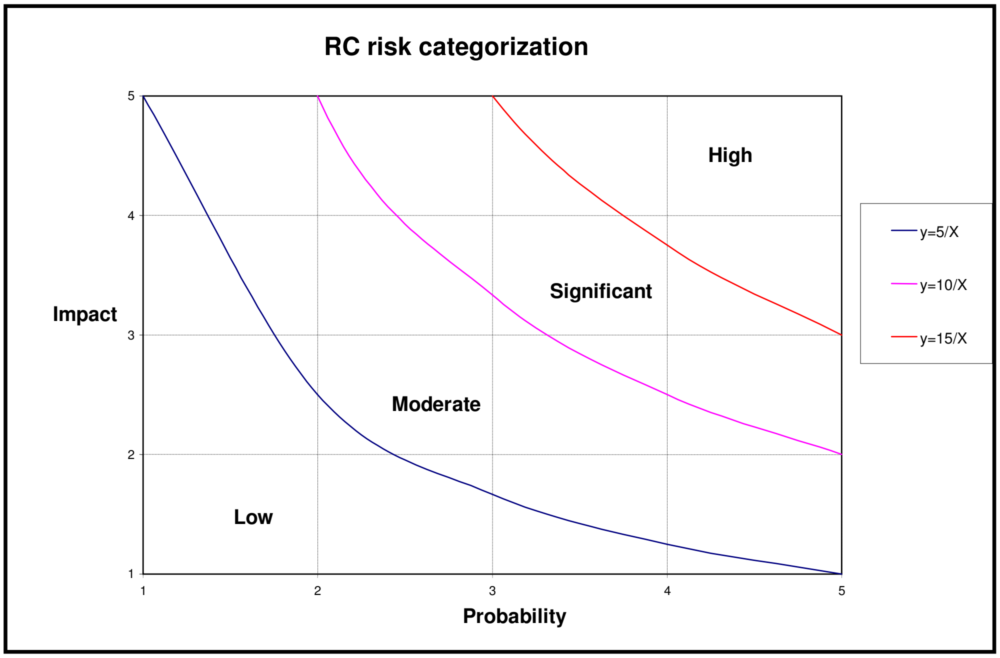

Figure 3.7. RC Process Rating Curves

Final step of RC process is to decide the risk level of work package and declare corresponding additional response cost (AC). Based on the rating scores, chosen response strategies and estimation of additional cost values, through rating curves the level of the risk of the work package and corresponding additional response cost value are determined. Additional cost value or cost of response and risk level of the work package in terms of linguistic variables facilitate the process of risk analysis of the expert through Monte Carlo simulation.

As risk carding process is the combination of risk identification and classification and rating phases and constitutes the base for risk analysis, it should be accepted as the core of IRMS RM process and should be carried out carefully. Major advantage of RC is that although the process looks like a step wise procedure, it allows feedbacks, modifications and alterations of the steps which provide a flexible nature to the process.

Third phase of IRMS RM process is called risk analysis. Risk analysis covers quantification of risk factors and supplies necessary information for risk revising and handling. There exist several risk management decision support systems those use MC simulation for risk assessment and quantification. However, major difference of IRMS from other support systems is that risk rating approach and MC simulation is used together firstly in the literature to quantify impact of risk sources on work packages. Risk analysis starts with risk rating in risk classification and rating phase and is finalized at risk analysis and response development phase by MC simulation.

Simulation is any analytical method that is meant to imitate a real life system, especially when other analysis are mathematically too complex or too difficult to reproduce. Spreadsheet risk analysis uses both a spreadsheet model and simulation to analyze the effect of varying inputs on outputs of the modeled system. One type of spreadsheet simulation is Monte Carlo simulation, which randomly generates values for uncertain variables over and over to simulate a model.

Monte Carlo simulation was named for Monte Carlo, Monaco, where the primary attractions are casinos containing games of chance. Games of chance such as roulette wheels, dice, and slot machines exhibit random behavior. The random behavior in games of chance is similar to how Monte Carlo simulation selects variable values at random to simulate a model. When you roll a dice, you know that a 1, 2, 3, 4, 5, or 6 will come up, but one does not know which for any particular trial. It is the same with the variables that have a known range of values but an uncertain value for any particular time or event (e.g., interest rates, staffing needs, stock prices, inventory, and phone calls per minute). For each variable, one should define the possible values with a probability distribution. The type of distribution one should select depends on the uncertainty associated with the variable. Some common distribution types are shown in Figure 3.8.

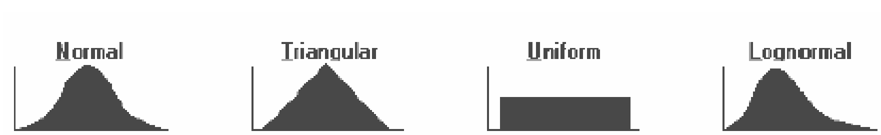

Figure 3.8. Common probability distribution functions

A simulation produces numerous scenarios of a model by repeatedly picking values from the probability distribution for the uncertain variables and using those values for the cell. Commonly, IRMS MC engine calculates hundreds or thousands of scenarios in just a few seconds. Since all those scenarios produce associated results, MC engine also keeps track of the forecasts for each scenario. Forecasts are cells (usually with formulas of functions) those are important outputs of the model. For each forecast, MC engine remembers the cell value for all the trials (scenarios). During the simulation, one can monitor a histogram of the results, which shows how they stabilize toward a smooth frequency distribution as the simulation progresses. After hundreds or thousands of trials, one can view sets of values, the statistics of the results (such as the mean forecast value), and the probability of any particular value.

As the current study is pertinent to cost estimation, IRMS MC engine considers each work package and calculates a cost value based on criteria of risk level and additional response costs. The procedure starts with choosing best suited distribution function for each work package. IRMS provides six major and common probability distribution options for the decision maker for applying risk analysis:

(I). Uniform distribution function at which all values between the minimum and maximum occur with equal likelihood. In this distribution minimum and maximum values are fixed.

(II). Normal distribution function by which many natural phenomena can be modeled. Some values of the uncertain variable is the most likely (the mean of the distribution), the uncertain variable could as likely be above the mean as it could be below the mean (symmetrical about the mean), and is more likely to be in the vicinity of the mean than far away.

(III). Triangular distribution function which describes where the minimum, maximum, and most likely values are known. The minimum and maximum values are fixed and the most likely number of items falls between the minimum and maximum values, forming a triangular-shaped distribution, which shows that values near the minimum and maximum are less likely to occur than those near the most likely value.

(IV). Beta distribution function which is a very flexible distribution commonly used to represent variability over a fixed range. One of the more important applications of the beta distribution is its use as a conjugate distribution for the parameter of a Bernoulli distribution. In this application, the beta distribution is used to represent the uncertainty in the probability of occurrence of an event. It is also used to describe empirical data and predict the random behavior of percentages and fractions. In this distribution, the uncertain variable is a random value between 0 and a positive value and the shape of the distribution can be specified using two positive values.

(V). Trapezoidal distribution which represents three values as minimum value, middle range and maximum value.

(VI). Custom distribution which can be formed based on the data set available such as discrete values.

After choosing one of these distribution types, necessary parameters (coefficients, minimum and maximum values, etc.) are defined by taking final risk rating value or risk level and corresponding additional risk response cost into account. Total project cost is the sum of all these work package cost values. If the simulation is run, total project cost for different scenarios is calculated and corresponding probability values for different cost ranges are obtained. It should not be forgotten that the cost calculated by using MC simulation does not contain the effect of global risk sources. This cost symbolizes only project cost influenced by project based risk sources. Therefore, project cost should be revised by applying the effect of global risk sources on project cost. IRMS MC engine summarizes MC simulation process in a tabular format, an example of which is shown in Table 3.4.

Table 3.4. An example of MC risk analysis summary output

WORK PACKAGE	Final Risk Rating (RR)	Risk Level	Chosen Distribution Function	Estimated Cost Before MC	Cost range after MC
WORK PACKAGE 1	RR1	LOW	TRIANGULAR	**C1**	**$C1_{min}$-$C1_{max}$**
WORK PACKAGE 2	RR2	HIGH	NORMAL	**C2**	**$C2_{min}$-$C2_{max}$**
WORK PACKAGE 3	RR3	SIGNIFICANT	UNIFORM	**C3**	**$C3_{min}$-$C3_{max}$**

According to IRMS model, same rating procedure can be applied to global risk sources. In this case, the rating procedure is not carried out to find cost of work packages; on the contrary, it is aimed to calculate a global risk rating score. The expert should assess probability and impact values for country risk sources as political, economical, social and legal; and force majeure risk sources (Table 3.5). The average of all of these risk sources can be stated as global risk rating score and can be applied to revise project cost value. However, one rating value is meaningless unless it is converted to a quantifiable term. Therefore, same rating curves can be used to convert the global rating value to linguistic terms as low, moderate, significant and high. After global rating value is converted to quantifiable terms, it is recommended that based on the global rating value or risk level, the project cost value should be increased by a pre-defined percentage of the project cost value calculated by MC simulation. At this point, IRMS does not provide any percentage scale to the expert because this percentage amount depends on many parameters like company strategy, company work load, company strengths and weaknesses etc. Therefore, it is not easy to formulate all these parameters for defining a percentage value. For this reason, IRMS leaves the responsibility for assessment of global risk percentage to the experts or decision makers.

Table 3.5 HRBS of Global Risk Sources

GLOBAL RISK SOURCES (R.G.)				
COUNTRY RISKS (R.G.C.)				OTHERS (R.G.O.)
POLITICAL (R.G.C.P.P)	SOCIAL (R.G.C.S.S)	ECONOMICAL (R.G.C.E.E)	LEGAL (R.G.C.L.L)	FORCE MAJEURE (R.G.O.F.F)
.01 Political instability	.01 Social differences (religious, cultural lingual etc.)	.01 Poor economical/financial standing	.01 Immaturity of legal system	.01 Earthquake
.02 Influence of power groups	.02 Social tensions (religious, ethnic, regional etc.)		.02 Poor legal Regulatory Framework	.02 Flood
.03 Internal conflicts (tensions, civil disorder, terrorism, guerrilla activities etc.)	.03 Poor socio-economic standing (corruption, poverty etc.)		.03 Poor Dispute Resolution Mechanism	.03 Fire
.04 Regional-External conflicts (cross-border conflict, foreign pressure etc.)				.04 War and riots
.05 Nationalization or Expropriations				.05 Contagious diseases
.06 Democratic accountability				.06 Cease or delay of work

Risk revising is the final stage within the risk management process. Until now, the project risks have been identified, classified and rated; some kinds of risks response strategies have been developed, assessed and the effect of risk sources on project cost have been analyzed. The risk sources must be monitored to follow how well the risk response strategies/measures are working and to take effective actions when the risk occurs. As construction projects are very dynamic in nature, status of the risk sources may change. Therefore, the status of the risk sources and their impacts on work packages should be monitored regularly and necessary modification should be done. In IRMS RM process, risk revising is provided by kinds of curves like risk rating summary curve which displays each risk source with its probability and impact values, RM status report which summarizes whole process by indicating risk level, pre-rating, post-rating and final rating values, additional response cost values of each work package for the whole project. Major aim of the IRMS revising phase is to compare and revise rating values and to evaluate analysis results. For this reason, IRMS provides several options to the user to increase revising effectiveness such as Delphi application, corporate memory alternative etc.

As a result of the risk assessment comparison, deviated risk sources; in other words, risk sources which have spectacular different probability and impact values like $\Delta \geq 2$ (Δ symbolizes the difference between rating values assessed by different experts) are identified and listed for re-assessment and re-analysis tasks. For example, a construction company makes a preparation for a tender. Project risk management process has been executed by two risk experts A and B. These two experts have rated the probability and impact values of the risk sources identified by the risk administrator. For the same work package, these two experts may rate same risk sources as illustrated in Table 3.6. Although the risk scores for the same risk source is the same as 10, expert A has rated the probability of occurrence of the risk source as 2 over 5 and the impact of the risk source on the specified work package as 5 over 5. On the contrary, expert B has rated the probability of occurrence of the risk source as 5 over 5 and the impact of the risk source on the specified work package as 2 over 5. As stated earlier, the system observes and monitors in the context of risk assessment comparison task and alerts related risk source with $\Delta \geq 2$ for re-assessment and re-analysis. Moreover, IRMS contains a corporate memory which stores retrospective information of the past projects. Corporate memory provides the ability to re-use of past project information to facilitate decision making process. As a corporate memory is a experience-based library, it will contain various kind of projects. As a result, necessary information even rating values can be re-used for the similar projects which increases the effectiveness of the decision making process. Therefore, risk assessment comparison and integration of corporate memory orientate the experts from subjective judgments to objective decisions.

Table 3.6. An Example for risk assessment comparison

WORK PACKAGE 1	PROBABILITY VALUE	IMPACT VALUE	RISK SCORE	Δ
EXPERT A	2	5	**10**	**3**
EXPERT B	5	2	**10**	**3**

3.2.2. Risk use case diagram

Risk use case diagram is a graphical illustration that shows typical interactions between a user and a computer system to be modeled. The use case diagram contains the essential players called as risk expert or decision maker, and the routines or use cases that the system must perform in order to apply required functions. Thus, the relationships between the user whether a human or software based, and the use cases define the use case diagram. Besides the human based actor as risk expert, databases which provide system information stated as software actor or component. In computer system logic, a use case can be executed by many actors whether they are experts or databases. Similarly, one actor is able to carry out more than one use cases.

Use case diagram of IRMS consists of two human actors as risk administrator and planning expert, and five types of software actor as HRBS, Response Breakdown, MC Engine, Report Engine and Corporate Memory. Planning expert provides the components of the project as work packages to the risk expert to assess the risk sources for each work package. Risk administrator carries out the whole risk management process and is responsible to form the fundamental structure of the process which may be developed by different users. Furthermore, IRMS provides the flexible platform which allows multi user case at which each user has different responsibilities. Figure 3.9 represents use-case diagram of IRMS decision support system.

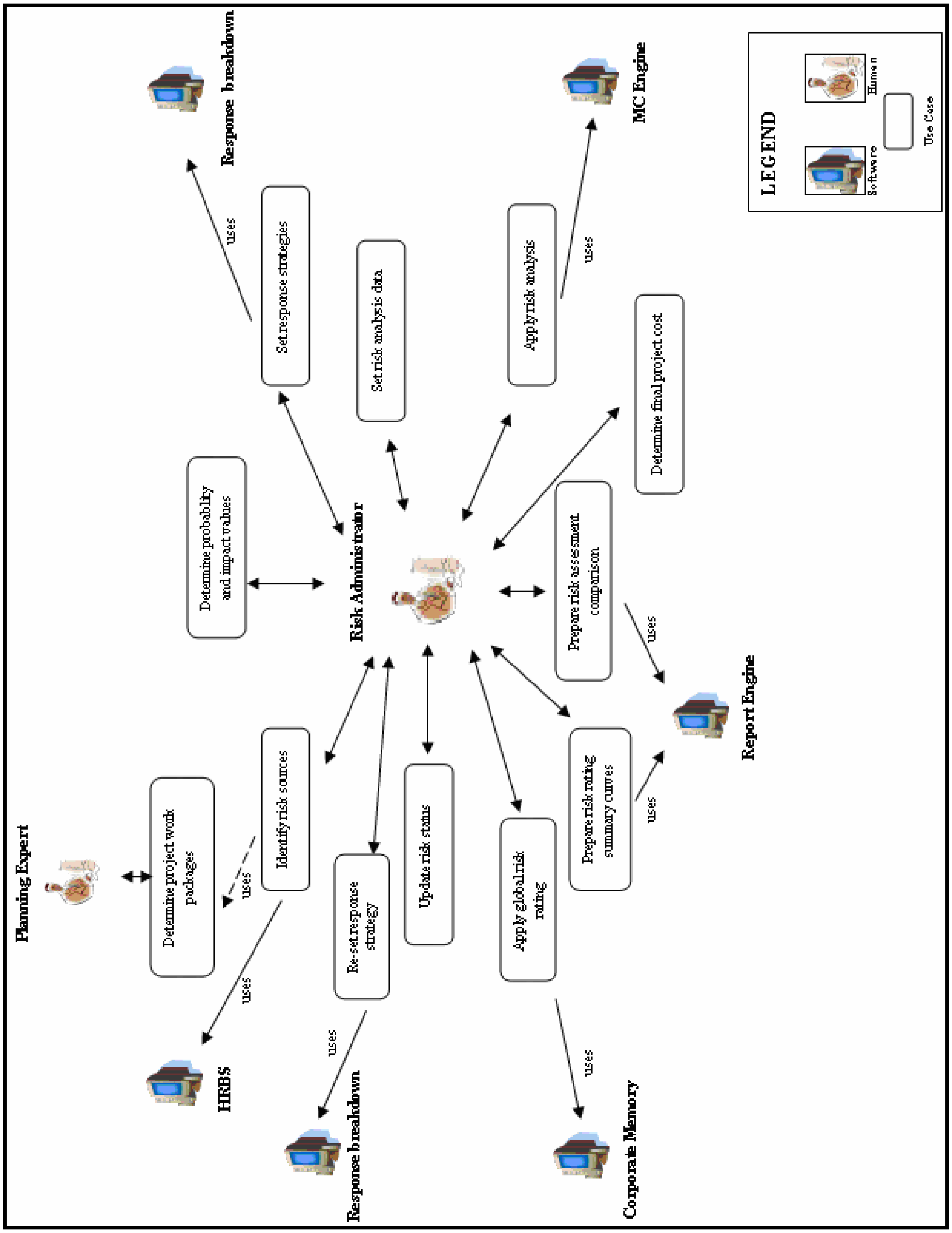

Figure 3.9. Use Case Diagram of IRMS Decision Support System

3.2.3. IRMS system architecture

Integrated Risk Management System (IRMS) is a computer-based system designed to assist a decision-maker (or group of decision-makers) to make better, faster, or cheaper decisions. The studies about the development a software prototype have been carried out by using a computer language called as Delphi. The Borland Delphi 7.0 is used to code IRMS model based on the object-oriented approach. IRMS is an information system, which gives the user the practical data, information as well as different recommendations. As explained in chapter 2, number of risk management support systems those fully support the whole risk management process is rather low in construction risk management literature. Existent decision support systems, support only specific phases of the whole RM process and do not supply necessary outputs to the project parties. In addition, IRMS supports scenario analysis and offers an integrated environment to effectively and interactively apply what-if planning and provides a consistent framework for inter disciplinary communication and teamwork. The system supports early problem detection by frequently risk monitoring feature and integrates the management of the processes of planning, engineering, documentation, procurement, and construction management. The major aim of IRMS components is to ensure construction of the project performance model using built-in risk breakdown structure and setting the relations between risk, response and performance by referring to the past cases.

IRMS has superior features when it is compared with the other existent decision support systems. IRMS project risk management process starts with acquiring and storing necessary project information. For each project, the system demands project information regarding the type of the project, location of the project, including region and city; project delivery system like design-built (DB), engineering-procurement-construction (EPC), built-operate-transfer (BOT) etc; payment type, whether unit price or lump-sum; currency to be used, project budget and duration. In addition, the system automatically records the date of evaluation of the project, as a reminder for remind for the forthcoming sessions. Project information card is illustrated in Figure 3.10.

PROJECT INFORMATION CARD							
1	PROJECT NAME						
2	PROJECT DESCRIPTION						
3	PROJECT TYPE						
4	PROJECT LOCATION	COUNTRY					
		REGION/CITY					
5	PROJECT DURATION	MONTH					
6	PROJECT TIME FRAME	START DATE					
		END DATE					
7	PROJECT DELIVERY SYSTEM (CONTR.TYPE)	DB		EPC		OTHER	
		DBB		BOT			
8	PARTY ARRANGEMENT	SINGLE COMPANY		CONSORTIUM			
		JOINT VENTURE		OTHER			
9	PAYMENT TYPE	UNIT PRICE		COST + FEE			
		LUMP SUM		OTHER			
10	CURRENCY	$		LOCAL CURRENCY			
		EURO					
11	PROJECT BUDGET						
12	DATE OF EVALUATION						
13	RISK ADMINISTRATOR						

Figure 3.10. Project Information Card

Major idea behind the detailed project information demand is that information entered for each project is stored in a project library and if RM process would be applied for the similar future projects, stored knowledge like work packages and corresponding assessed risk sources, outputs can be used by doing some modifications without repeating the whole processes. The volume of the corporate memory expands with the usage frequency of the IRMS; i.e. evaluation of the new projects with IRMS means expansion of the corporate memory which results in better estimation accuracy. Actually, the method that IRMS uses for re-use of the retrospective knowledge is the method of case-based reasoning (CBR). To find similar past projects, weights for each information component are assessed and similarity percentages are obtained. The system provides the user to modify the weights of the past project knowledge components as calibration option.

IRMS supports the decision maker at all phases of the RM process. The HRBS given at risk identification phase facilitates the task of identification of risk sources. As the main logic of the IRMS is assignment of the risk sources to specified work packages, the platform, to rate the probability of occurrence of risk sources for the corresponding work packages and the impact of those risk sources on these work packages, is provided and the cost control mechanisms as response strategies are integrated which can be executed in parallel while carrying out the rating process. Assessment of WBS with HRBS results in integration of RM with other project management functions like cost, resource planning etc. On the other hand, RC process aims to identify risk sharing scenarios among the project participant by defining the ownership of each risk source; and to illustrate how the risk ratios and corresponding cost vary.

It is commonly acknowledged that among the stages of the RM process, risk identification and assessment stages have the largest impact on the accuracy of any risk analysis exercise. To increase the effectiveness of these phases, some risk identification and assessment group techniques are suggested by some researchers like Chapman (1998). For example, brainstorming technique, Nominal group technique, and Delphi method can be given as examples for such group techniques. All those techniques increase the effectiveness of the risk assessment results which affects the result of RM process directly. For this reason, IRMS supplies a multi-user platform to apply one of the working group techniques for risk identification and assessment. The method that IRMS uses is similar to Delphi technique. In this task, the number of the participants is not limited. During this process, the experts or process participants do not contact with the other group members or other risk experts. Although this technique is the most time consuming one, the results shows that it is the most effective one. The comments are submitted by using reports or notes and each comment is recorded to the memory. In IRMS, working group technique application starts with the definition of the risk administrator for each project. The administrator has the responsibility to get the work packages from the planning expert, enter the work packages to the system, assign risk sources to the specified work packages and make the first rating process. If RM process will be executed by the multi-user option, other experts carry out the process for the work packages defined by risk administrator and rate the pre-defined risk sources for each work package. The experts do not have the responsibility and ability to make any modifications pertinent to base information of the RM process. However, they can make comments through notes which are stored at the front page of the system. IRMS is designed to import and export information through e-mail or memory cards, by just entering the passwords defined by the risk administrator.

To facilitate the usage of the outputs of the processes by the experts, IRMS has the capability of preparing detailed reports through report engine. Reports can be separated as tabular reports and graphical reports. Tabular reports are the ones which illustrate work packages of the project, assessed risk sources for each work packages, pre-rating, post-rating and final rating values, estimated cost, additional response cost values, final project cost values. Furthermore, the details of the RC process is provided in a report format for detailed monitoring tasks which cover parties of contract, related risk clauses and ownership of the risk sources. On the other hand, graphical reports are risk maps that include probability and impact values of risk sources for each work package, risk magnitude charts that illustrate the risk level of each work package etc. The system architecture of the IRMS is shown in Figure 3.11.

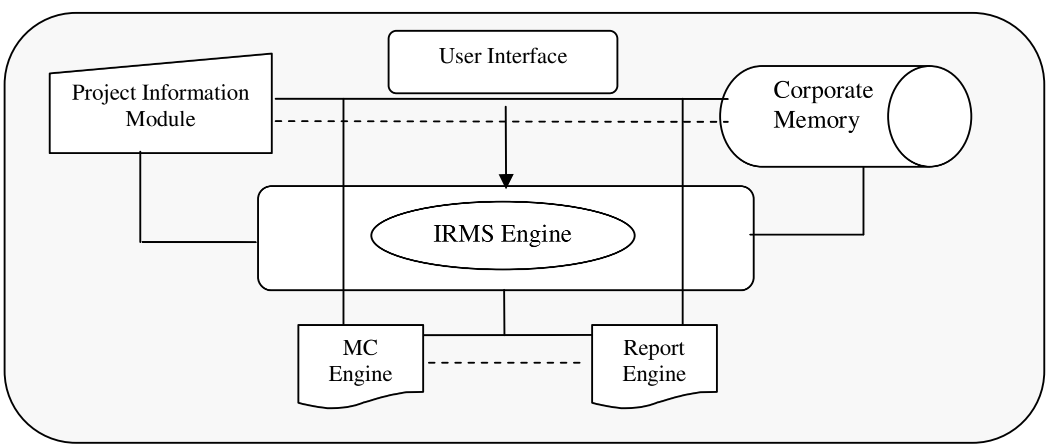

Figure 3.11. IRMS System Architecture

CHAPTER 4

MODEL TESTING

4.1 Demonstration of an IRMS application on a real case

As stated in chapter 3, IRMS decision support system is designed to assist experts at the bidding stage of international construction projects. The system is developed to provide a consistent, efficient and flexible platform for the risk experts. The system facilitates the RM process by providing some important modules to increase the efficiency, accuracy and speed of the tasks. For instance, IRMS supports project information library or corporate memory which enables the usage of retrospective project analysis leading to an increase in the evaluation speed and accuracy, and prevents repeating the whole RM cycle. Furthermore, IRMS provides the decision maker a risk pool called as HRBS and facilitates risk identification phase and prevents confusion of risk terminology. IRMS model gives more attention to risk identification, classification and rating phases which constitute the fundamentals of the risk analysis and response development activities. For this reason, a special process as RC process is provided by IRMS to formalize and systematize the identification and rating phases. RC process covers assignment of the risk sources from HRBS to pre-defined work packages by using a uniform language coding system. In addition, the system finalize risk analysis which is started from risk classification and rating phase, by executing MC simulation and enables calculation of final project cost based on the defined risk sources. To monitor and update the status of the risk sources and work packages, some tabular and graphical reports are provided by the IRMS report engine to carry out re-evaluation task by the experts.

In this chapter, to illustrate how the model works and to demonstrate the applicability and accuracy of the IRMS RM model and corresponding system, a real case project is evaluated and each phase of the IRMS RM process is executed by an expert. Almost all of the features of the model are illustrated by a real case example, details of which are given below.

IRMS RM session starts with the registration of project information which will be recorded in corporate memory. The example project is a real project which has just started in Poland, by a leading Turkish construction company. The city of the project is Cracow which is one of the biggest cities in Poland. The project is an urban transportation project which covers 5.7 km train line, with 2 underground and 5 stations construction and, electro-mechanical installation works. All information regarding the details of the project like schedule, budget, payment type etc are registered by using the project information card. The project information card of the "Cracow Urban Transport Project" is shown in Figure 4.1.

PROJECT INFORMATION CARD							
1	PROJECT NAME	CRACOW URBAN TRANSPORT PROJECT FAST TRAIN INFRASTRUCTURE WORKS					
2	PROJECT DESCRIPTION	5.7 KM FAST TRAIN PROJECT WITH 2 UNDERGROUND and 5 STATIONS					
3	PROJECT TYPE	INFRASTRUCTURE/TRANSPORT					
4	PROJECT LOCATION	COUNTRY	POLAND				
		REGION/CITY	CRACOW				
5	PROJECT DURATION	MONTH	MS1=10, MS2=16, MS3=19, MS4=33				
6	PROJECT TIMEFRAME	START DATE	25.08.2003				
		END DATE	25.08.2008				
7	PROJECT DELIVERY SYSTEM (CONTR.TYPE)	DB		EPC		OTHER	
		DBB	√	BOT			
8	PARTY ARRANGEMENT	SINGLE COMPANY	√	CONSORTIUM			
		JOINT VENTURE		OTHER			
9	PAYMENT TYPE	UNIT PRICE		COST + FEE			
		LUMP SUM	√				
10	CURRENCY	$		LOCAL CURRENCY			
		EURO	√				
11	PROJECT BUDGET	29.163.000					
12	DATE OF EVALUATION	20.08.2005					
13	RISK ADMINISTRATOR	AEA					

Figure 4.1. Project Information Card of the Poland project

If the project information card of the example project is examined, it is noticed that the project consists of four milestones with 10, 16, 19 and 33 months respectively. Furthermore, tender documents indicate that the progress payments will be certified based on the defined four milestones instead of monthly progress payments. Although the contract allows 15% advance payments, the schedule should be taken into consideration as a risk source if the duration of the milestones is considered. According to tender documents, the type of the project delivery system is "design-bid-build". In this type of contract, the contractor is responsible for the construction of civil works and electro-mechanical installation works only. All of the design tasks are carried out by design companies under the control of the client. With this kind of a project delivery system, the ownership of design risk source belongs to the designer or client.

In this project, the contractor is not a member of consortium or does not have any partner. This situation leads to the elimination of JV partner risk sources. Furthermore, the payment mechanism is lump-sum type of payment which contains some kinds of risk sources compared to unit price type of payment. The currency of the project is Euro which is less risky than the local currency. The estimated budget of the project is around 29.163.000 Euro for construction of sub/super structure construction works and electro-mechanical installations.

After project information is registered, the project is divided into work packages. The number of work packages depends on the kind and complexity of the project and analysis detail request of the risk administrator. In this project, first level breakdown is found sufficient for the risk analysis by the expert. The work packages and corresponding estimated budgets are listed in Table 4.1. RC process starts after definition of work packages. Before starting RC process, risk administrator decides on the number of risk experts who will join the RC process and rate the defined risk sources. In this project, single decision maker option is selected and thus risk administrator is the only expert to rate the assigned risk sources. As stated before, IRMS provides a template HRBS to facilitate risk identification phase. Actually, the template HRBS is constituted to cover whole project documents including contracts, project participant profiles, project country conditions and technical issues. For this reason, categorized risk sources can easily be assigned to the work packages.

Table 4.1. 1st level WBS and Estimated Budget Values of the Poland project

Work Package #	Work Package Name	Estimated Budget (Euro)
WP1	SUB/SUPER STRUCTURE CONSTRUCTION	10,704,728
WP2	UTILITY SYSTEM INSTALLATION	2,720,268
WP3	ROAD/LANDSCAPE SYSTEMS INSTALLATION	2,030,972
WP4	POWER SYSTEM INSTALLATION	4,497,752
WP5	TRACK SYSTEM INSTALLATION	4,994,024
WP6	OPERATING SYSTEM INSTALLATION	4,216,029

The major issues pertinent to risk identification process for the defined work packages are explained below:

- ✓ If the tender documents are examined, it can be noticed that there is inconsistency between the durations of the milestones.
- ✓ For some of the work packages like operating system installation strict quality requirement is noticed.
- ✓ Similarly, for power system and track system installation the health and safety issues will be an important risk source.
- ✓ Environmental risk source category will be one of the major risk categories in this project if the regulations of the Cracow Municipality are examined.
- ✓ For this kind of projects, the scope changes may always be a risk source element.
- ✓ Most of the components of the design risk category will be owned by the client due to “design-bid-build” type of project delivery system.
- ✓ The research about the client indicates that, there is a public reaction and bad attitude towards foreign contractors due to religious differences.

- ✓ Some clauses of the contract state that, the sub-contractors for specified work tasks should be Polish companies only. This situation may create extra risk due to subcontractor selection process.
- ✓ As the contractor participates to the tender as a single company, JV risk source is not possible for this project.
- ✓ In this project, consultant is a recently established French company. However, it is identified that most of the employees of this company is from Poland. Therefore, this situation may lead to some risk sources regarding consultant category.
- ✓ As most of the work packages are related to electro-mechanical installation works, the imported equipments and materials will be custom cleared in accordance to Polish laws. This situation could create additional risks especially in the delivery of imported materials.
- ✓ One major risk source is labor risk category. In tender documents, it is declared that the nationality of the laborers have to be Polish. Furthermore, it is known that the productivity of the east European workers is rather low when compared to Turkish workers.
- ✓ As the company has dealt previously with only construction works in similar projects, some risks may be faced regarding the cost estimation of electro-mechanical works, due to lack of enough experience.
- ✓ As excavation work is one of the major component of the project and the climate especially at winters will affect the project performance, external and site conditions should be evaluated. On the other hand, as the project will be realized in city centrum, there is not any risk source regarding the accessibility.
- ✓ Contract based risk sources should be considered in this project. Although the contract will be arranged based on the FIDIC type of contracts, it is known that there are some problems regarding dispute resolution mechanisms. Therefore, some major clauses of FIDIC contract may not be incorporated into the contract like dispute resolution mechanisms etc.

- ✓ Bureaucracy in Poland should be considered as one of the major risk source categories. The municipality may postpone the payments or approvals that could have detrimental effects on project performance.
- ✓ Finally, the company should carry out an internal scanning to identify risk sources regarding project management concept.

The stated arguments are basic issues to be considered before starting the rating process. After identification and assignment of the risk sources for the work packages, the ownership of each risk source is identified based on the contracts among the project parties. In this project, the contractor may have two kinds of contract; such as contract with the client and typical contract prepared by the contractor which is between the contractor and the sub-contractors. In this project, the contractor has lump-sum subcontracting strategy by which all of the work packages are subcontracted to different companies.

In risk carding process, three rating tasks are carried out as pre-response rating, post-response rating and final rating. In pre-response rating, the values are rated without carrying out response development. On the other hand, post-response rating is carried out based on the response strategy developed by the expert by using response breakdown of the IRMS. Final response rating values represent the preferences of the expert based on the rating and response cost values. The expert may apply several response strategies which depend on risk source type, contract clauses, estimated cost value etc. While applying the rating process, same risk source may be assigned to various work packages with different rating values. Furthermore, for the same risk source which is assigned to different work packages, various response strategies can be developed according to strategic issues. One of the difficult tasks in RC process is estimation of response costs for each risk source. The expert may define some formulas or categorize the actions and assign cost values to estimate risk response cost as an additional cost to the estimated cost. In this project, some response strategies are correlated with estimated budget. For instance, "inappropriateness of budget estimate", schedule based risk sources, project management based risk sources are defined as a percentage of the estimated budget based on the experience or retrospective data. In addition, the risk source “negative attitude towards foreign contractors” is also correlated with the estimated budget of each work package which is a very subjective judgment. On the other hand, for some types of risk sources, response cost is calculated through the cost of claim mentality. For example, it is thought that for claim preparation consultancy of an expert may be required. Furthermore, for some claim applications, a project consultant company may be demanded. Therefore, for different categories of risk sources, various response cost values are assigned. The details of RC process are illustrated in Figures 4.2-4.7.

WORKPACKAGE 1	SUB/SUPER STRUCTURE CONSTRUCTION	
ESTIMATED COST	10.704.728	EURO

				PRE-RESPONSE			POST-RESPONSE					FINAL		
NO	RISK CODE	RISK DESCRIPTION	OWNERSHİP	PROBABILITY	IMPACT	RATING	RESPONSE STRATEGY	PROBABILITY	IMPACT	RATING	RESPONSE COST	STRATEGY CHOSEN	FINAL RISK RESPONSE COST	EXISTENCE OF NEW RISK
1	R1.S.02	unrealistic milestones	CONTRACTOR	2	5	10	R.R.1.01	2	2	4	223000		0	
2	R1.S.03	working hour restrictions	CLIENT	2	3	6		2	3	6	0		0	
3	R1.E.01	strict env. requirements	CONTRACTOR	3	3	9	R.T.1.02	2	3	6	5000	√	5000	
4	R1.E.02	vagueness in regulations	CONTRACTOR	4	3	12	R.R.1.01	4	2	8	20000	√	20000	
5	D1.C.02	vagueness in construction method	CONTRACTOR	1	4	4	R.T.1.02	1	3	3	5000	√	5000	
6	P1.C1.01	negative attitude towards foreign contractors	CONTRACTOR	4	4	16	R.R.1.01	4	3	12	107000	√	107000	C1.B.03,C1.B.04
7	P1.C1.02	poor performance of client	CLIENT	3	3	9		3	3	9	0		0	
8	P1.C1.04	vagueness of req./client expectation	CLIENT	2	5	10		2	5	10	0		0	
9	P1.S.02	vagueness in scope	CONTRACTOR	2	4	8	R.T.1.01	2	3	6	10000	√	10000	
10	P1.C2.01	poor performance of consultant	CONSULTANT	3	4	12		3	4	12	0		0	
11	P1.P.03	poor performance of PM staff	CONTRACTOR	2	5	10	R.R.1.04	1	1	1	27000	√	27000	
12	P1.P.04	poor communication between parties	CONTRACTOR	2	4	8	R.R.1.03	1	3	3	5000	√	5000	
13	P1.P.05	lack of experience of PM staff	CONTRACTOR	1	5	5	R.R.1.04	1	1	1	54000	√	54000	
14	R2.M.04	delay in material delivery	CONTRACTOR	3	5	15	R.T.1.02	2	3	6	37000	√	37000	
15	R2.M.06	improper material definition	CLIENT	1	2	2		1	2	2	0		0	
16	R2.E.01	unavalibility of equipment	CONTRACTOR	3	5	15	R.T.1.02	3	3	9	55500		0	
17	R2.L.02	poor productivity of workers	CONTRACTOR	3	4	12	R.T.1.02	3	1	3	5000	√	5000	
18	R2.L.04	restrictions on foreign workers	CONTRACTOR	5	5	25	R.R.1.01	5	3	15	10000	√	10000	
19	R2.F.01	inappropriateness of budget estimate	CONTRACTOR	2	5	10	R.R.2	2	4	8	214000		0	
20	P2.E.01	vagueness of ground conditions	CONTRACTOR	3	4	12	R.T.1.02	3	2	6	100000	√	100000	
21	P2.S.01	physical constraints	CONTRACTOR	1	4	4	R.T.1.01	1	2	2	5000	√	5000	
22	C1.C.05	dispute resolution clauses	CONTRACTOR	4	5	20	R.T.1.01	3	4	12	20000	√	20000	
23	C1.B.01	delay in site hand-over	CLIENT	4	1	4		4	1	4	0		0	
24	C1.B.03	delay in permits/approvals	CLIENT	4	4	16		4	4	16	0		0	
25	C1.B.04	delay in progress payments	CLIENT	4	5	20		4	5	20	0		0	
26	D1.D.03	delay in design	DESIGNER	3	4	12		3	4	12	0		0	
27	D1.D.04	complexity	CONTRACTOR	3	2	6	R.T.1.02	2	2	4	10000	√	10000	

TOTAL VALUE	292
PRE-RESP. RATING	10,81
ADDITIONAL COST	0
% OF AC TO EC	0
RISK CATEGORY	SIGNIFICANT

TOTAL VALUE	200
POST-RESP. RATING	7,41
ADDITIONAL COST	912500
% OF AC TO EC	8,52%
RISK CATEGORY	MODERATE

TOTAL VALUE	214
FINAL. RATING	7,93
ADDITIONAL COST	420000
% OF AC TO EC	3,92%
RISK CATEGORY	MODERATE

Figure 4.2. Risk Carding Process Sheet of the Poland project WP1

WORKPACKAGE 2	UTILITY SYSTEM INSTALLATION	
ESTIMATED COST	2.720.268	EURO

				PRE-RESPONSE			POST-RESPONSE					FINAL		
NO	RISK CODE	RISK DESCRIPTION	OWNERSHIP	PROBABILITY	IMPACT	RATING	RESPONSE STRATEGY	PROBABILITY	IMPACT	RATING	RESPONSE COST	STRATEGY CHOSEN	FINAL RISK RESPONSE COST	EXISTENCE OF NEW RISK
1	R1.S.03	working hour restrictions	CLIENT	2	3	6		2	3	6	5000	√	5000	
2	R1.Q.02	defective design	DESIGNER	1	5	5		1	5	5	0		0	
3	R1.E.01	strict env. requirements	CONTRACTOR	3	4	12	R.T.1.02	2	4	8	5000	√	5000	
4	R1.E.02	vagueness in regulations	CONTRACTOR	3	4	12	R.R.1.01	3	3	9	20000	√	20000	
5	D1.S.02	vagueness in scope	CONTRACTOR	4	5	20	R.T.1.01	3	3	9	10000	√	10000	
6	P1.C1.01	negative attitude towards foreign contractors	CONTRACTOR	4	4	16	R.R.1.01	4	3	12	27000	√	27000	C1.B.03,C1.B.04
7	P1.C1.02	poor performance client	CLIENT	3	3	9		3	3	9	0		0	
8	P1.C1.05	change in requirements	CONTRACTOR	2	3	6	R.T.1.01	2	2	4	10000	√	10000	
9	P1.S.02	poor performance sub-contractor	CONTRACTOR	4	4	16	R.T.1.02	3	2	6	5000	√	5000	
10	P1.C2.02	conflicts	CONTRACTOR	4	5	20	R.T.1.01	3	4	12	10000	√	10000	
11	P1.P.01	strict documentation requirements	CONTRACTOR	3	2	6	R.R.1.03	2	1	2	10000	√	10000	
12	P1.P.03	poor performance of PM staff	CONTRACTOR	2	4	8	R.R.1.04	1	1	1	7000	√	7000	
13	P1.P.04	poor communication between parties	CONTRACTOR	3	3	9	R.R.1.03	2	2	4	5000	√	5000	
14	R2.M.04	delay in material delivery	CONTRACTOR	3	5	15	R.T.1.02	2	4	8	20000	√	20000	
15	R2.M.05	restrictions on imports	CONTRACTOR	2	2	4	R.T.1.01	1	2	2	20000	√	20000	
16	R2.L.02	poor productivity of workers	CONTRACTOR	3	4	12	R.T.1.02	2	3	6	5000	√	5000	
17	R2.L.04	restrictions on foreign workers	CONTRACTOR	5	3	15	R.R.1.01	5	2	10	10000	√	10000	
18	R2.F.01	inappropriateness of budget estimate	CONTRACTOR	2	4	8	R.R.2	2	4	8	54000	√	54000	
19	C1.C.01	vagueness of clauses	CONTRACTOR	3	4	12	R.T.1.01	3	3	9	20000		0	
20	C1.C.04	lack of major contract clauses	CONTRACTOR	4	4	16	R.T.1.01	4	3	12	20000	√	20000	
21	C1.C.05	dispute resolution clauses	CONTRACTOR	4	5	20	R.T.1.01	3	4	12	20000	√	20000	
22	C1.B.03	delay in permits/approvals	CLIENT	4	4	16		4	4	16	0		0	
23	C1.B.04	delay in progress payments	CLIENT	4	4	16		4	4	16	0		0	
24	P2.S.01	physical constraints	CONTRACTOR	4	4	16	R.T.1.01	4	3	12	5000	√	5000	

TOTAL VALUE	295	TOTAL VALUE	198	TOTAL VALUE	201
PRE-RESP. RATING	12,29	POST-RESP. RATING	8,25	FINAL. RATING	8,38
ADDITIONAL COST	0	ADDITIONAL COST	288000	ADDITIONAL COST	268000
% OF AC TO EC	0	% OF AC TO EC	10,59%	% OF AC TO EC	9,85%
RISK CATEGORY	SIGNIFICANT	RISK CATEGORY	MODERATE	RISK CATEGORY	MODERATE

Figure 4.3. Risk Carding Process Sheet of the Poland project WP2

WORKPACKAGE 3 ROAD/LANDSCAPE SYSTEMS INSTALLATION

ESTIMATED COST 2.030.972 EURO

				PRE-RESPONSE			POST-RESPONSE					FINAL		
NO	RISK CODE	RISK DESCRIPTION	OWNERSHIP	PROBABILITY	IMPACT	RATING	RESPONSE STRATEGY	PROBABILITY	IMPACT	RATING	RESPONSE COST	STRATEGY CHOSEN	FINAL RISK RESPONSE COST	EXISTENCE OF NEW RISK
1	D1.C.03	novelty	CONTRACTOR	2	3	6	R.T.1.02	1	2	2	50000		0	
2	P1.C1.01	negative attitude towards foreign contractors	CONTRACTOR	4	4	16	R.R.1.01	4	3	12	20000	√	20000	C1.B.03,C1.B.04
3	P1.C1.04	vagueness of req./client expectation	CONTRACTOR	3	5	15	R.T.1.01	3	3	9	10000	√	10000	
4	P1.S.01	unavalibility of sub-contractor	CONTRACTOR	2	4	8	R.R.1.01	2	3	6	10000	√	10000	
5	P1.P.04	poor communication between parties	CONTRACTOR	3	3	9	R.R.1.03	2	2	4	5000	√	5000	
6	P1.P.05	lack of experience of PM staff	CONTRACTOR	1	3	3	R.R.1.04	1	1	1	101000		0	
7	R2.M.04	delay in material delivery	CONTRACTOR	3	3	9	R.T.1.02	2	2	4	20000	√	20000	
8	R2.M.05	restrictions on imports	CONTRACTOR	3	3	9	R.T.1.01	3	2	6	20000	√	20000	
9	R2.M.06	improper material definition	CLIENT	2	4	8		2	4	8	0		0	
10	R2.L.04	restrictions on foreign workers	CONTRACTOR	5	2	10	R.R.1.01	5	1	5	10000	√	10000	
11	R2.F.01	inappropriateness of budget estimate	CONTRACTOR	3	4	12	R.R.2	3	3	9	40000	√	40000	
12	C1.C.05	dispute resolution clauses	CONTRACTOR	4	5	20	R.T.1.01	3	4	12	20000	√	20000	
13	C1.B.03	delay in permits/approvals	CLIENT	3	4	12		3	4	12	0		0	
14	C1.B.04	delay in progress payments	CLIENT	4	4	16		4	4	16	0		0	
15	P1.C1.03	lack of enough qualified personnel of client	CLIENT	2	3	6		2	3	6	0		0	

TOTAL VALUE	159
PRE-RESP. RATING	10,60
ADDITIONAL COST	0
% OF AC TO EC	0
RISK CATEGORY	SIGNIFICANT

TOTAL VALUE	112
POST-RESP. RATING	7,47
ADDITIONAL COST	306000
% OF AC TO EC	15,07%
RISK CATEGORY	MODERATE

TOTAL VALUE	118
FINAL. RATING	7,87
ADDITIONAL COST	155000
% OF AC TO EC	7,63%
RISK CATEGORY	MODERATE

Figure 4.4. Risk Carding Process Sheet of the Poland project WP3

WORKPACKAGE 4	POWER SYSTEM INSTALLATION	
ESTIMATED COST	4.497.752	EURO

				PRE-RESPONSE			POST-RESPONSE					FINAL		
NO	RISK CODE	RISK DESCRIPTION	OWNERSHİP	PROBABILITY	IMPACT	RATING	RESPONSE STRATEGY	PROBABILITY	IMPACT	RATING	RESPONSE COST	STRATEGY CHOSEN	FINAL RISK RESPONSE COST	EXISTENCE OF NEW RISK
1	R1.H.01	strict health & safety requirements	CONTRACTOR	3	3	9	R.T.1.02	2	3	6	5000	√	5000	
2	D1.D.04	complexity of design	CLIENT	1	3	3		1	3	3	0		0	
3	R1.E.01	strict env. requirements	CONTRACTOR	2	2	4	R.T.1.02	2	1	2	5000	√	5000	
4	P1.C1.01	negative attitude towards foreign contractors	CONTRACTOR	4	4	16	R.R.1.01	4	3	12	44000	√	44000	C1.B.03,C1.B.04
5	P1.C1.04	vagueness of req./client expectation	CONTRACTOR	2	4	8	R.T.1.01	2	2	4	10000	√	10000	
6	P1.S.01	unavalibility of sub-contractor	CONTRACTOR	2	5	10	R.R.1.01	2	4	8	10000	√	10000	
7	P1.S.02	poor performance of sub-contractor	CONTRACTOR	2	4	8	R.T.1.02	2	2	4	5000	√	5000	
8	P1.C2.01	poor performance of consultant	CONSULTANT	3	3	9		3	3	9	0		0	
9	P1.P.03	poor performance of PM staff	CONTRACTOR	2	3	6	R.R.1.04	1	1	1	11000	√	11000	
10	P1.P.05	lack of experience of PM staff	CONTRACTOR	1	3	3	R.R.1.04	1	1	1	25000	√	25000	
11	R2.M.03	unavalibility of material	CONTRACTOR	2	4	8	R.T.1.02	2	3	6	5000	√	5000	
12	R2.M.04	delay in material delivery	CONTRACTOR	3	5	15	R.T.1.02	2	4	8	50000	√	50000	
13	R2.E.06	restriction on imports	CONTRACTOR	3	3	9	R.T.1.01	2	2	4	20000	√	20000	
14	R2.L.02	poor productivity of workers	CONTRACTOR	3	4	12	R.T.1.02	2	3	6	5000	√	5000	
15	R2.L.04	restrictions on foreign workers	CONTRACTOR	5	3	15	R.R.1.01	5	2	10	10000	√	10000	
16	R2.F.01	inappropriateness of budget estimate	CONTRACTOR	2	5	10	R.R.2	2	4	8	90000		0	
17	P2.S.01	physical constraints	CONTRACTOR	3	3	9	R.T.1.01	3	2	6	5000	√	5000	
18	C1.C.05	dispute resolution clauses	CONTRACTOR	4	5	20	R.T.1.01	3	4	12	20000	√	20000	
19	C1.B.03	delay in permits/approvals	CLIENT	4	5	20		4	5	20	0		0	
20	C1.B.04	delay in progress payments	CLIENT	4	5	20		4	5	20	0		0	

TOTAL VALUE	214	TOTAL VALUE	150	TOTAL VALUE	152
PRE-RESP. RATING	10,70	POST-RESP. RATING	7,50	FINAL. RATING	7,60
ADDITIONAL COST	0	ADDITIONAL COST	320000	ADDITIONAL COST	230000
% OF AC TO EC	0	% OF AC TO EC	7,11%	% OF AC TO EC	5,11%
RISK CATEGORY	SIGNIFICANT	RISK CATEGORY	MODERATE	RISK CATEGORY	MODERATE

Figure 4.5. Risk Carding Process Sheet of the Poland project WP4

WORKPACKAGE 5	TRACK SYSTEM INSTALLATION														
ESTIMATED COST	4.994.024	EURO													
				PRE-RESPONSE			POST-RESPONSE					FINAL			
NO	RISK CODE	RISK DESCRIPTION	OWNERSHİP	PROBABILITY	IMPACT	RATING	RESPONSE STRATEGY	PROBABILITY	IMPACT	RATING	RESPONSE COST	STRATEGY CHOSEN	FINAL RISK RESPONSE COST	EXISTENCE OF NEW RISK
1	R1.S.01	inappropriate schedule estimate	CONTRACTOR	4	4	16	R.T.1.02	4	2	8	200000		0	
2	R1.S.02	unrealistic milestones	CONTRACTOR	3	5	15	R.R.1.01	3	2	6	100000	√	100000	
3	R1.S.03	working hour restrictions	CLIENT	3	4	12		3	4	12	0		0	
4	R1.Q.01	strict quality requirements	CONTRACTOR	4	4	16	R.T.1.02	4	3	12	5000	√	5000	
5	R1.H.01	strict health&safety requirements	CONTRACTOR	3	2	6	R.T.1.02	3	1	3	5000	√	5000	
6	R1.E.01	strict env. requirements	CONTRACTOR	4	4	16	R.T.1.02	3	3	9	5000	√	5000	
7	D1.D.03	delay in design	DESIGNER	2	5	10		2	5	10	0		0	
8	P1.C1.01	negative attitude towards foreign contractors	CONTRACTOR	4	4	16	R.R.1.01	4	3	12	50000	√	50000	C1.B.03,C1.B.04
9	P1.C1.04	vagueness of req./client expectation	CONTRACTOR	2	4	8	R.T.1.01	2	2	4	10000	√	10000	
10	P1.S.01	unavalibility of subcontractor	CONTRACTOR	3	4	12	R.R.1.03	3	3	9	10000	√	10000	
11	P1.S.02	vagueness in scope	CONTRACTOR	2	4	8	R.T.1.01	2	3	6	10000	√	10000	
12	P1.C2.01	poor performance of consultant	CONSULTANT	3	4	12		3	4	12	0		0	
13	P1.P.03	poor performance of PM staff	CONTRACTOR	2	4	8	R.R.1.04	1	1	1	25000	√	25000	
14	P1.P.04	poor communication between parties	CONTRACTOR	3	3	9	R.R.1.03	2	2	4	5000	√	5000	
15	R2.M.03	unavalibility of materials	CONTRACTOR	3	4	12	R.T.1.02	3	2	6	5000	√	5000	
16	R2.M.04	delay in material delivery	CONTRACTOR	3	4	12	R.T.1.02	2	3	6	50000	√	50000	
17	R2.M.05	restrictions on imports	CONTRACTOR	3	4	12	R.T.1.01	2	3	6	20000	√	20000	
18	R2.E.03	delay in delivery of equipment	CONTRACTOR	2	4	8	R.T.1.02	2	3	6	75000	√	75000	
19	R2.E.06	restriction on imports	CONTRACTOR	2	4	8	R.T.1.01	2	3	6	20000	√	20000	
20	R2.L.02	poor productivity of workers	CONTRACTOR	3	4	12	R.T.1.01	2	3	6	5000	√	5000	
21	R2.L.04	restrictions on foreign workers	CONTRACTOR	5	4	20	R.R.1.01	5	4	20	10000	√	10000	
22	R2.F.01	inappropriateness of budget estimate	CONTRACTOR	3	4	12	R.R.2	3	2	6	100000		0	
23	P2.E.03	unfavourable weather conditions	CONTRACTOR	3	4	12	R.T.1.06	2	2	4	50000	√	50000	
24	P2.S.01	physical constraints	CONTRACTOR	3	4	12	R.T.1.01	3	3	9	5000	√	5000	
25	C1.C.05	dispute resolution clauses	CONTRACTOR	4	5	20	R.T.1.01	3	4	12	20000	√	20000	
26	C1.B.03	delay in permits/approvals	CLIENT	4	5	20		4	5	20	0		0	
27	C1.B.04	delay in progress payments	CLIENT	4	5	20		4	5	20	0		0	

TOTAL VALUE	344
PRE-RESP. RATING	12,74
ADDITIONAL COST	0
% OF AC TO EC	0
RISK CATEGORY	SIGNIFICANT

TOTAL VALUE	235
POST-RESP. RATING	8,70
ADDITIONAL COST	785000
% OF AC TO EC	15,72%
RISK CATEGORY	MODERATE

TOTAL VALUE	249
FINAL. RATING	9,22
ADDITIONAL COST	485000
% OF AC TO EC	9,71%
RISK CATEGORY	MODERATE

Figure 4.6. Risk Carding Process Sheet of the Poland project WP5

WORKPACKAGE 6	OPERATING SYSTEM INSTALLATION	
ESTIMATED COST	4.216.029	EURO

				PRE-RESPONSE			POST-RESPONSE					FINAL		
NO	RISK CODE	RISK DESCRIPTION	OWNERSHİP	PROBABILITY	IMPACT	RATING	RESPONSE STRATEGY	PROBABILITY	IMPACT	RATING	RESPONSE COST	STRATEGY CHOSEN	FINAL RISK RESPONSE COST	EXISTENCE OF NEW RISK
1	R1.S.01	inappropriate schedule estimate	CONTRACTOR	2	3	6	R.T.1.02	2	2	4	160000		0	
2	R1.Q.01	strict quality requirements	CONTRACTOR	3	3	9	R.T.1.02	3	2	6	5000	√	5000	
3	P1.C1.01	negative attitude towards foreign contractors	CONTRACTOR	4	4	16	R.R.1.01	4	3	12	42000	√	42000	C1.B.03,C1.B.04
4	P1.S.02	vagueness in scope	CONTRACTOR	2	3	6	R.T.1.01	1	2	2	10000	√	10000	
5	P1.C2.01	poor performance of consultant	CONSULTANT	2	3	6		2	3	6	0		0	
6	P1.P.03	poor performance of PM staff	CONTRACTOR	1	2	2	R.R.1.04	1	1	1	21000	√	21000	
7	P1.P.04	poor communication between parties	CONTRACTOR	2	3	6	R.R.1.03	1	2	2	5000	√	5000	
8	R2.M.04	delay in material delivery	CONTRACTOR	3	3	9	R.T.1.02	3	2	6	40000	√	40000	
9	R2.M.05	restrictions on imports	CONTRACTOR	3	4	12	R.T.1.01	3	2	6	20000	√	20000	
10	R2.M.06	improper material definition	CLIENT	2	4	8		2	4	8	0		0	
11	R2.E.03	delay in equipment delivery	CONTRACTOR	2	3	6	R.T.1.02	2	2	4	60000		0	
12	R2.E.06	restriction on imports	CONTRACTOR	3	4	12	R.T.1.01	3	3	9	20000	√	20000	
13	R2.L.02	poor productivity of workers	CONTRACTOR	4	4	16	R.T.1.01	3	3	9	5000	√	5000	
14	R2.L.04	restrictions on foreign workers	CONTRACTOR	5	3	15	R.R.1.01	5	2	10	10000	√	10000	
15	R2.F.01	inappropriateness of budget estimate	CONTRACTOR	3	5	15	R.R.2	3	5	15	84000	√	84000	
16	P2.S.01	physical constraints	CONTRACTOR	3	3	9	R.T.1.01	3	2	6	10000	√	10000	
17	C1.C.05	dispute resolution clauses	CONTRACTOR	4	5	20	R.T.1.01	3	4	12	20000	√	20000	
18	C1.B.03	delay in permits/approvals	CLIENT	4	4	16		4	4	16	0	√	0	
19	C1.B.04	delay in progress payments	CLIENT	4	5	20		4	5	20	0	√	0	

TOTAL VALUE	209
PRE-RESP. RATING	11,00
ADDITIONAL COST	0
% OF AC TO EC	0
RISK CATEGORY	SIGNIFICANT

TOTAL VALUE	154
POST-RESP. RATING	8,11
ADDITIONAL COST	512000
% OF AC TO EC	12,14%
RISK CATEGORY	MODERATE

TOTAL VALUE	158
FINAL. RATING	8,32
ADDITIONAL COST	292000
% OF AC TO EC	6,93%
RISK CATEGORY	MODERATE

Figure 4.7. Risk Carding Process Sheet of the Poland project WP6

After final risk rating and corresponding response cost values of each work package are obtained, first part of the RC process is completed. As stated in chapter 3, the rating value does not mean any thing by itself. Therefore, final rating value is converted to linguistic term and categorized as low, moderate, significant and high. Linguistic terms represent the situation better than rating values alone and facilitate to understand risk level of the work packages. IRMS report engine provides a tabular report which summarizes the first part of the RC process, contain whole important values and items of the project risk rating. The summary output of the project risk rating of the Poland project is given in Table 4.2.

Table 4.2. RC process project risk rating summary output

Work package	pre-response rating value	post-response rating value	final rating value	final risk level	final additional response cost (EURO)	% of AC to EC
WP1	10.81	7.41	7.93	moderate	420000	3.92%
WP2	12.29	8.25	8.38	moderate	268000	9.85%
WP3	10.60	7.47	7.87	moderate	155000	7.63%
WP4	10.70	7.50	7.60	moderate	230000	5.11%
WP5	12.74	8.70	9.22	moderate	485000	9.71%
WP6	11.00	8.11	8.32	moderate	292000	6.93%

According to IRMS RM model, the total project cost calculated from risk analysis by MC simulation should be revised by the global risk rating value. Global risk sources are the ones which affect whole project performance based on the political, economical, social and legal country risk sources. In addition to country risk sources, force majeure risk sources such as war, earthquake, flood, etc. may be an important risk source element depending on the country topography and location. If global risk rating is carried out, it is noticed that country specific risk sources such as social and legal country risk sources are more important than force majeure risks. The result of global risk rating shows that there is significant risk potential in this project if global risk sources are considered. At this point, IRMS leaves the decision for contingency percentage (risk premium) to the expert as it depends on many factors like company mission and strategy, company work volume etc. For this project, it is decided to increase the total project cost about 10% based on the company strategy, workload and experience of the risk expert. Risk carding process ends with the calculation of the global risk rating and second part of the analysis starts with the information obtained from RC process. The details of global risk rating are illustrated in Figure 4.8.

GLOBAL RISK RATING

GLOBAL RATING

NO	RISK CODE	RISK DESCRIPTION	PROBABILITY	IMPACT	RATING
1	C.P.P.01	Political instability	2	4	8
2	C.P.P.02	Influence of power groups	3	3	9
3	C.P.P.03	Internal conflicts (tensions, civil disorder, terrorism, guerrilla activities etc.)	2	3	6
4	C.P.P.04	Regional-External conflicts (cross-border conflict, foreign pressure etc.)	3	3	9
5	C.P.P.05	Democratic accountability	3	3	9
6	C.P.P.06	Nationalization or Expropriations	3	4	12
7	C.S.S.01	Social differences (religious, cultural lingual etc.)	4	5	20
8	C.S.S.02	Social tensions (religious, ethnic, regional etc.)	4	5	20
9	C.S.S.03	Poor socio-economic standing (corruption, poverty etc.)	4	4	16
10	C.E.E.01	Poor economical/financial standing	4	3	12
11	C.L.L.01	Immaturity of legal system	4	5	20
12	C.L.L.02	Poor of legal Regulatory Framework	5	5	25
13	C.L.L.03	Poor of Dispute Resolution Mechanism	4	5	20
14	O.F.F.	Force Majeure	1	1	1

TOTAL VALUE	187
GLOBAL RATING	13
RISK CATEGORY	SIGNIFICANT

Figure 4.8. RC process global risk rating sheet of Poland project

Project and global risk rating constitutes first part of the risk analysis process. As IRMS model is composed of jointed segments, second part of the risk analysis which is executed at risk analysis and response development phase includes MC simulation. As the software of the IRMS is still in proto-type stage, MC simulation tasks are carried out by the support of risk analysis software called @Risk for Poland project. To facilitate risk analysis tasks, the summary output of the project risk rating process and global risk rating value and the corresponding risk category, guide the decisions of the expert. The expert should choose a probability distribution function (pdf) for each work package and enter necessary parameters or coefficients and values to the software to run the MC simulation.

In Poland project risk analysis, triangular distribution function is chosen for all work packages to simulate real-case environment. In this pdf, minimum, most likely and maximum values are required as parameters for the simulation. Estimated budget values are accepted as minimum cost value as they are calculated for "no risk" case. Furthermore, most likely values are calculated by as the sum of estimated cost values with additional response cost values. The major difficulty in triangular pdf is pertinent to estimation of maximum value parameter. At this point, IRMS leaves the incentive to the expert. The expert can decide on the maximum value by considering the risk rating value, corresponding cost value, estimated budget of the work package, company strategy, risk attitude and past experience and can make a forecast for each work package. The results of the MC simulation for Poland project is illustrated in Figures 4.9-4.11.

RISK ANALYSIS PROCESS WITH MONTE CARLO SIMULATION		
Work Package	**Description**	**Total Cost (€)**
WP1	SUB/SUPER STRUCTURE CONSTRUCTION	11,078,061
WP2	UTILITY SYSTEM INSTALLATION	2,942,268
WP3	ROAD/LANDSCAPE SYSTEMS INSTALLATION	2,160,305
WP4	POWER SYSTEM INSTALLATION	4,689,419
WP5	TRACK SYSTEM INSTALLATION	5,317,357
WP6	OPERATING SYSTEM INSTALLATION	4,459,029
		33,711,084

Figure 4.9. Total cost of each work package based on MC simulation

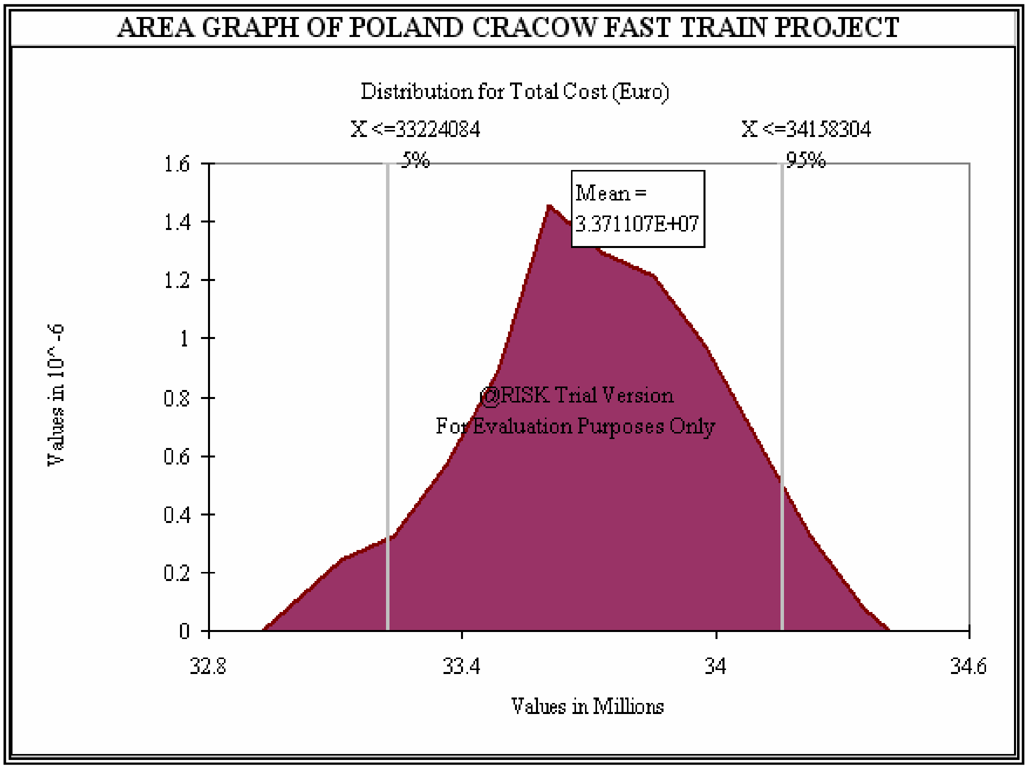

Figure 4.10. Area graph of Poland Cracow project

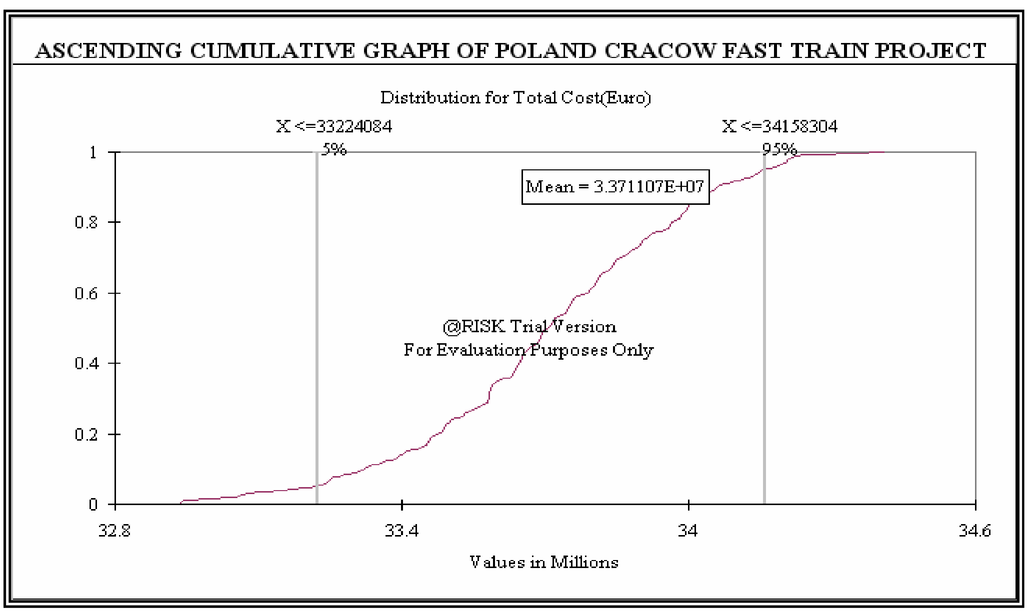

Figure 4.11. Cumulative graph of Poland Cracow project

The results of the MC simulation indicates that the mean value of the "Poland Cracow Fast Train Project" may be around 33.711.000 Euro with a probability of 51% based on the rating values, additional cost values and company strategy and objectives based subjective decisions. There is only 5 % chance that cost will be greater than 34.158.000 Euro. 33.711.000 Euro with % 50 probabilities of occurrence shows that there are some problems pertinent to initial cost estimates of the Poland project and these values should be checked and revised again. There is 15.55 % difference between the initial estimate value and the mean value of MC simulation. In this case the expert suggested revision of the estimated budget and increasing total project cost value to around 33.900.000 Euro of which is 75/25 value (there is 75 % chance that cost will be lower than 33.900.000 Euro).

If the actual results of this project are examined, the contractor offered a cost value of 29.163.000 Euro as total project cost and won the tender. However, the results indicate that although the project is at the 3rd milestone, the project needs a budget of 32.481.000 Euro, excluding variation order costs. This result shows that the accuracy of the IRMS is around %96 and may increase at the project completion which points out how well the model works.

CHAPTER 5

CONCLUSION

Systematic risk management covers identification of risk factors, quantification of risk impacts on project success by considering a number of scenarios, development of proactive response strategies before risks occur and monitoring of risks so that plans may be revised to achieve preset objectives.

If RM in construction sector is investigated, it is noticed that the literature is rich enough in terms of conceptual studies. As it is very hard to propose generic risk analysis models applicable to all kinds of projects, researchers proposed conceptual frameworks for the management of risk in construction projects. Starting from early 1980's, lots of studies are conducted by researchers and institutions to formalize RM process. For example, PRAM drafted by Chapman (1997), RAMP promoted by Institution of Civil Engineers (1998), and PMBoK proposed by Project Management Institute can be listed as RM methodologies which aim to increase formality of the RM process and facilitate application of RM activities. Similarly, in recent years, several researchers such as Tah and Carr (2000), Jaafari (2001) have proposed various RM process models as well as information models which accommodate changing nature of the construction industry, that is growing importance of information technology as a source of competitive advantage .

Although construction risk management literature is very rich in conceptual frameworks and models to overcome informality of RM efforts, number of systems which fully support RM process is very low. It is agreed by many researchers that risk management support tools should be integrated with other project management functions, be used during the whole project life cycle, and support all phases of RM. As stated in chapter 2, most of the existing support tools are designed to be used for quantitative risk assessment. Therefore, although there are numerous software systems that support individual phases of RM, the need for the development of integrated support tools is unavoidable.

Major aim of this thesis is to propose an integrated RM methodology which may be used during all phases of the RM process. This methodology can be used at tender stage of a construction project and integrated with other project management functions such as cost estimation and scheduling. Within the context of this thesis, a prototype decision support tool has been developed so that the proposed methodology can be utilized systematically for cost estimation during the bid preparation step of especially international construction projects. The proposed DSS, IRMS is designed to overcome some pitfalls of the existing RM support tools such as lack of a generic risk terminology and consistent risk breakdown structure, over simplistic tools to quantify risk and a linear risk management process where feedback information is neglected.

IRMS is a fully integrated DSS which provides a consistent and efficient platform for application of RM. The system supports contribution of soft systems like knowledge and experience based issues to hard systems such as identification and analysis techniques and takes risk attitude of decision makers into consideration. IRMS RM process model is composed of four jointed phases such as risk identification, risk classification and rating, risk analysis and response development and finally, risk revising. As IRMS approach is based on the principle of separating the project into work packages, and assignment of risks to the specified work packages; it enables the establishment of relationships between hierarchical risk breakdown structure (HRBS) and work breakdown structure (WBS), and integration of risk management activities with other project management functions, such as cost estimation. First two phases of the IRMS RM process model are carried out through a special process called risk carding process. In this process, different kinds of risk sources are assigned to pre-defined work packages by using a template named HRBS. HRBS provided by IRMS facilitates the identification process and increases the efficiency of the decision making task. In IRMS, a coding system is developed for each risk to formalize the identification process. After identification and assignment of the risk sources, ownership of each risk source is decided by conducting a contract evaluation task. After all, three different risk rating computations are carried out as pre-response risk rating process, post-response risk rating process and final risk rating process. Three tiers of risk rating are carried out to check how the risk levels and costs change, if different response strategies are formulized. After final rating and cost value are determined, risk rating value may be converted to linguistic terms by using risk rating categorization curves. After project risk rating is determined, global risk rating value is calculated which should be included into the Monte Carlo analysis in order to finalize the project cost value. Based on the information gathered as a result of risk rating, risk analysis is carried out by Monte Carlo simulation. The results of the MC simulation are monitored to see how costs may change under different risk scenarios. One of the major strengths of IRMS is that it supports all phases of RM by summarizing the risk and cost information in the form of tables, graphs and risk maps. All steps of the RC process may be documented in the form of spreadsheets and thus decision-makers can see the overall picture with the help of risk-response-cost-ownership information summarized in reports.

IRMS is composed of mainly four modules or engines as IRMS engine, MC engine, report engine and corporate memory. The system demands detailed project information data at the start of the RM session. Major idea behind the detailed project information demand is that information entered for each project is stored in a project library and if RM process would be applied for the similar future projects, stored knowledge like work packages and corresponding assessed risk sources, outputs can be used by after some minor modifications without repeating the whole processes. The other strength of IRMS is the corporate memory formation. If IRMS is used frequently and risk information as well as expected and actual costs are entered into the corporate memory, this valuable information may be used to produce more reliable forecasts for the forthcoming projects. It is proposed that case-base reasoning (CBR) method may be used for the cost estimation of forthcoming projects if enough data regarding risk-cost relationships are available in the corporate memory. Another feature of IRMS is that it enables multi-user risk assessment process. Different users such as JV partners, client, contractor or different individuals in a single organization such as project manager, cost estimator etc may use the same multi-user platform provided by IRMS for risk assessment process and in the light of the different options, based on the Delphi process, a common point, which reflects the groupthink, may be reached.

Although IRMS DSS is at the developing stage, the applicability and accuracy of the prototype model is tested on a real-case project. For Poland Cracow municipality project which covers sub/super structure construction works, and electro-mechanical installation tasks IRMS RM methodology is applied and results of the model is monitored. The initial cost estimate of the project by the company was 29.163.000 Euro and the actual cost happened to be 32.481.000 Euro excluding the cost of change orders. The mean cost calculated by IRMS is 33.711.000 Euro, showing on acceptable performance. However, the aim was not to test its prediction accuracy, rather, it was to demonstrate how IRMS may be applied on a real construction project.

User feedback after this application supports the idea that IRMS can provide an efficient and a flexible platform which enables to solve sophisticated construction project problems and facilitates the decision making process of the experts in a complex environment.

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