

A PROTOTYPE RISK MANAGEMENT DECISION SUPPORT TOOL FOR CONSTRUCTION PROJECTS

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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 RM concept and the number of support tools which facilitate the process is rather low. Decision support tools are necessary for the systematic identification of risks, scenario generation, and proactive management of risk and integration of RM activities with other project management functions. The aim of this study is to introduce a conceptual RM model and a prototype RM decision support system which is specifically developed for construction companies. The proposed decision support system, namely Integrated Risk Management System (IRMS), is designed to support the user at all phases of the RM process and to assist cost estimation in the bid preparation stage. The performance of the tool is tested on six international construction projects. Results demonstrate that IRMS can be used effectively for systematic management of risks and its prediction capability is high. Shortcomings of the tool and necessary refinements are also reported.

KEYWORDS: risk management, decision support systems.

INTRODUCTION

Significant changes in the 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 the international construction market. Risk management (RM) is an important 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.

Risk management has taken its part in project management literature in early 1970's and preserved its importance as a research topic since today. There are various process models proposed in the literature such as PRAM (Project Risk Analysis and Management) developed by Chapman (1997), RAMP (Risk Analysis and Management for Projects) proposed by Institution of Civil Engineers (ICE) (1998) and PMBoK (Project Management Body of Knowledge) by Project Management Institute (PMI) (2000). The construction management literature is also rich in terms of conceptual risk management frameworks. Researchers have proposed various conceptual risk management frameworks to overcome the informality of

risk management efforts in the construction industry. However, as Dikmen et al. (2004) stated, risk management paradigms usually exist as methodologies rather than systems which can support RM process. There is only a limited number of risk management support systems (RMSS) developed for the construction industry. Another RMSS prototype is developed by Tah and Carr (2000) which is based on a formal methodology for construction project risk management, including a generic process model and underlying information model. Jaafari (2001) proposed a generic model, called IFE (Integrated Facility Engineering) that consists of various modules like information module, neural network and simulation engines and reporting functions.

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 tasks (scope, time, cost, quality, human resources, communication, claim 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.

PROPOSED RISK MANAGEMENT SUPPORT SYSTEM

The aim of this study is to propose a risk management decision support system which can be used in international construction projects at the bidding stage. The proposed model is designed to overcome some of the shortcomings pertinent to RMSS. Integrated Risk Management System (IRMS) is a decision support system which integrates all phases of RM and incorporates different risk perceptions of project participants by its multi-user option. With its built-in risk breakdown structure, risk identification process is systematized and a common risk language is formed. The system is designed to prepare various kinds of reports, charts and maps to increase the awareness of managers about the existence and magnitude of different risk factors. It enables monitoring of risk impacts throughout the project life cycle and updating of risk management plans. One of the vital features of IRMS system is incorporation of risk knowledge associated with previous projects, for the risk assessment of forthcoming projects. The system has a corporate memory which is formed by storing project data created by using IRMS.

IRMS system architecture

The Borland Delphi 7.0, MS Visio 2003, MS SQL and MS Access 2003 are used to develop and code IRMS model based on the object-oriented approach. The major aim of IRMS components is to ensure construction of the project cost performance model using built-in risk breakdown structure and setting the relations between risks, response and performance by referring to the past cases. IRMS project risk management process starts with acquiring and storing necessary project information. Major idea behind the detailed project information demand is that information entered for each project is stored in a project library, a SQL (Structured Query Language) type knowledge database. The information stored in the database such as country and project information, risk sources and consequences in terms of time and cost may be used during the risk identification and analysis phases of forthcoming projects. The volume of this corporate risk memory expands and accuracy of predictions tends to increase as a company utilizes IRMS more frequently.

IRMS supplies a multi-user platform to facilitate group decision making during risk identification and assessment. The administrator has the responsibility to get the work packages from the planning expert, enter them into the system, assign risk sources to the specified work packages and carry out the first rating process. If RM process is executed by using the multi-user option, other experts carry out the same process for all work packages defined by the risk administrator and rate the pre-defined risk sources for each work package. The experts do not have the opportunity to make any modifications pertinent to base information of the RM process. However, they can make comments through notes. IRMS is designed to supply a multi-user platform by forming a SQL based main server to import and export information by entering the passwords defined by the risk administrator. The system architecture and data flow of the proposed system is shown in Figure 1.

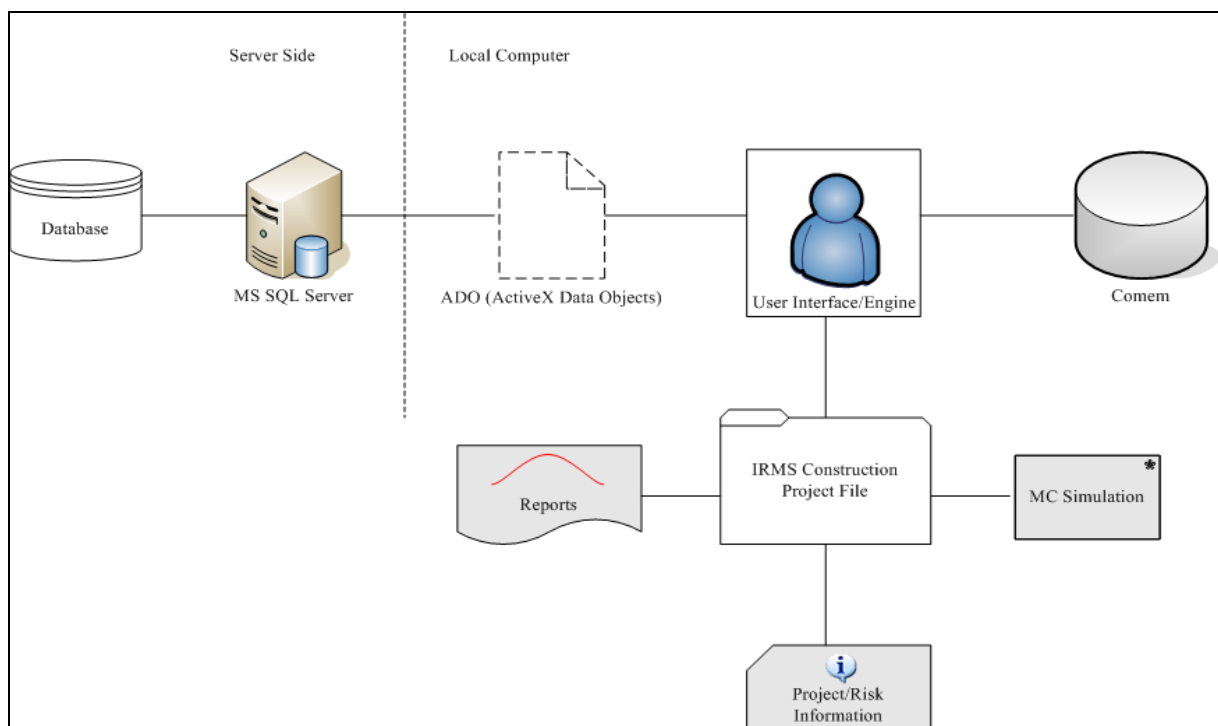


Figure 1: IRMS System Architecture Data Flow

IRMS risk management process model

IDEF0 modelling technique is used to develop the IRMS process model. The model consists of the following phases (Figure 2) such as setting project information, risk identification, risk rating and response development, risk analysis and risk revising and monitoring.

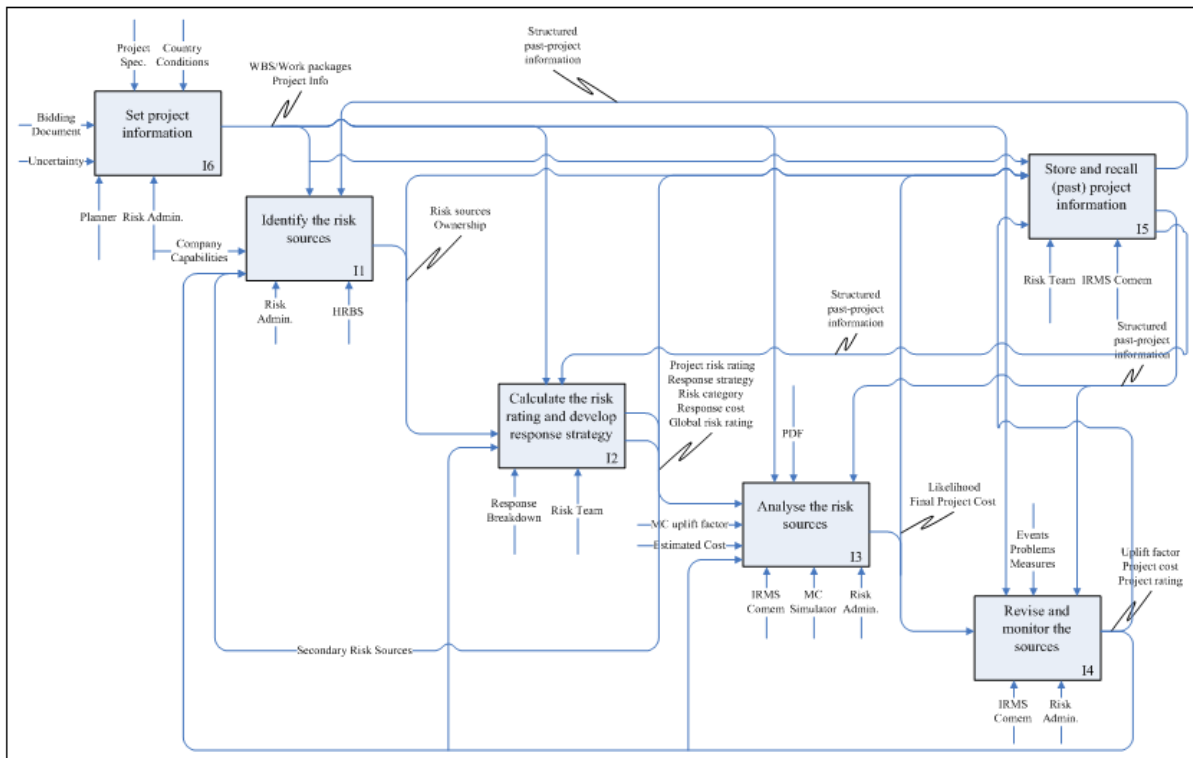


Figure 2: IRMS IDEF0 Process Model

IRMS risk identification phase

Risk identification is the process of defining “risk sources” which will have an impact on project success whereas the overall project success criterion is defined as “cost” in IRMS. Although risk identification seems to be a simple process when compared to other risk management tasks, it is one of the most important and complex task for a decision-maker, as poor definition of risk may result in 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, called as HRBS (Hierarchical Risk Breakdown Structure). A HRBS template which incorporates a pre-defined coding system is embedded in the system to establish a common language for users.

In IRMS, the risk sources are handled as either project specific risks which can be assigned to project work packages or global risk sources those affect the whole project. The five-level HRBS template that includes 77 risk sources 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. The user is expected to identify potential risk events (risk factors) under each category and create a risk checklist for the project. The HRBS is flexible, thus the expert can make modifications, add new risk categories or delete irrelevant ones. Risk codes create a common understanding between project participants and improve the communication of risk information between different parties. IRMS provides a tutorial to the user which includes the codes, meanings and examples for the corresponding risk sources to prevent misunderstanding of risk items by different users under different conditions.

IRMS risk rating and response development phase

After the risks are identified for each package and the project, a risk rating process is carried out by the users for initial assessment of the risk level. Risk rating task covers assessment of probability of occurrence of identified risk sources and their impacts, if they occur. 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/her subjective judgments, a user assigns probability and impact values so that the risk rating can be calculated for each package and project. The aim of risk assessment is not to quantify risks but identify critical risk factors and compare relative magnitude of risks.

IRMS model integrates and systematizes all explained tasks of risk identification, risk rating and response development by using a process called as Risk Carding (RC). The logic of RC is to define 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. The system calls automatically the risk code of the corresponding risk. After a risk is identified, the process continues with contract evaluation in order to determine the “ownership” of the identified risk source. 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 the feasibility of the identified strategy should be assessed by the decision-maker by monitoring its cost, residual and secondary risks.

IRMS global risk rating process

According to IRMS model, the same risk rating procedure used for risk assessment of work packages can be applied to global risk sources. The expert should assess the probability and impact values for country risk sources such as political, economical, social, legal and force majeure risks given in HRBS and compute a global risk score. Finally, total project cost is uplifted by a pre-defined percentage decided in the light of the global risk score. At this point, IRMS does not propose any percentage scale to the expert, since this percentage depends on many parameters like company strategy, company work load, company strengths and weaknesses etc. For this reason, IRMS leaves the responsibility of assessing the global risk percentage to the experts. However, if IRMS is used for many projects and therefore a more reliable corporate memory is achieved, then, the relationship between cost and risk rating may be learned from previous projects and a realistic contingency value may be selected using this information.

IRMS risk analysis phase

Risk rating approach and Monte Carlo (MC) simulation are used together to quantify the impact of risk sources on work packages. The risk rating score is an important input for the user while choosing the appropriate distribution parameters to be used during MC simulation. As the current study is pertinent to cost estimation, IRMS MC Simulator is used to calculate total project cost considering risk categories and additional response cost of each work package. After defining probability distribution functions among the most widely used probability distribution options such as uniform, normal, triangular, beta, trapezoidal and custom distributions, and assigning correlations between them, the simulation is run, 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 the subjective correlation values considering common risk factors affecting work packages. The details of MC simulation can be found in Arikan (2005). Finally, cost calculated by using MC simulation is uplifted by applying a percent value that reflects the impact of global risk sources on project cost. At this point, IRMS does not propose any percentage scale to the expert because this percentage depends on many parameters like company strategy, company work load, company strengths and weaknesses etc. For this reason, IRMS leaves the responsibility for assessment of global risk percentage to the experts or decision makers.

IRMS risk revising and monitoring phase

Risk revising and monitoring is the final stage within the risk management process. The risk sources must be monitored in order 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 risk sources may change. Therefore, the status of risk sources and their impacts on work packages should be monitored regularly by comparing the forecasted values with the actual ones and necessary modifications should be done as the project proceeds. In this respect, IRMS assists the user to monitor changes in risk levels and corresponding costs at different stages of project life cycle.

IRMS corporate memory (Comem)

IRMS Comem is a smart knowledge database which stores project, country, risk and cost related information for the retrospective use of data in the forthcoming projects. The main philosophy of the system is to classify and structure all kinds of risk information in order to enable learning from risks and decrease the subjectivity during the risk assessment process. Comem is a relational database that is composed of three types of domains such as project domain, risk domain and actor domain.

The risk expert shall use the search engine of the Comem to find out previous projects which meet the pre-defined criteria such as project type, country, global risk rating etc. Comem supplies structured past project information (both planned and actual) to facilitate the risk assessment and evaluation process of a forthcoming project. For example, a decision-maker may search previous projects that used a particular response strategy in order to estimate its cost in the current project. The actual costs and risk ratings of work packages may be recalled in order to decide on the lower and upper limits to be used in the probability distribution of a similar work package in the current project.

APPLICATION OF IRMS TO REAL PROJECTS

The developed IRMS prototype has been tested on six completed projects which were carried out in Saudi Arabia, Turkey, Turkmenistan, Iraq, Russian Federation and United Arab Emirates (Table 1). The aim of this study is to monitor possible difficulties faced by the users and test the accuracy of its outputs. Thus, the experts were requested to carry out a risk assessment exercise by using IRMS assuming that they are estimating the cost at the start of the project. The original values (estimated costs) are considered as base costs and contingencies are determined according to risk ratings calculated by using IRMS. All experts

are members of the project management team of the case study projects and have sufficient knowledge about the risk events that actually happened throughout the project.

Case 1 is a petrochemical processing plant construction in Saudi Arabia. In this project, the project delivery system is design-bid-build in which the design works are under the responsibility of the client. The risk expert is the technical office manager of the related construction company. In this project, the risk expert considered “construction risk” source as the most critical one and identified 44 types of project risk factors. “Labour risk”, “material risk”, “quality risk” and “design risk” categories embraced a high number of significant risk factors. Similarly, the global risk rating indicated a high risk value. A screen shot of the IRMS tool for petrochemical processing plant construction project and one of the corresponding reports are shown in Figure 3 and Figure 4, respectively.

Case 2 is a hydro-electric power plant (HEPP) project which was realized in Turkey. The project delivery system is design-build and the associated parties are; members of a consortium that consists of a foreign construction company, a Turkish construction company and a Turkish design company. The risk expert is the manager of the foreign construction company. During the risk assessment phase, risk expert identified 33 types of risk sources and assigned a total of 141 risk factors to 8 work packages. Among the 33 types of risk sources, the ones under the category of “client”, “project management” and “contract” are identified as the ones having the highest impact on project cost. In addition, the global risk rating process carried out by the risk expert using HRBS resulted in a high rating (11.32, a value between 10 and 15, which indicates high risk as suggested by the Baccarini and Archer, 2001). The project and global ratings imply that project is a high risk project.

Case 3 is the refinement and storage units construction of a refinery in Turkmenistan. The project delivery system is design-build and the project is carried out by a joint venture formed by Turkish and German contractors. The risk expert is the construction manager of the joint venture. According to IRMS model, the major risk categories are identified as “labour risk”, “project management risk” and “sub-contractor risk”. The global risk rating corresponds to moderate risk category which foresees less global risk impact when compared to the first two cases.

Case 4 is a residential building project in Iraq. This project is a design-build project. In this project, the job is carried out by a single contractor and the risk expert is the technical office manager of this construction company. According to the information entered by this expert into the IRMS model, this project has less technical risk sources compared to other cases but the “scope risk” and “contract risk” may have significant impacts on cost. On the other hand, according to IRMS outputs, the global risk rating is found to be the highest among all case study projects.

Case 5 is a gas compressor station reactivation project in Russian Federation. This project is a design-bid-build project. In this project, there is a single contractor and the risk expert is the technical office manager of this construction company. According to the information entered by the expert into the IRMS model, this project has less technical risk sources compared to other cases but the “site conditions risk”, “external conditions risk”, and the resource based risks such as “material, equipment, labour and fund” may have significant impacts on cost. On the other hand, according to IRMS outputs, the global risk rating is similar to the Turkmenistan case and can be perceived as moderate category.

Last project is a drainage and sewage system construction project which is realized in Dubai, United Arab Emirates. The project delivery system is design-build. The risk expert is the project manager of the construction company and has great experience in infrastructure projects. The IRMS results indicate that the project has potential risk sources which arise from mainly “requirements” and “parties”. The expert defined 31 types of risk sources among which “quality”, “health and safety” and “project management” mostly govern the project cost. The global risk rating is found to be the lowest of all six cases, which influences the project cost less, when compared to other cases.

Figure 3: A Screen Shot of the IRMS

Table 1 shows the general information about the examined six cases. These cases cover a wide geographic region and they are within a reasonable cost range (small and large projects within the range of 6 million to 75 million US \$). Moreover, the case study projects are carried out in countries that have different risk levels. Among the cases, the most risky country is Iraq and the least risky one is United Arab Emirates.

DISCUSSION OF CASE STUDY FINDINGS

As well as its capability to systemize the risk management process, the performance of IRMS can be measured by how well the risk impacts are reflected onto the price. Table 2 is a comparison table which shows the results of IRMS, mainly cost estimates (that have 50%, 75% and 100% probability of occurrence), project risk rating, global risk rating and actual cost figures. The results show that although outputs of IRMS are highly pessimistic compared to initial cost estimates, they are very close to actual costs, excluding the change order costs. The highest error, which is calculated by considering the difference between the mean value provided by IRMS and the actual cost figure is around 6%, which is an acceptable result.

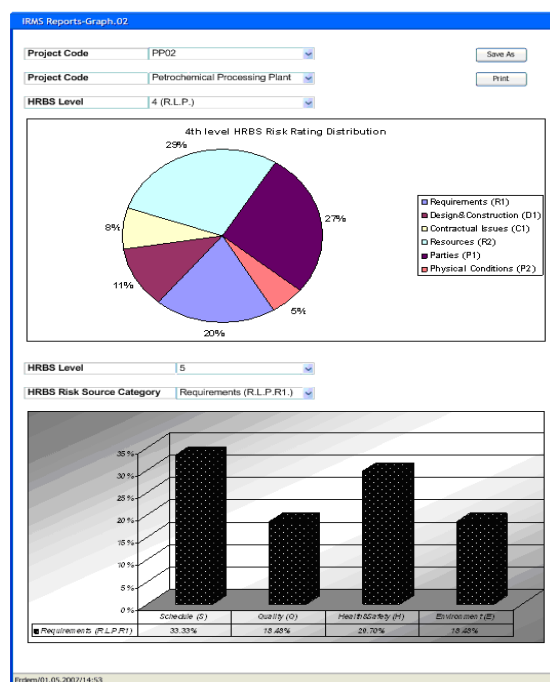


Figure 4: An Example of IRMS Report

Table 1: Information Summary of the Examined Cases

Project	Country	Estimated	Realized
		Cost (E) (\$)	Cost (R) (\$)
Petrochemical Processing Plant Construction	Saudi Arabia	27.220.000	36.003.000
Hydro Electric Power Plant Cons.	Turkey	76.095.000	86.743.000
Refinement and Storage Units Construction	Turkmenistan	17.084.000	20.704.000
Residential Building Cons.	Iraq	15.500.000	20.462.000
Gas Compressor Station Cons.	Russian Federation	5.828.000	7.251.000
Drainage and Sewerage System Construction	United Arab Emirates	12.500.000	13.700.000

Although point accuracy is not the primary goal of IRMS, the results show that the cost estimation capability of the IRMS is highly satisfactory. All of the experts perceived IRMS as a practical tool that facilitates systematic management of risks. One of the major strengths of the system, as identified by experts is its HRBS that helps the systematic identification of risk sources and easy communication of risk information between project participants. Moreover, experts mentioned that the multi-user risk assessment feature can be very useful as it can increase awareness on risk issues (magnitude, ownership, possible response strategies etc.).

On the other hand, experts experienced difficulty in understanding the RC process and argued that the response costs cannot be estimated easily. Also, the experts criticized the time elapsed for the entry of basic information and proposed that the data entry speed may be enhanced by providing short-cuts. All of the experts used triangular and trapezoidal distributions and claimed that these two would be applicable for all the projects. The major difficulty faced by the experts was deciding on the upper and lower limit values in the distributions. One of the shortcomings of IRMS is denoted to be the subjectivity of the risk ratings and their impacts on project cost. It is believed that the multi-user option and corporate risk memory will decrease subjectivity and increase the trust of decision-makers on the IRMS outputs.

Table 2: IRMS Outputs

Project	Outputs of IRMS about costs(\$)			Outputs of IRMS about risk ratings		Error (%)	
	50% (EIRMS-Mean)	75%	100%	Final Project Risk Rating	Global Risk Rating	Without IRMS [(R-E)/E]*100	With IRMS [(R-EIRMS-Mean)/EIRMS-Mean]*100
Petrochemical Process. Plant	35.626.000	36.411.000	38.260.000	12.45	10.42	32.27	1.06
Hydro Electric Power Plant	87.595.000	88.411.000	90.054.000	12.07	11.32	13.99	-0.97
Refinement & Storage	21.377.000	21.800.000	22.860.000	9.88	9.57	21.19	-3.15
Residential Building Cons.	20.554.000	21.051.000	21.930.000	10.24	19.71	32.01	-0.45
Gas Comp. Station	7.051.000	7.373.000	7.693.000	11.48	9.91	24.41	2.83
Drainage Sys.	14.561.000	14.900.000	15.500.000	12.55	8.84	9.6	-5.6

CONCLUSIONS

Within the context of this study, a prototype decision support tool, namely IRMS has been introduced. 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), over simplistic tools to quantify risk (by using risk rating and MC simulation together) 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 storage of risk information in a memory based on a SQL server so that the relation between risk-response and cost can be learnt from previous projects. 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 six completed international construction projects. Its cost prediction capability is found to be very high. Although the outputs of the model are found very close to actually realized cost figures, the accuracy of IRMS must be tested on several other cases before it can be claimed to be a reliable tool. In this study, experts used IRMS on already completed projects. However, IRMS must be used at the start of a project and the actual costs must be compared with the initial estimates to test its performance more realistically. Next step of the research is to finalize the structure of the risk memory and test its performance by entering real project data.

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