Dikmen, I, Birgonul, M T, Anac, C, Tah, J H M and Aouad, G
Learning from Risks: A Tool for Post-Project Risk Assessment.

Dikmen, I, Birgonul, M T, Anac, C, Tah, J H M and Aouad, G (2008) Learning from Risks: A Tool for Post-Project Risk Assessment. *Automation in Construction*, 18 (1). pp. 42-50.
doi: 10.1016/j.autcon.2008.04.008

Learning From Risks: A Tool for Post-Project Risk Assessment

I. Dikmen[1], M.T. Birgonul[2], C. Anac[3], J.H.M.Tah[4], G. Aouad[5]

[1,2]Middle East Technical University, Civil Engineering Dept., Ankara, Turkey

[3] IC Ictas Construction, Kizilirmak Sok No:31 Kocatepe, Ankara, Turkey

[4] Oxford Brookes University, School of the Built Environment, Oxford, UK

[5] University of Salford, School of Construction and Property Management, Salford, UK

Email[1]: idikmen@metu.edu.tr

Abstract:

Risk management (RM) comprises of risk identification, risk analysis, response planning, monitoring and action planning tasks that are carried out throughout the life cycle of a project in order to ensure that project objectives are met. Although the methodological aspects of RM are well-defined, the philosophical background is rather vague. In this paper, a learning based approach is proposed. In order to implement this approach in practice, a tool has been developed to facilitate construction of a lessons learned database that contains risk related information and risk assessment throughout the life cycle of a project. The tool is tested on a real construction project. The case study findings demonstrate that it can be used for storing as well as updating risk related information and finally, carrying out a post-project appraisal. The major weaknesses of the tool are identified as, subjectivity of the risk rating process and unwillingness of people to enter information about reasons of failure.

Keywords: lessons learned, post-project appraisal, risk management, vulnerability.

1. Introduction:

Risk management (RM) is about defining sources of uncertainty (risk identification), estimating the consequences of uncertain events/conditions (risk analysis), generating response strategies in the light of expected outcomes and finally, based on the feedback received on actual outcomes and risks emerged, carrying out identification, analysis and response generation steps repetitively throughout the life cycle of a project to ensure that the project objectives are met. RM in construction is a tedious task as the objective functions tend to change during the project life cycle, and the scenarios are numerous due to sensitivity of projects to uncontrollable risks stemming from the changes in the macro-environment, existence of high number of parties involved in the project value chain, and one-off nature of the construction process. There are various studies in the construction management literature that pinpoint the importance of "a risk-driven approach" as a critical success factor for construction projects [1-6]. One of the earliest efforts to define RM process belonged to [7], who proposed a step-wise procedure of risk identification, measurement, evaluation and re-evaluation. Further, [1-4] proposed reference frameworks comprising of risk identification, risk analysis, response planning, continuous monitoring 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 project RM. RISKMAN endorsed by European Community [8]; Project Risk Analysis and Management Methodology (PRAM) introduced by Association of Project Managers [9]; Risk Analysis and Management for Projects Methodology (RAMP) promoted by [10]; and [11], all attempt to eliminate informality of RM activities and integrate RM with other project management functions.

RM is a way of thinking and a philosophy that permeates the entire spectrum of project activities [6]. In spite of the fact that the methodological aspects of RM are well-defined, the philosophical background is rather vague. Although, RM is based on a variety of decision-making theories and associated techniques, Green [12] criticizes that soft paradigm of RM is not conceptually well-defined. Dikmen et al. [13] argue that major challenges of RM are mainly due to poor definition of risk and vagueness about how and why risks should be managed in construction projects. They mention that RM is usually seen as an activity carried out for better quantification of risk impacts and contingency management. However, it should also endorse effective monitoring of risks, better communication of risk information between project participants and construction of a corporate risk memory to introduce experience-based solutions of how risks can be managed.

In this paper, it is hypothesised that a learning-based approach, which will be explained in the next section, may have the potential to remove some of the bottlenecks that plug the way of successful RM applications in practice. The objectives of the paper are two-folds; proposing a learning-based approach for RM and demonstrating how it can be realised in practice by means of a tool developed for construction of lessons learned databases that contain risk-related information. The paper is organised in four parts: the necessity of a learning-based approach for RM is discussed, benefits and shortcomings of lessons learned databases are mentioned, a tool developed to facilitate learning-based RM is presented and its performance during post-project appraisal is evaluated referring to a real construction project.

2. Learning From Risks:

The term "learning from risk" is used to suggest "a knowledge-driven risk management process" and "focus on lessons learned" for better risk management (RM). In order to facilitate learning from risk events, companies may construct a corporate risk memory in which the risk information is stored as well as lessons learned about effectiveness of response strategies and factors that affect the risk consequences. Focus on learning as a part of RM may help overcoming some of the challenges about risk analysis, change the way risks are managed and enhance benefits of RM. Atkinson et al. [14] argue that readily available repositories of risk data from past projects are fundamental to the quality of estimates. Learning from risks may lead to construction of more realistic risk models and more informed guesses about the future. Before and after analysis can be carried out to understand risk impacts and identify the reasons of success and failure. Focus on learning from risks may help institutionalisation of risk information and change the project-based RM practice to a corporate-level RM approach. By concentrating on the "learning" part, companies may conceive RM as a contributor to their performance along their learning and growth perspective rather than a standalone process carried out to predict what may go wrong in a project. Thus, it is believed that focus on "learning from risks" may enhance the RM process and a corporate risk memory may facilitate organisational learning.

As defined in the current literature, risk repositories are mainly about statistical data regarding the project outcomes (cost, time etc.) under different situations (where different risks actually happened). The circumstances under which the outcomes were achieved are not usually recorded, thus, the interrelations between risk factors and project outcomes can hardly be understood. This creates a major problem while assessing the magnitude of risk in the forthcoming projects. Moreover, information about the intangible risk factors (such as political risk etc.) can hardly be included within the repositories. In this paper, it is argued that information about both tangible and intangible risk factors should be incorporated into the corporate memory. Furthermore, as well as the risk outcomes and sources, the link between them should also be defined in order to assess "project vulnerability". A system's vulnerability represents the extent or the capacity of system to respond or cope with a risk event [15]. Zhang [15] uses the term project vulnerability to open up the link between risk events and consequences. He argues that the probabilistic relationships between risk events and consequences do not completely describe project risks as they fail to capture the influence from "project systems". The actual consequences of risk events depend on an organisation's capability to manage risks, thus, the company factors as well as the project characteristics that affect project vulnerability should be taken into account [15]. So, "learning from risks" should include "lessons learned about project vulnerability".

Identification of critical knowledge and its utilisation is a challenge for any project organisation [16]. There are two basic strategies for managing knowledge: codification strategy and personalisation strategy. The first strategy is about codifying the knowledge and storing it in databases. Personalisation strategy incorporates sharing knowledge by personal interaction. Stein and Zwass [17] define organizational learning as the mean by which knowledge from past is brought to bear on present activities. In project-based industries like construction, continuity in knowledge transfer from project level to enterprise level is required for an efficient organizational learning. Experiences are bound to people, often not a part of a project's documentation and seldom transferred to other people during the course of the project. Experiences can only be accessible through informal networks [18]. Procedures and tools that systematically manage project knowledge and meta-knowledge are needed to decrease the risk of project amnesia [16].

3. Knowledge transfer using lessons learned databases:

Newell et al. [19] argue that the common strategy for knowledge transfer between projects is to capture "lessons learned". Post-project appraisal and project review practices are widely utilised by the companies to collect, store and share the lessons learned in a project, however the level of satisfaction from these practices is rather low [19-20]. The barriers to knowledge transfer between the projects by means of post-project appraisal are:

1. Time and budget restrictions: Lack of enough employee time to document the lessons learned creates a major hindrance for cross-project learning [20-22].

2. Organizational culture: Organisational culture may be a major barrier or enabler of learning from projects. The blame culture [22] , avoidance of employees to admit mistakes [21] , immaturity of project management systems, lack of management support, lack of incentives [22] and inappropriate organizational politics [23] can create barriers for learning.

3. Project-based nature: Williams [22] mentions about issues within projects that inhibit learning such as temporary nature of project organisations and complexity of projects. However, this does not mean that all projects are

completely different. While the particular focus of each project may be unique, processes across projects are likely to share much in common [19]. Cooper et al. [24] argue that this misguided belief inhibits learning rather than the nature of projects.

4. The type of knowledge: The basic criticism of lessons learned databases originates from the two differing views about knowledge transfer. The dominant view of knowledge [25] sees it as a resource that is possessed and thus, it can be transferred between projects and groups via knowledge repositories [19]. The assumption of this perspective is that tacit knowledge can be converted into explicit knowledge. According to the other perspective [26], knowledge is embedded in social and organisational practices and relationships, which can not be converted into explicit knowledge. This view suggests a network approach and dialogue for knowledge transfer. Tsoukas [27] mentions that two perspectives are mutually compatible rather than exclusive [19]. Some knowledge can be possessed independently of practice making knowledge transfer by lessons learned databases possible, whereas other knowledge type is situated in practices making social networks the only choice for knowledge exchange. The contribution of lessons learned databases to a company's success depends on the nature of knowledge generated at the project level and possibility to define the lessons learned explicitly.

   Apart from the explicit-tacit nature of knowledge generated during project execution, according to Newell et al. [19], the failure of lessons learned databases can be attributed to the type of knowledge captured in the databases.

They argue that the knowledge about "what was done" is stored in databases rather than the reasons "why" and "how". For lesson learned databases become successful, knowledge beyond the confines of the project that could improve the performance of forthcoming projects should be captured and documented. The same issue is also stressed by Williams [22]. He proposes that generic lessons should be incorporated into lessons learned databases (facilitating isomorphic learning) as well as systemic reasons for project outcomes rather than obvious and simple facts about the project. Thus, one of the major reasons of failure of knowledge transfer in companies is that knowledge captured is not useful and can not be transferred to forthcoming projects which may be eliminated by designing learning systems that have the appropriate knowledge content.

As a result, the requirement for lessons learned systems vary with the type of knowledge generated at the project level (depending on the nature of projects), the organisational culture, maturity of project management systems, incentives, resources and guidelines provided to employees (depending on the strategic importance of cross-project learning for the company). Williams [22] denotes that there is no "one size fits all" for lessons learned databases as well as the process of project review process.

The aim in this paper is not to propose a post-project appraisal tool that can be used in every company but to propose a structured process to support learning-based risk management. The critical question is "Can knowledge be generalized, so that cross-project learning is possible?" We argue that the risk events that actually happened in construction projects may give an idea about what is likely to occur in similar projects. Using a generic list of potential sources of risk may help risk identification, but it can provide limited information about possible risk events in a project. For example, during the risk assessment process at the start of a project, if there is political instability in a country, a decision maker may predict that the government may change and this may lead to some problems. An actual risk event such as "bureaucratic delays due to change in government" provides the decision-maker with an idea about the potential problems that may emerge if there is political instability in a country. Similarly, by investigating the frequency of risk events in previous projects, the probability of occurrence in the forthcoming projects can be estimated. However, the generalisation of probability and impact is not possible due to "vulnerability". For instance, the managerial complexity of a project is more likely to have a higher impact on performance if the project management team has little previous experience on managing similar projects. Likewise, existence of an escalation clause may minimise the impact of foreign exchange risk on profitability. In this work, contract conditions, response strategies and management capability are identified as sources of vulnerability. Drawing a complete picture of a risk event considering sources of vulnerability may enhance the knowledge transfer between projects and may even lead to risk reduction if vulnerability is minimised in the forthcoming projects. As a conclusion, it is believed that although risk events may be specific to a project, similar sources of risk and vulnerability exist in all projects. Information about "what actually happened (risk events)", "reasons of a risk event (risk sources)" and "how the risks are managed (response strategy)" can be transferred between projects as there are usually generic risk paths (source-event-vulnerability-consequence chain) applicable to all project circumstances.

As a conclusion, it is argued that lessons learned databases that include risk related information may facilitate knowledge transfer between projects and help an enterprise to develop its risk management competency.

4. Development of a Tool for Learning Based RM:

4.1 Fundamentals of the tool

Within the context of this research, a tool, mainly a database system, is developed to facilitate learning from risks in construction companies. As a part of Integrated Definition Methods, function modelling method (IDEF0) is chosen for information modelling phase. Microsoft (MS) Access is used to develop a relational database that forms the basis of the corporate risk repository. The process model, depicted in Figure 1, embraces the risk management activities at different stages of a project. First step of the process is identification of risk items at the pre-project stage. This stage is accomplished by defining the uncertainties regarding mainly the external conditions (financial, political etc.) and vagueness about factors such as client objectives, contract clauses and project requirements. A risk breakdown structure is proposed to be used to systemize this process. Risk assessment is the second stage where quantification of risk items by means of probability and impact estimation is carried out. Probability and impact of each risk factor is determined by using expert judgment and risk repositories that contain risk related information about previous projects. The company factors (vulnerability issues) that may affect manageability of risks are taken into account so that realistic estimates can be made about risk magnitudes. The third stage in the model, risk handling phase, allows the definition of response strategies for the identified risk factors. Also, secondary risks are determined at this phase. Appropriate response actions can be chosen from an action catalogue. At the end of this phase, risk magnitudes are revised and an action plan to be implemented throughout the project is prepared. Monitoring phase is mainly about data capturing about risk events that actually happened during the project. Effectiveness of risk response plans are logged along with actual risk event data periodically. Handling risk during the project is about execution of action plans and recording the final consequences of risk events. There is a cyclic relationship between monitoring and handling processes. The process model suggests a final process to evaluate the final risk impacts at the post-project stage. The main idea of this process is to build risk event histories in the form of micro-articles. The actual impact values associated with the risk events are recorded and categorized according to their sources as defined in the risk breakdown structure. The risk impact values stored in risk catalogues are revised, new risk factors are added or some of them are eliminated considering the lessons learned throughout the project. During the post-project appraisal phase, sources of project vulnerability are also evaluated.

[Figure 1]

The use case diagram given in Figure 2 is a set of scenarios describing the typical interactions between a user and a system. It includes four human actors: risk manager, risk assessor, risk handler and risk supervisor. Risk manager starts the RM process by defining project activities and task groups. Regarding the type of project and requirements, risk manager may use different project planning software available in the market. Risk breakdown structure has a coding system to organize risks according to the identified work packages. Risk breakdown structure is the basis of the risk catalogue in which all verified risk information is kept. Risk catalogue is a list of all possible risk items (can be in the form a small database or spread sheet) categorized according to their sources. Risk manager inherits the identified risk factors to risk assessment expert for quantification. Risk assessor uses the company database for estimating the levels of probability and impact and takes into account of information such as complexity of the project and resources of the company during risk assessment. Company's strategic objectives and risk attitude also play an important role on quantification of risk ratings. All intangible and tangible information collected by the risk assessor is entered into risk rating tables. A risk rating table is a list of all risk factors together with their probability and impact values. The risk assessor provides the risk handler with the risk ratings associated with work packages where the responsibility of the risk handler is defined as the determination of an action plan using the action catalogue. Action catalogue includes possible response actions that can be used to mitigate or eliminate risks in a project. In case secondary risks are defined as a result of formulated strategies, risk handler and risk assessor work in coordination to minimize the overall risk rating of the project and decide on the final risk-response structure. Risk supervisor records the risk events happened throughout the project by preparing risk registers. Changes in risk levels (actual risk impacts) from the initially defined values are monitored by the risk supervisor and revising the risk ratings is under his responsibility throughout the project. The use case diagram also demonstrates the post project appraisal functions as a part of the system. After the formation of a risk event database, risk manager decides on the final (revised) impact values. Risk management team collaborates to discuss about final magnitude of risks happened during the project and revises the risk rating tables for further use, if necessary. Software tools demonstrated in this diagram simply represent the digital repositories and software to enable risk actors to access, use and record risk related information throughout the whole life cycle of the project.

[Figure 2]

After defining the main RM functions and digital repositories to assist these processes, the identified data classes and their physical relations are represented by a class diagram as shown in Figure 3. The class diagram for the proposed risk management system identifies the main data groups, relations and their attributes prior to implementation to the relational database software.

[Figure 3]

4.2 Features and Benefits of the Tool

The features and expected benefits of the tool can be summarised as follows:

1. Systematic risk identification and classification: The need for a common understanding of risk sources prior to the start of a project has been highlighted by many researchers [28]. A predefined list of common risk sources may assist decision-makers in the risk identification process. A hierarchical risk breakdown structure (HRBS) and a coding system may help development of a common language about risks and easy retrieval of similar risk sources when needed. In this study, a template HRBS is prepared considering three levels: risk type, risk category and risk source. The structure of the HRBS and some examples regarding the risk sources are depicted in Table 1. In total, there are 73 risk sources identified within the proposed HRBS. Whenever a risk factor is identified by the user, it is assigned a HRBS code and placed under the appropriate category.

[Table 1]

2. Storing risk-related information: As discussed in the previous paragraphs, risk events that actually happened in a project constitute an important source of information that

can be used in forthcoming projects. However, an organisation's capability to manage risks is another important source of information. They are defined as "sources of project vulnerability" by [15] and "internally generated risks" by [29]. Internally generated risks are defined as the risks that have their origins within the project organisation or its host, arising from their rules, policies, processes, structures, actions, decisions, behaviours or cultures. In the current study, those factors are not identified as "risk sources" but factors about "vulnerability". The main argument is that, companies should store information about how the risks are managed, which factors affected the risk consequences and the success of the pre-defined action plans. The tool is designed so that risk sources, events, consequences and factors about project vulnerability are reported during post-project appraisal.

3. Guidance on different phases of RM: It is believed that RM should be a continuous activity throughout the project. Thus, the risks and related factors should be entered and assessed at each stage. In this study, three main phases are defined as pre-project, during project, post-project phases (Figure 1). The tool is designed so that risk information is entered at the start of a project and updated throughout the project. Updated information includes the magnitude of risks (using a 1-5 Likert scale or actual impact on time and cost, if available) and justification of revised ratings. Justification statement is expected to cover reasons why there are deviations from the initial risk ratings. The deviations (if they exist) usually depend on poor assessment of probability and impact of risk in the earlier stages of a project or poor assessment of level of project vulnerability. By this process, users can monitor the changes in risk magnitudes throughout the different stages of a project and make more informed guesses for the forthcoming projects. It should be pointed out that the aim of the tool is not to suggest a

quantitative model for risk analysis. Its aim is to provide a decision-maker with risk-related information regarding previous projects so that he can make more reliable assessments of probability and impact of risks in the forthcoming projects.

4. Automatic report generation: The tool has some reporting options. Documentation of risk-related information increases the awareness of people on relative magnitude of different risk sources and relative importance of factors that affect consequences. Thus, it may provide an effective platform where the risk information can be shared and discussed among users. It can also automatically generate post-project risk event histories which can directly be inserted in post-project appraisal reports. Risk event histories shall contain some information about changes in project success criteria (such as duration and cost) due to a risk event, revised ratings and information regarding the vulnerability of the project due to pre-defined response strategies, contract conditions and managerial capability of the company.

5. Application to a Real Project:

The prototype tool is tested on a real construction project which was carried out by an international contractor doing business in Turkey. The contractor is a European company which is one of the leading providers of construction services in Central and Eastern Europe. It employs over 45,000 people at more than 500 locations and attains a building performance of more than 10 billion Euros. The case study project is their first job in Turkey. The sample project is an energy project that has been executed in the north-east region of Turkey. Project has been financed and delivered according to a private agreement between two governments including another hydro-electrical power plant (HEPP) on the upstream side of the sample project. Project consists of civil works, mechanical and electrical instrumentation works with installed capacities of 300 MW and 115 MW. Civil works are executed by an international consortium between Turkish and European companies. At the time of testing the tool, the project was about to finish, thus the case study does not cover the risk management process during the whole life of the project. The project manager used the tool mainly for post-project risk evaluation and generation of a post-project appraisal report. Consequently, only the effectiveness of the tool for post-project risk evaluation could be tested.

Table 2 shows a list of risk items prepared for the case study project. Using the hierarchical risk breakdown structure (HRBS), a total of 17 risk factors were identified at the start of the project. For each risk factor, the owner of the risk and as-planned response strategy were also specified.

[Table 2]

Figure 4 presents a snapshot about assessment process and revised risk ratings in the case study project. For example, although “late delivery of site” was not considered to be a significant risk factor, it finally had a considerable impact on the project cost. Although the contractor accelerated the job, due to the fact that most of the critical activities (such as construction of cut-off wall etc.) are postponed to the high flood season, to eliminate flood risk, some other changes had to be made (such as the height of the cut-off wall had to be increased etc.) resulting in extra costs and delays as well as the cost of acceleration. It became a claim issue between the client and contractor as rules of cost compensation due to acceleration of works were not clearly defined in the contract.

[Figure 4]

Table 3 shows a part of the post-project risk event history prepared by the project manager. The risk events are specified and their final impacts are recorded. This information is stored under the risk sources having specific RBS codes, which can be retrieved for the forthcoming projects. Apart from the risks, it is clear that the impact of risk events significantly depend on factors about vulnerability. It is clear from Table 3 that errors as well as vague conditions in the contract and lack of experience of the company about local practices magnified the impact of risk factors.

[Table 3]

The project manager was satisfied with the tool as it is easy to use and helps documentation of risk-related information which would otherwise be lost. The tool provides a guide for the user about how risks can be managed throughout a project. He mentioned that the tool can be especially used for storing and updating information regarding country related risk sources. Lessons learned about country risks can be used while preparing risk management plans in forthcoming projects. He also stressed that it was a good exercise to compare the pre-project and post-project risk ratings. The major difficulties faced by the user were assigning risk ratings which are highly subjective and entering exact cost and time figures which were hard to quantify because risk events were highly interrelated. He mentioned that another bottleneck of the tool may be people's unwillingness to talk about problems faced in a project, especially wrong strategies and managerial decisions. Thus, assessment of vulnerability can be a difficult task. Another difficulty in creating risk event histories may be the lack of commitment of project management team as companies are not eager to dig deep on the loss of a past project rather than looking forward to new opportunities in the market.

5. Conclusions

Within this research, a learning based approach is proposed for risk management. Learning from actually happened risk events can be facilitated by a risk memory in which risk-related information is stored and updated throughout a project's life cycle. Based on risk information regarding the previous projects, decision-makers may give more reliable decisions about forthcoming projects. Rather than a quantitative approach for risk modelling, the intangible risk information may be used to develop informed scenarios about the future. A change is necessary in RM philosophy from "management of adverse effects" to "learning from risks to eliminate risks at the first place". Focus on learning may shift expectations towards assessment of total impacts (risk sources together with vulnerability factors), better response planning and monitoring rather than prediction and quantitative assessment.

In this paper, in order to demonstrate how learning from risks can be facilitated in practice, a tool developed for construction of a lessons learned database and life cycle risk management process is presented. MS Access is used to develop a relational database that can be used to define, assess, monitor, store and document four types of risk related information: sources, events, consequences and vulnerability. It is believed that factors related with project vulnerability, which are the response strategies, contract conditions, management and project-related factors should be defined and stored because the link between a source and consequence is mainly determined by these factors. As those factors are basically about company factors, this kind of risk information has the highest potential to affect future decisions. Lessons learned with respect to those rather controllable factors may result in better management of risks in the forthcoming projects. The HRBS embedded in the tool, codification system, the reporting options, risk updating procedure that is carried out throughout the project and post-project risk event histories are among the strengths of the developed tool, which are believed to increase the ability of "learning from risks" in an organization.

The tool is tested on a real construction project. As the project was at its final stage, case study findings can only demonstrate its performance at the post-project appraisal stage. However, the expert who acted as the project manager of the case study commented on the applicability of the tool during the project. Findings show that it can be used for storing as well as updating risk related information and finally, post-project appraisal at the end of a project. However, subjectivity of the ratings and cultural impediments about storing knowledge on failures (mainly, wrong decisions etc.) may decrease its usability and reliability. In order to minimize subjectivity, the risk ratings may be given by the project management team members separately, it can be checked whether significant differences exit between the scores or not, and final scores can be decided by brainstorming and consensus.

The quality of decision support provided by the tool can only be as good as the risk data entered by the users. Moreover, it is clear that the major benefit of the tool is not quantification of risks. As most of the risk-related information is intangible and details are entered into the tool by writing explanatory notes and essays, their usage in the forthcoming projects for mathematical formulation of risk models is limited. However, post-project risk event histories have a potential to provide the decision-maker with a rough idea about what can go wrong in a project, what their global impacts would be and which factors may affect risk consequences. It is believed that the performance of the tool can be increased by addition of a "search" option where similar projects carried out in the past can be retrieved when new project information is entered into the tool. Similarity can be defined according to the attributes such as type of work, country etc. and post-project risk event histories may help decision-makers to give more informed decisions in similar projects. Case study findings also reveal that in construction projects, one of the major sources of risk is contract conditions. A module about standard forms of contact (for example FIDIC, which is widely used in international projects) may be added to the tool so that users may directly refer to already defined contract clauses rather than entering the standard clauses separately for each project. The tool can also be customized according to specific company needs. For a company specialized in a certain type of project (such as housing, industrial plants etc.), risk events commonly seen in those projects can be inserted into the tool as well as specific response strategies. The tool should be tested on a number of cases and preferably throughout the whole life of a project before it can claimed to be a reliable tool for continuous risk management. Nonetheless, the tool is believed to be a good example that demonstrates how a learning based approach for risk management can be implemented in practice.

Acknowledgement

The authors would like to thank British Council for their financial support under the Science Partnership Programme.

References

[1] Hayes, R.W, Perry, J.G, Thompson, P.A. and Willmer, G., Risk management in engineering construction, Thomas Telford Ltd, London, 1986.

[2] Flanagan, R. and Norman, G., Risk management and construction, Blackwell Scientific Publications, Oxford, 1993.

[3] Raftery, J., Risk analysis in project management, E&EN Spon, London, 1994.

[4] Edwards, L., Practical risk management in the construction industry, Thomas Telford Publications, London, 1995.

[5] Chapman, C. and Ward, S., Project risk management: processes, techniques, and insights, Wiley, Chichester, 1997.

[6] Jaafari, A., Management of risks, uncertainties and opportunities on projects: time for a fundamental shift, International Journal of Project Management, 19 (2001) 89-101.

[7] Hertz, D.B. and Thomas, H., Risk analysis and its application, John Wiley & Sons, Chicehster, 1983.

[8] Carter, B., Hancock, T., Morin, J. and Robin, N., Introducing RISKMAN: The European Project Risk Management Methodology, NCC Blackwell Limited, UK, 1994.

[9] Chapman, C., Project risk analysis and management: PRAM the generic process, International Journal of Project Management, 15 (5) (1997) 273-281.

[10] Institution of Civil Engineers, RAMP: Risk Analysis and Management for Projects, Thomas Telford, London, 1998.

[11] PMBoK, A Guide to Project Management Body of Knowledge, Project Management Institute, New Square, PA, USA, 2000.

[12] Green, S.D., Towards an integrated script for risk and value management, Project Management, 7 (1) (2001) 52-58.

[13] Dikmen, I., Birgonul, M.T., Tah, J.H.M. and Aouad, G., A learning based approach for risk management, International Symposium towards the Formation of Theory for the Built Environment, edited by Lauri Koskela and Phil Roberts, Salford, UK, 2007, pp. 21-36.

[14] Atkinson, R., Crawford, L. and Ward, S., Fundamental uncertainties in projects and the scope of project management, International Journal of Project Management, 24 (2006) 687-698.

[15] Zhang, H., A redefinition of the project risk process: Using vulnerability to open up the event-consequence link, International Journal of Project Management, (2007) doi:10.1016/j.ijproman.2007.02.004.

[16] Kasvi, J.J.J., Vartiainen, M. and Hailikari, M., Managing knowledge and knowledge competences in projects and project organizations, International Journal of Project Management, 21 (2003) 571-582.

[17] Stein, E.W. and Zwass, V., Actualizing organizational memory with information systems, Information Systems Research, 6 (2) (1995) 85-117.

[18] Schindler, M. and Eppler, M.J., Harvesting project knowledge: a review of project learning methods and success factors, International Journal of Project Management, 21 (3) (2003) 219-228.

[19] Newell, S., Bresnen, M., Edelman, L., Scarbrough, H. and Swan, J., Sharing knowledge across projects-Limits to ICT-led project review practices, Management Learning, 37(2) (2006) 167-185.

[20] Keegan, A. and Turner, J. R., Quantity versus quality in project-based learning practices, Management Learning, 32 (2001) 77-98.

[21] Disterer, G., Management of project knowledge and experiences, Journal of Knowledge Management, 6(5) (2002) 512-520.

[22] Williams, T., How do organizations learn lessons from projects – And do they?, IEEE Transactions on Engineering Management, (2007) (forthcoming)

[23] Bourne, L. and Walker, D.H.T., Advancing project management in learning organizations, The Learning Organization, 11(3) (2004) 226-243.

[24] Cooper, K.G., Lyneis, J.M. and Bryant, B. J., Learning to learn, from past to future, International Journal of Project Management, 20 (2002) 213-219.

[25] Nonaka, I. and Takeuchi, H., The Knowledge-Creating Company: How Japanese Companies Create the Dynamics of Innovation, Oxford University Press, Oxford, 1995.

[26] Blackler, F., Knowledge, knowledge work and organizations: An overview and interpretation, Organisation Studies, 16(6) (1995) 1201-1241.

[27] Tsoukas, H., The firm as a distributed knowledge system: A constructionist approach, Strategic Management Journal, 17 (1996) 11-25.

[28] Tah, J. H.M. and Carr, V., Information modelling for a construction risk management system, Engineering, Construction and Architectural Management Journal, 7(2) (2000) 107-119.

[29] Barber, R.B., Understanding internally generated risks in projects, International Journal of Project Management, 23 (8) (2005) 584-590.

Fig. 1. Process model

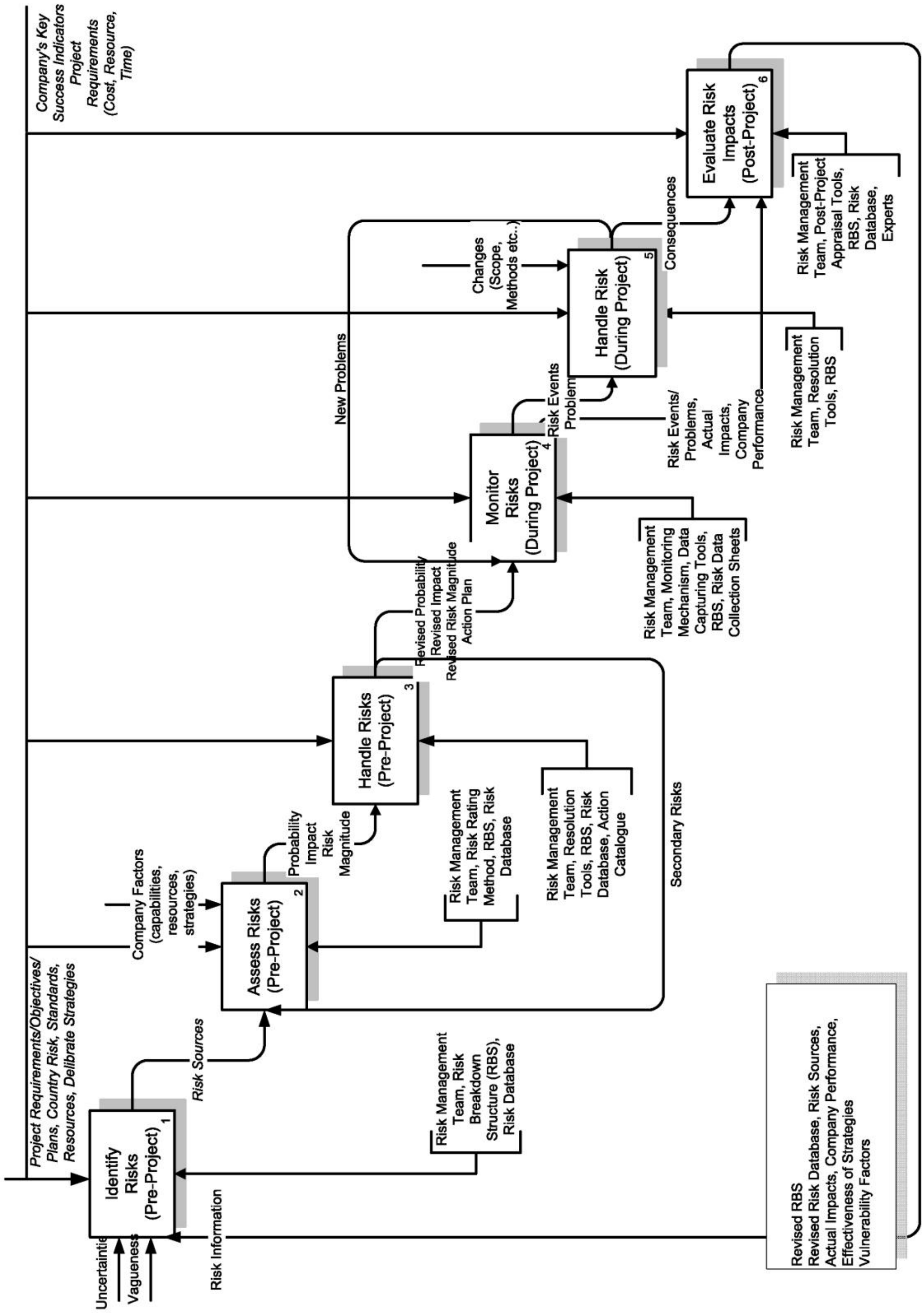

Fig. 2. Use case diagram

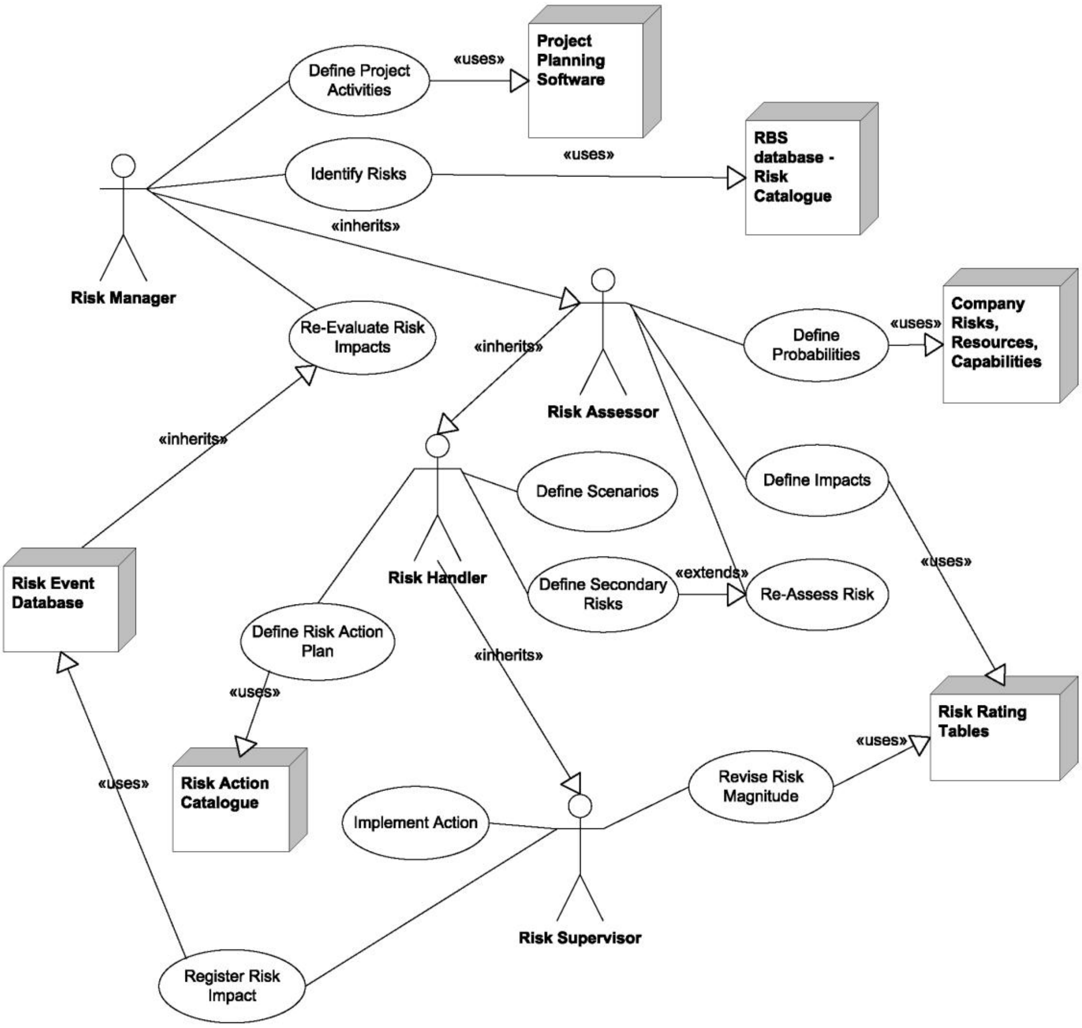

Fig. 3. Class Diagram

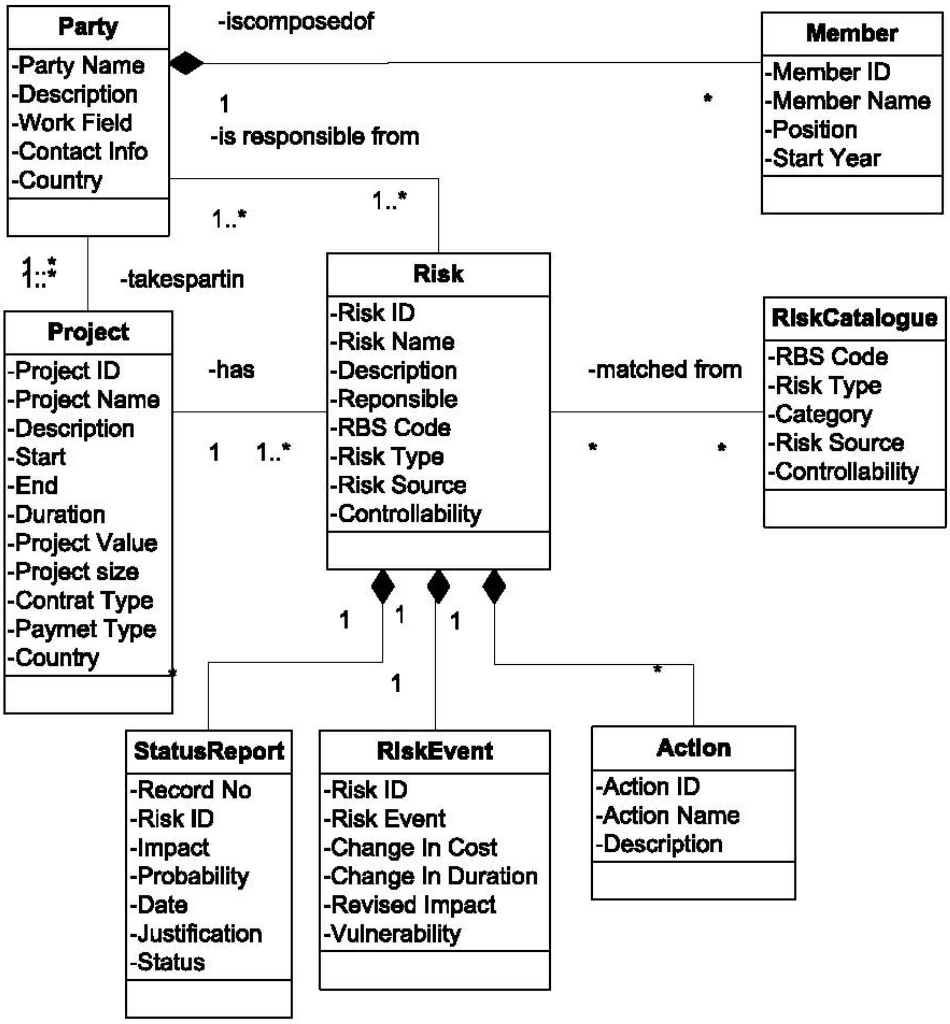

Fig.4. Updating risk-related information

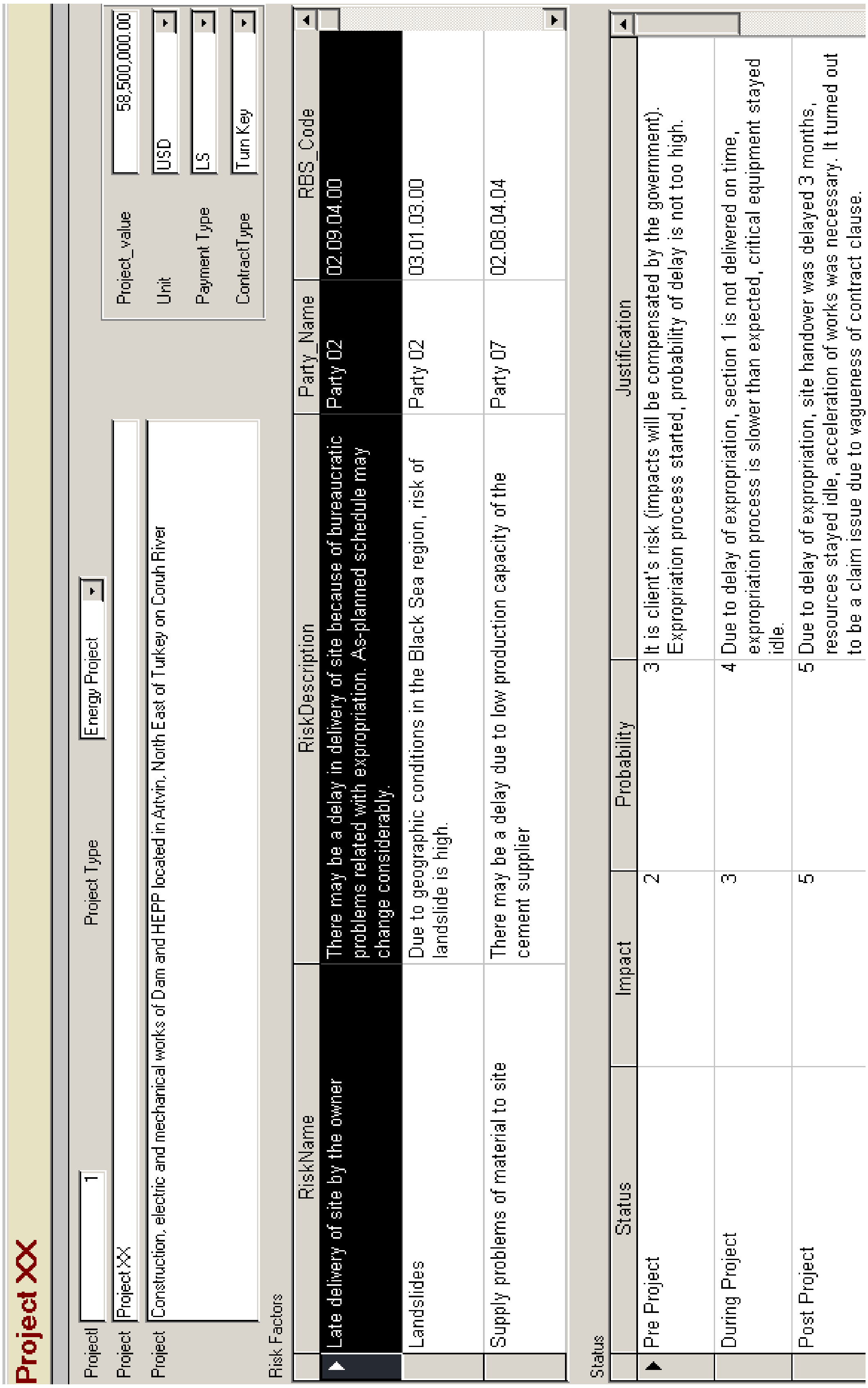

Table 1. The structure of the HRBS

Risk Type	Risk Category	An example of a risk source defined under each category
Country	Economic	Changes in currency rates
	Legal	Changes in regulatory framework
	Political	Change in government
	Socio-cultural	Religious differences between the home and host countries
Project	Construction	Unproven technology/ construction method
	Contract	Vagueness of standards/ specifications
	Design	Design errors
	Finance	Inadequate budget
	Management	Change in staff
	Owner	Change orders
	Parties	Poor performance of JV partner
	Resources	Unavailability of labour
	Site	Poor accessibility
External	Force majeure	Natural disasters-earthquake
	Environmental	Weather conditions

Table 2. Risks factors identified at the start of the project

RBS Code	Risk Type	Category	Source	Risk Factor
01.01.01.00	Country	Economic	Change in exchange rates	Unexpected changes in exchange rates due to economic instability in Turkey
01.05.01.00	Country	Socio-cultural	Differences between host and home country	Differences in religion, language and culture between the foreign company members and local workers
02.09.04.00	Project	Owner	Bureaucratic delay	Late delivery of construction site by the owner due to late expropriation
02.09.06.00	Project	Owner	Delay in payments	Delays in progress payments
02.09.05.00	Project	Owner	Change orders	Additional works may cause problems as the payment type is lump-sum.
02.08.04.04	Project	Resources	Unavailability of materials	Unavailability of high quality cement in the nearby factories
02.08.03.03	Project	Resources	Productivity of equipment	The breakdown/poor productivity of critical equipment
02.02.01.00	Project	Contract	Vagueness of contract clauses	The allocation of risks between JV partners regarding the milestones in the schedule and compensation principles are not clearly defined.
02.02.01.00	Project	Contract	Vagueness of contract clauses	Rules for the payment of Value Added Tax (VAT) are not clearly defined.
02.02.01.00	Project	Contract	Vagueness of contract clauses	Differences between the Turkish and English versions of the contract.
02.05.04.00	Project	Management	Change in staff	Change in top management
02.05.07.00	Project	Management	Management of claims	Poor performance in claim management activities due to lack of experienced staff
02.07.04.00	Project	Parties	Poor relations	Poor communication between JV partners
03.02.01.00	External	Environmental	Geological conditions	Insufficient geological surveys (unforeseen geological conditions)
03.02.02.00	External	Environmental	Weather conditions	Adverse weather conditions
03.01.01.00	External	Force majeure	Earthquake	Medium level of earthquake risk
03.01.03.00	External	Force majeure	Landslide	Significant landslide risk due to the geographical location of the project

Table 3. Post-project risk event histories

RBS Code	Risk source	Risk Event	Cost impact ($)	Time impact (months)	Final impact (1-5 scale)	Vulnerability
02.09.04.00	Bureaucratic delay	Due to delay of expropriation, site handover was delayed.	1 000 000	3	5	Strategy used to minimise the risk of delay was acceleration. Although the project is finished on time, due to vagueness of contract about acceleration, cost compensation was not possible. It is a claim issue.
03.02.01.00	Geological conditions	After cut off wall was constructed, it was realised that a certain portion of the wall could not reach the bedrock. The wall had to be reconstructed to reach the original bedrock.	1 500 000	4	5	The cut off wall machine was sent to the home country as soon as the cut off wall construction was over. When rework was required, it had to be brought back resulting in extra cost and delay. Client insists that the geological risk had to be foreseen by the contractor. It turned out to be a claim issue.
02.02.01.00	Vagueness of contract clauses	The price difference due to change in exchange rates and construction price indices could not be claimed because the escalation formula in the contract was vague.	1 000 000	No impact on time	4	The escalation formula had two parts. The second part of the escalation formula gave a negative value for a specific period of time. It is clearly stated in the contract that the minimum value for the first part should be taken as zero, if it is negative. But a similar condition for the second part was not specified. Client made deductions rather than escalation. This is a claim issue.
02.09.05.00	Change orders	As a result of client's change orders, the quantities increased but the payments regarding the increased quantities were done using unit prices of the government, not based on the lump sum amount.	500 000	No impact on time	4	The interpretation of lump-sum contract in the Turkish practice is different than the general practice. If the quantities are less the reservation amounts, the deductions are made based on the lump-sum prices, if they increase, additional part is paid using unit prices of the government. The unit prices were significantly lower than the lump-sum prices.