APPLICATION OF AN INTEGRATED RISK MANAGEMENT SYSTEM (IRMS) TO AN INTERNATIONAL CONSTRUCTION PROJECT

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Integrated Risk Management System (IRMS) is a decision support tool designed to support users at all phases of risk management and to assist cost estimation in the bid preparation stage, especially in international construction projects. IRMS process model consists of four integrated phases such as risk identification, risk rating and response development, risk analysis, and finally, risk revising and monitoring. A hierarchical risk breakdown structure is provided in the system which facilitates systematic risk identification process. Risk coding option embedded in the system creates a common language between the project participants. IRMS carries out an iterative risk rating and response generation process as an input for Monte Carlo Simulation. Moreover, IRMS is designed to store and retrieve risk information from a corporate memory that helps learning from projects. IRMS also allows multi-user risk rating. It increases the awareness of project participants on the magnitude of risks and helps visualization of risk scenarios by its effective reporting options. It can be used throughout the project life cycle and risk scenarios can be revised as the project proceeds. In this paper, application of IRMS prototype is illustrated by a real case study. The example project is a hydro electric power plant project (HEPP) which has been carried out by an international consortium in Turkey. Performance, shortcomings and benefits of IRMS are discussed by referring to experiences gained as a result of this application.

Keywords: decision support systems, international construction projects, risk management.

INTRODUCTION

Risk management (RM) is a critical part of international project management as these projects are subject to more risks than domestic projects due to complexity of logistics, communication channels, cultural differences and vulnerability to host country conditions. RM has taken its part in project management literature in early 1970s and preserved its importance as a research topic today. There are various process models proposed within the literature such as PRAM (Chapman, 1997), RAMP (Institution of Civil Engineers, 1998), PMBoK (Project Management Institute, 2000) etc. The construction management literature is also rich in terms of conceptual risk management models, developed specifically for different types of construction projects. Although many researchers have proposed conceptual frameworks and methodologies which aim to overcome the informality of RM efforts in the

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construction industry, they usually exist as stand-alone methodologies rather than integrated systems which can fully support RM process in construction projects (Dikmen *et al.*, 2004). The necessity of developing integrated risk management support tools has been acknowledged by many authors such as Tah and Carr (2000), Jaafari (2001) and Alesin (2001). In this research, support tools are defined as information systems that store, process and provide access to risk information. They are necessary to facilitate identification of risk factors, building a risk model to monitor the change in project outcome according to different scenarios regarding risks, response strategies, risk allocation between parties etc. As development of the risk management plan, which is the output of all RM activities at the start of the project, is an iterative process and should be revised periodically during the project, a decision platform is necessary to carry out tedious risk analysis calculations, monitor results of what-if analysis, store and update risk information and produce necessary reports (such as risk maps, influence diagrams, decision trees etc.) so that risk information can be shared. The word "integration" usually indicates the integration of RM with other project management fields (scope, time, cost, quality, human resources, 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 RM processes with each other; and finally integration of RM activities in one company with those in other project participants. In this paper, initial attempts to develop an "integrated decision support tool" will be discussed. An application will be demonstrated to discuss potential strengths and weaknesses of the proposed tool.

PROPOSED RISK MANAGEMENT SUPPORT SYSTEM: IRMS

Integrated Risk Management System (IRMS) is a decision support tool, developed by the authors of this paper which is mainly designed to facilitate cost estimation of international construction projects at the bidding stage. The aim of this study is to give some brief information about IRMS and illustrate applicability of its prototype to a real HEPP project realized by an international consortium in Turkey. The strengths of IRMS are integration of all phases of RM and its ability to incorporate different risk perceptions of project participants by its multi-user option. The Borland Delphi 7.0 is used to code IRMS based on the object-oriented approach. By using IRMS, a decision-maker may;

- Identify risks and create a common language between project participants by using the built-in risk breakdown structure and the risk coding option, respectively.

- Assess risks systematically and monitor the impacts of different response strategies as well as risk allocation scenarios on project cost by using a procedure called as "risk carding process".

- Develop a work breakdown structure to build a cost model and carry out Monte Carlo Simulation to monitor variability of project cost as a result of thousands of risk scenarios.

- Store risk and project related information (such risk ratings from previous projects, estimated-realised costs, contract conditions, project information etc.), retrieve and use them in the forthcoming projects. A Case-based

Reasoning Module is designed to predict costs by referring to previous risk-cost relationships.

- Produce various types of reports (probability-impact ratings, risk allocation reports etc.), charts and risk maps to summarise risk information.

- Define new risks, strategies and revise risk ratings based on the suggestions of other participants. IRMS creates a platform for risk information sharing and rating by its multi-user option.

IRMS PROCESS MODEL

One of the earliest efforts to define risk management process belonged to Hertz and Thomas (1983), who proposed a step-wise procedure of risk identification, measurement, evaluation and re-evaluation. Further, Hayes *et al.* (1986), Flanagan and Norman (1993), Raftery (1994), Edwards (1995) proposed reference frameworks comprising of risk identification, risk analysis, response planning, continuous monitoring, feedback for risk learning and action planning. All of these frameworks imply a systematic approach for management of risk by following a risk identification-analysis-response-monitor loop. Moreover, several institutions provided procedural, task-based guides for construction risk management. RISKMAN endorsed by European Community (Carter *et al.* 1994); Project Risk Analysis and Management Methodology (PRAM) introduced by Association of Project Managers (Chapman 1997); Risk Analysis and Management for Projects Methodology (RAMP) promoted by Institution of Civil Engineers (1998); and PMBoK guide of Project Management Institute (2000), all attempt to eliminate informality of risk management activities and integrate risk management with other project management functions. With slight differences in model architectures, number of separate phases, level of detail and coverage of project life cycle, all of the above mentioned RM process models and reference frameworks share a common goal and have similar characteristics. Similarly, IRMS process model consists of four jointed phases as risk identification, risk rating and response development, risk analysis, and risk revising and monitoring (Figure 1). IRMS approach is based on the principle of separating the project into work packages and assigning risks to specified work packages. A work breakdown structure is created by the user and risks are assigned to work packages (or the project as a whole) by using Hierarchical Risk Breakdown Structure (HRBS), which incorporates a pre-defined coding system, to establish a common language for users. Figure 1 represents the risk management process as a puzzle, since all tasks are pre-defined and in order to successfully carry out the process, individual tasks should be carried out as defined in the system; in other words, neither part of the puzzle can change its position. This logic is maintained by a process called as "risk carding (RC) process" which integrates and systematizes all explained tasks of risk identification, risk rating and response development. The logic of RC is defining a "card" for each risk that will be used as the basis of risk analysis. RC process starts with the identification of a risk source. As risk may be used to imply source, consequence or probability of occurrence of a negative event, poor definition of risk leads to a major inconsistency and wrong formulation of the risk model. IRMS handles risk as a "source" and prevents the possibility of inconsistent definition of risk by providing a consistent platform, which is called as HRBS. 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 five-level HRBS template is formed by taking into account the contract clauses, project participants, project and country

conditions as well as construction and design related issues which may affect project performance. In the first level of hierarchy, the risks are grouped under two categories: local and global. Local risks are the project-specific factors whereas global risks are related with the country factors or acts of god. Further, project risks are categorized in six groups, which are design and construction, requirements/ constraints, parties, resources, physical conditions, contractual issues. Under each category, there are various sub-factors. For example, under the "requirements/constraints" category, there exist schedule, cost, quality, health and safety, environment and others. Users are required to identify the risk factors considering their own conditions under each category. For instance considering the amount of liquidated damages specified in the contract, if necessary, they can create a risk factor entitled as "liquidated damages" under "schedule constraints". Thus, the user is expected to identify risks by entering risks under each category and create a risk checklist for the project.
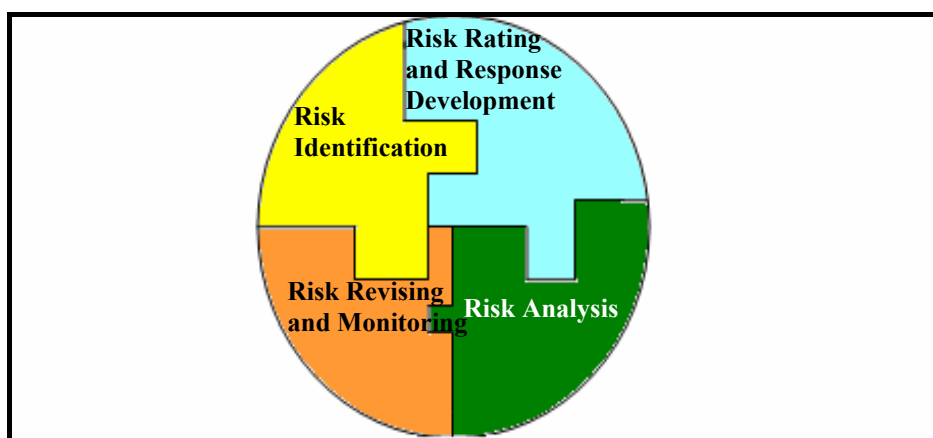

Figure 1: IRMS Process Model

The HRBS is flexible, thus the expert can make modifications, add new risk categories or delete irrelevant ones. Furthermore, as risks are created, the system automatically assigns codes. After a risk is identified, the process continues with contract evaluation in order to determine the "ownership" of the identified risk source. There usually exist a number of participants to realize a construction project which leads to complex risk allocation schemes. User assigns risks to related parties according to contract clauses, thus, owners of each identified risk are determined. Next, the risk rating of each risk source is calculated by simple multiplication of its probability of occurrence and its impact. For the probability and impact values, a Likert scale (1 to 5) is used. Based on his subjective judgments, a user assigns probability and impact values so that the risk rating can be calculated for each package and project. After the initial rating process (pre-response rating) is completed, responses are determined and rating process is repeated (post-response rating). This is an iterative process as each response has a cost and may lead to secondary risks. The RC process provides a flexible environment to the user where he may decide to apply the response strategy, alter or cancel it for the corresponding risk source until he is satisfied with the final risk rating score and cost of responses. At each step, IRMS provides the user with risk maps, a list of critical risks, scenarios of risk ownership and response costs. The RC process is summarized in Figure 2. It has to be noted that the aim of risk rating process is not to quantify risk levels, but instead, it is to demonstrate how relative risk level changes according to different response strategies

and ownership scenarios. IRMS presents the risk scenarios but it is the user who decides which risks are more critical and should be managed according to his subjective judgments. However, in order to assist the user about risk categorization, a set of curves proposed by Baccarini and Archer (2001) (y=K/x) are presented. Four regions are determined to categorize the risk level of work packages/project. It is clear that determination of K value may vary from one risk expert to another depending on his risk attitude and perception. Therefore, although default values such as K=5, 10, and 15 are proposed for the risk categories, IRMS is designed to accommodate other K values as suggested by the user. Thus, these curves may guide the decision-maker about which risks are critical and shall be minimized or eliminated if possible.

The risk rating score is an important input for the user while choosing the appropriate distribution parameters to be used during Monte Carlo (MC) simulation. IRMS MC engine is used to calculate total project cost considering risk categories and additional response cost of each work package. After choosing probability distribution functions from a list of the most widely used probability distributions such as uniform distribution, normal distribution, triangular distribution, beta distribution, trapezoidal distribution and custom distribution, and assigning correlations between distributions, the simulation is run. As a result of simulation, total project cost for different scenarios are computed and corresponding probability values for different cost ranges are obtained. The default distribution function of IRMS is triangular distribution and simplified rules are proposed to the users while choosing the most likely, minimum, maximum values of the triangular distribution according to the risk rating score as well as subjective correlation values considering common risk factors affecting work packages.

Risk revising and monitoring is the final stage within the risk management process. 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 dynamic in nature, status of the risk sources may change. Therefore, the status of the risk sources and their impacts on work packages can be monitored regularly and necessary modifications can be done as the project proceeds. IRMS assists the user to monitor changes in risk levels and corresponding costs at different stages of project life cycle.

According to IRMS model, the same risk rating procedure used for the risk assessment of work packages can also be applied to global risk sources. In this case, the rating procedure is not carried out with the aim of finding cost and individual risk rating of work packages; but instead, it is aimed to calculate a global risk rating score. The expert should assess probability and impact values for country risk sources such as political, economical, social and legal and compute a global risk score. Finally, total project cost is uplifted by a pre-defined percentage.
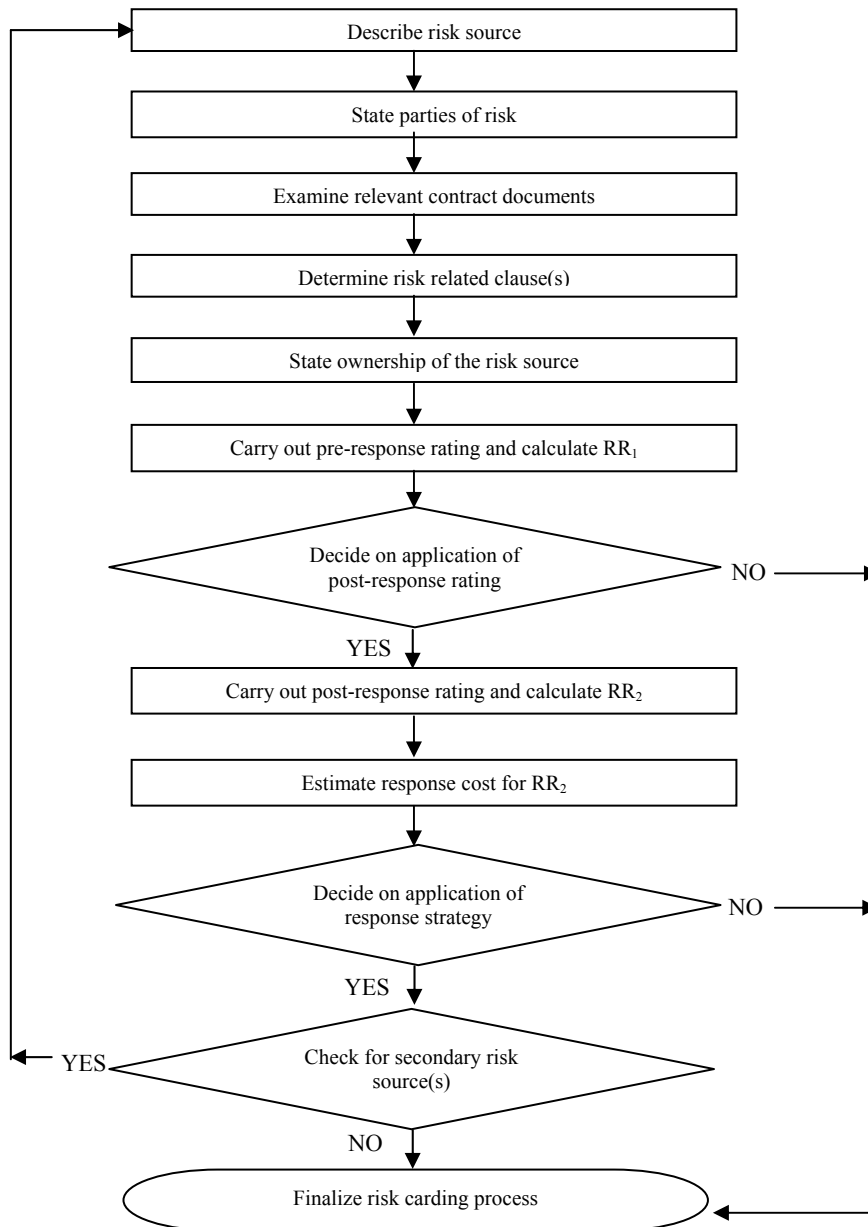
Figure 2: Risk carding process

IRMS APPLICATION ON A HEPP PROJECT

A pilot study has been carried out to test the applicability of IRMS model and prototype software on a real project. The names of the company and the project are withheld due to confidentiality reasons. An IRMS session starts with the registration of project information which will be recorded in corporate memory. The project is an HEPP in North East region of Turkey and covers construction of a dam, a hydroelectric power plant and appurtenant structures and design, supply, transportation, storage, erection, testing and commissioning of all electro-mechanical equipments. In this study, the project manager from Company A, which is one of the biggest construction companies in Europe, provided all the necessary information and the authors helped him to enter the required data in IRMS.

For this project, Company A established a consortium with a Turkish construction company and a local design company. The consortium members shall cooperate in order to negotiate a complete offer for the engineering and civil works; assist the owner about financing of the project; and arrange adequate credit facilities. Client is the State Hydraulic Works. Each of the three companies in the consortium is responsible to the client separately. Therefore, clear definition of responsibilities of consortium members is necessary. The project delivery system is "design-build" and the payment type is lump-sum. The currency of the project is US$, which is less risky than the local currency. The estimated budget of the project is around 78 million US$. The cost of civil works shall be paid by the owner according to a predetermined drawdown schedule in terms of interim payment certificates.

After project information is registered, the project is divided into work packages (Figure 3). The number of work packages depends on the type and complexity of the project and level of details required by the risk administrator, who is the project manager in this case. Before starting RC process, risk administrator decides on the number of risk experts who will join the RC process. 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 (Figure 3). After identification and assignment of the risk sources to the work packages, the ownership of each risk source is identified based on the type of contracts among the project parties. In this project, the contractor has three different contracts; one with the client, one with the consortium members and another with the sub-contractors. The contractor has lump-sum subcontracting strategy by which all of the work packages are subcontracted to different companies. During the risk rating process, similar risk sources 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. A screenshot of IRMS during RC process is depicted in Figure 3.

After the RC process is over, which is an iterative process of identifying project-level risks, calculating ratings, developing response strategies and continuing till an acceptable risk-response structure is constructed, a global risk rating should also be calculated. In this project, the result of global risk rating shows that the risk level is "high". Before the Monte Carlo Simulation, IRMS asks the decision-maker to identify a contingency percentage (risk premium) to be added on the total cost of the project according to the magnitude of the global risk rating. For this project, the project manager decided to increase the total project cost about 10%.

In the risk analysis phase, the expert was asked to identify probability distributions for each work package according to the risk ratings calculated as a result of RC process. The default probability distribution function of IRMS is triangular distribution and simplified rules are proposed to the users while choosing the most likely, minimum, maximum values of the triangular distribution according to the risk rating score as well as subjective correlation values considering common risk factors affecting work packages. The user can also fit a custom distribution or calculate correlations using statistical data, if available. In this application, the expert decided to assign triangular distribution to all work packages and used default rules for assigning subjective correlations. Simulation settings are defined by using the simulation wizard of IRMS Monte Carlo engine, choosing Monte Carlo as the sampling method, defining 100000 iterations and 10% confidence level.
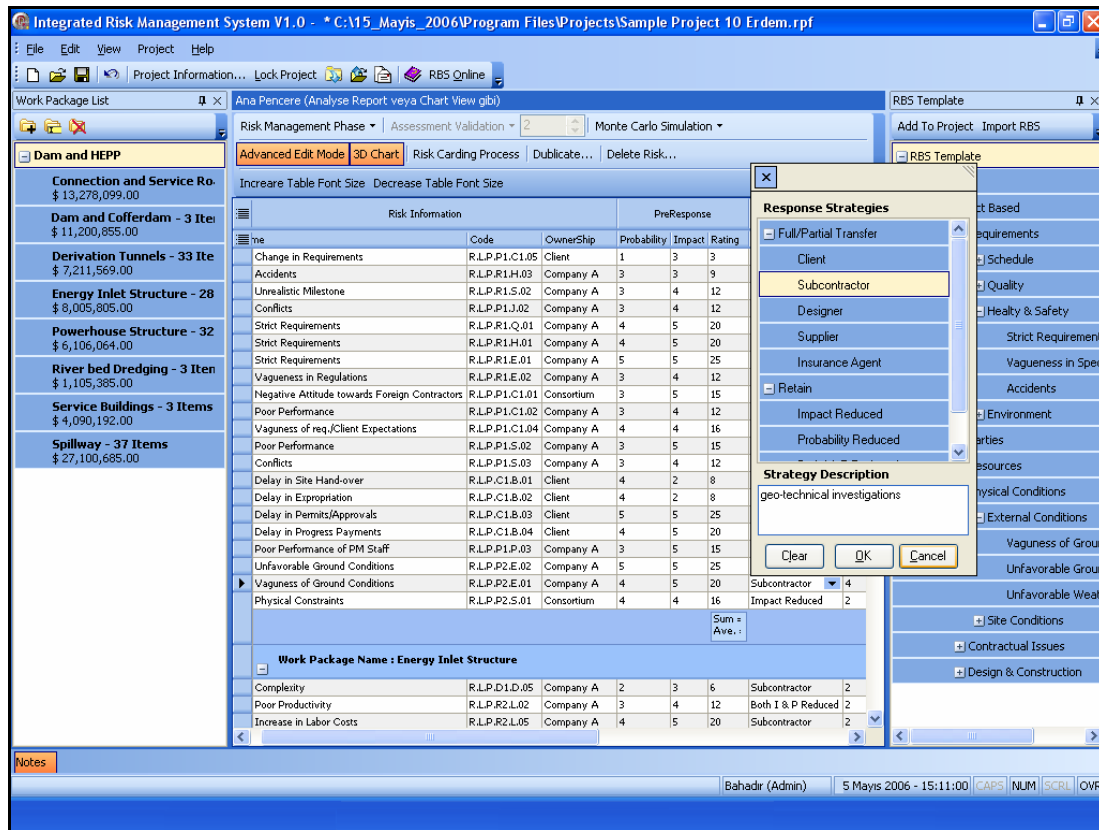
Figure 3: IRMS RC process of the example project

The results of MC simulation indicate that the mean value is 88.588.595 $. There is 13.4 % difference between the initial estimated 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 89.599.226 $, which is 75/25 value (there is 75 % chance that cost will be lower than 89.599.226 $). Figure 4 illustrates cumulative probability graph of total project cost. It should be reminded that the actual bid amount is usually different than the estimated cost value as IRMS does not consider the competitiveness issues and profitability objectives. Decision-makers should decide on an appropriate mark-up value considering the level of competition, need for project and short-term and long-term profitability objectives.

LESSONS LEARNED AND DISCUSSIONS

The aim of this application is not to test the accuracy of the model by comparing the initial estimated cost and the actual cost of the project. As such data does not exist, the performance of IRMS in cost prediction can not be tested. Moreover, as IRMS is being used in this company for the first time, there is no case library and the performance of the case-based reasoning module can not be monitored.

The aim of this application is to observe the potential difficulties that may be encountered by construction professionals while using IRMS. Although one application may not be enough to decide on the strengths and weaknesses of IRMS, some of the lessons learned that will help development of a better version of IRMS are discussed in the following paragraphs.
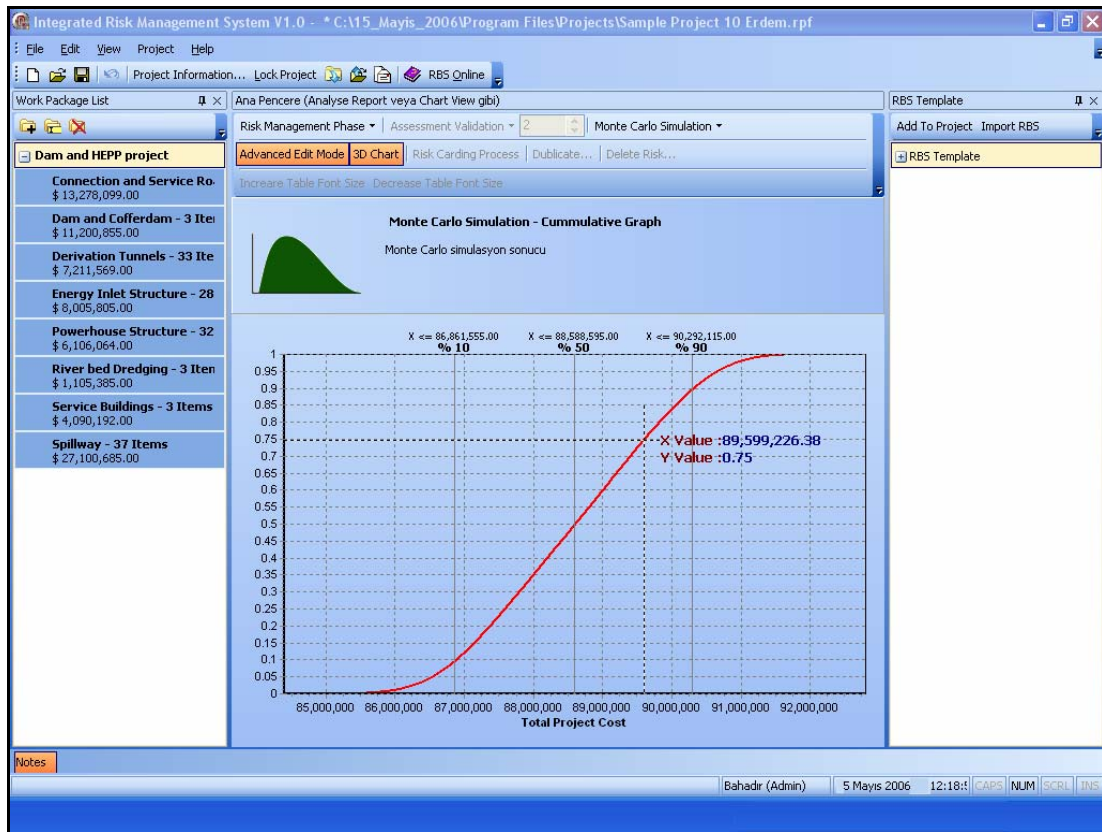
Figure 4: MC Simulation result of HEPP

According to the expert, who is the project manager of the HEPP explained in previous parts and who actually entered the relevant data into the IRMS software, the major strength of IRMS is the built-in HRBS. By using HRBS, he was able to systematically identify specific risk sources under different risk categories. He mentioned that HRBS decreases the risk of overlooking some of the significant risk factors. However, the major difficulty was deciding on the level of detail while defining the WBS and risks. For example, one can define thousands of problems that can happen due to various technical risk sources. Finally, he considered only the critical items. He also argued that the risk identification and rating processes should be carried out by a team of experts rather than a single person because all of the details of a project may not be known by even the most experienced project manager. Especially about the potential technical problems, assistance of technical staff is required. Thus, the multi-user option of IRMS is more preferable than the single-user option. But if the ratings are assigned by a number of people and there exist a significant disagreement between them, the risk administrator should find a way to manage them. It is anticipated that IRMS may generate required reports which show the risks that have the highest deviation between the assigned values and give a warning signal so that the risk administrator may seek extra information from the experts to learn the reasons why different ratings are assigned and their underlying assumptions. Finally, a single rating should be decided.

The expert argued that one of the strengths of IRMS is the risk carding process that increases the awareness of users about the relative magnitude of risks inherent in the project. One of his criticisms was about the definition of response strategies. He mentioned that IRMS may provide more guidance about possible response strategies.

He proposed that related contract clauses in standard forms of contract may also be included in IRMS and guide the decision-maker about distribution of risk ownership between the parties.

As a result, he declared that IRMS provides a systematic approach which increases the trust in estimated costs. It helps sharing of risk information and increases the awareness on level of risks associated with a project. However, the estimated cost can only be as accurate as the information fed into the software. Thus, subjectivity in risk ratings decreases the trust in IRMS outputs. Moreover, the most important difficulty encountered by the expert was understanding the Monte Carlo Simulation. For the probability distributions and correlations, he used the default rules given in IRMS. He argued that many experts would not be interested in defining custom rules themselves and they would choose the default options. It is clear that the information required from the experts for Monte Carlo Simulation should be tried to be minimized by defining more simplifying rules in later versions of IRMS.

Finally, it is anticipated that case-based reasoning module is a very significant part of IRMS as it may help elimination of some of the existing problems. If enough number of projects are imported to the case library, some of the relations (between risk rating and cost, project type and risk rating etc.) may be found by the case-based reasoning module and rules derived from experience may be used rather than general simplified rules. If case retrieval becomes possible and experts are able to find the similarity of a forthcoming project with the previous ones, subjectivity about ratings and cost values may be decreased.

CONCLUSIONS

Within the context of this study, a prototype decision support tool, namely IRMS has been introduced and a real case study is presented to demonstrate how it can be used for cost estimation during bid preparation. IRMS may overcome some pitfalls of the existing RM applications such as lack of a generic risk terminology and consistent risk breakdown structure (with its built-in HRBS) and a linear risk management process where feedback information is neglected (iterative risk carding, risk revising and monitoring processes). It also supports multi-user risk assessment process and storing of risk information in a memory so that the relation between risk-response and cost can be learnt from previous projects by using case-based reasoning. With its effective reporting system, it increases the awareness of managers on size, type and impact of risks and facilitates communication of risk information between the parties.

Applicability of IRMS prototype has been tested on a HEPP carried out by an international consortium in Turkey. The major strength of IRMS has been defined as the HRBS which significantly simplifies the risk identification process. Risk carding process is also proved to be an effective function which increases the awareness of users about the relative magnitude of risks inherent in the project. IRMS provides a systematic approach which increases the trust in estimated costs. One of the criticisms of the expert that participated in the case study is the amount of information required from the users to conduct a Monte Carlo Simulation. Finally, one application is definitely not enough to test the applicability and reliability of the model, thus, a number of potential users shall be requested to comment on IRMS's performance so that further improvements are made. Also, performance of the case-based reasoning module could not be monitored in this application. A number of applications should be carried out to test how it may increase prediction capability of IRMS.

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