ISBN: 9789052693958

TRACING RISK PATHS IN INTERNATIONAL CONSTRUCTION PROJECTS: A CASE STUDY

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Abstract

International construction projects are mostly known with poor cost performance. Their large sizes, multi-party environments, along with unfamiliarity of foreign firms with host country conditions create high chances of cost overrun and delay which lead to disagreements, claims and failures. Factors that result in cost overrun usually occur in the form of a chain of causally dependent events, each of which are either under the responsibility of one party, or shared among different project participants according to the related contract clauses. The diversity of the factors, namely global, country, company and project specific factors, increases the complexity of negotiation process between the project participants when cost overrun and delays occur in international projects. The major idea in this research is that cost overrun depends on causal relations between various risk sources (namely, risk paths) and sources of vulnerability that interfere with these paths. Using the data of 166 international construction projects and utilizing Structural Equation Modeling (SEM), a Risk-Path Model that represents the interactions among different risk and vulnerability paths is identified. In this paper, through a comprehensive case study, the complex risk emergence pattern in a real construction project is demonstrated.

Keywords: vulnerability, risk assessment, structural equation modeling.

INTRODUCTION

International construction projects are mostly known with poor cost performance [6, 7, 15]. Sources of cost overrun occur in the form of a chain of causally dependent events, each of which are either under the responsibility of one of the project parties, or shared among the parties based according to the related contract clauses. The diversity of these factors, namely global, country, company and project specific factors, is the other fact increasing the complexities of cost overrun negotiations, analysis, and estimations in international projects [13, 15, and 21]. Prediction of possible cost overruns and the influencing events, and formulating adequate mitigation and preventive strategies necessitate a comprehensive, proactive and systematic risk management process in international construction projects [4, 13, and 21]. Risk modelling is a critical step of risk management, however, as Han et al. [13] state, traditional methods are not adequate for modelling of diverse risks and complex interactions among risks in overseas projects. Cost-influencing risks should be identified in a way that is compatible to their emergence pattern in real construction projects, instead of being studied as independent factors. The major idea in this research is that risk factors occur in the form of *interactive risk paths*, and that early identification, and documentation of such interactive causalities may enhance the accuracy of early estimates, and decrease the conflicts during negotiations over the occurred overruns. In this paper, utilizing Structural Equation Modeling (SEM), a Risk-Path Model that represents the interactions among different risk and vulnerability factors is presented and a detailed case study is discussed to demonstrate how the proposed model can be used to identify risk paths in international construction projects.

BACKGROUND AND LITERATURE REVIEW

Interrelations among risk factors

Various checklists, taxonomies and databases are developed to facilitate identification of factors affecting cost performance of construction projects. However, since cost overruns are affected by a combination of interdependent risk factors rather than sole effects of independent risks [9, 13, and 14], examining the interactions among different risk factors is necessary in real construction projects. Interactions among different risk factors and how these factors lead to cost overrun have widely discussed in literature. For example, Burati et al. [5] argued that adverse changes during design and construction phases are the main causes for further reworks which will finally lead to considerable cost overruns. Design changes are considered as the sources of cost overrun by other researchers like Sempel et al. [17]. Factors like design errors, increase in the scope of the work, and adverse weather conditions are also mentioned as main sources of cost overrun, which by itself is identified to be one of the major sources of claims. Investigating the causes of cost deviations in construction projects, Akinci and Fischer [1] have examined a number of possible causalities. For example, increase in the scope of the project is claimed to affect project cost overrun through increase in unit cost of work. Also, the ambiguities associated with project scope and client objectives are stated to lead to scope changes which are one of the main causes of cost overrun. Moreover, vague contract clauses are claimed to result in some disputes one of the outcomes of which will be cost escalations. Factors like, unknown geological conditions and bad weather conditions are considered as the main causes of changes in productivity and work quantity which will lead to delays and subsequent cost increases. As country specific factors, country economic conditions are stated to cause increases in unit cost rates that will lead to project cost overrun. In their cross-impact model, Han and Diekmann [12] have demonstrated a number of causalities affecting project cost performance. For example, low design quality is considered to lead to redesigns and subsequent scope increase and schedule deviations which will cause cost overruns. As country factors, political conditions are considered to affect government acts and regulations which may lead to variations in contract conditions and subsequent scope changes. Country economic conditions are assumed to affect the availability of the resources which will impact labour productivity and project cost performance. Country economic conditions are also considered to affect cost performance through inflations. Company related factors, such as managerial capabilities and resources, are considered to lead to delays and subsequent cost overruns. Makulsawatudom et al. [16] have studied the causes of low productivity as one of the reasons of time and cost overruns in construction projects. Factors such as lack of material, incomplete drawings, poor communication, inception delays, reworks, etc. are considered as the parameters directly affecting productivity. As a comparable study, Alinaitwe et al. [2] have identified lack of skills, reworks, poor construction methods, poor communications, inaccurate drawings, bad weather conditions, etc. as the major factors leading to decrease of productivity and subsequent time and cost overruns. Zou et al. [21] have considered factors such as design changes, disputes, price fluctuation of materials, and incomplete documents as the factors that directly affect cost overrun some of which will have also effects on time overruns and decrease in quality of work. According to Alnuaimi et al. [3], client related factors, lack of national information, lack of experiences and skills, and country related factors are those leading to occurrence of change orders which will cause plan revisions and additional works that will subsequently result in time and cost overruns and disruptions. Sun and Meng [18] have identified factors such as inadequate managerial skills and experiences, bad weather conditions, unknown geological conditions, change in availability of resources, change in material cost, etc. as the causes of changes in construction projects. They mentioned extra works, rework, time loss, design revisions, decrease in productivity, etc. as the effects of occurred changes.

Problem Determination

In order for a realistic and accurate identification of risk scenarios and prediction of probable cost deviations, all of the aforementioned interrelations should be taken into account simultaneously. However, it is highly difficult, if not impossible, to consider all these dispersed interrelations without a systematic approach and a comprehensive risk model. Few studies have emphasized the importance of inclusive risk models that incorporate possible interactions, and the counter-effects among influencing factors. Han and Diekmann [12] argued that the existing risk models and analysis methods are inadequate since they are not realistic reflections of complex nature of existing risks in international construction projects. They propose the utilization of Cross Impact Analysis (CIA) method as an appropriate technique for analyzing the conditional probabilities of occurrence of various interrelated risk variables affecting project cost under high uncertainties. The integrated risk management system developed by Han et al. [13] is one of the most noticeable efforts in this regard. The notion of *risk path* is mentioned in this research and a scenario-based checklist that includes various causalities among risks throughout different stages of the project was developed. The SEM-based prediction model developed by Kim et al. [14] should be mentioned as one of the most recent efforts in this regard. The prediction capability of the SEM model, which comprises of a network of interrelated factors affecting project cost performance, is compared with that of ordinary regression analysis and Neural Networks. SEM is identified to show higher prediction performance mainly due to the fact that it considers the interrelations and complexities of the real case.

RESEARCH METHODOLOGY

This study is part of a larger research project whose ultimate objective is to develop a Multi Agent System (MAS) for simulation of argumentation-based negotiations among project parties, and for generation of a risk-sharing platform for the occurred cost overrun. At initial steps of the research, in order to develop the conceptual framework of the research, a number of case studies were conducted and cognitive maps demonstrating the risk emergence pattern of these projects were drawn. Examining these cognitive maps, the Vulnerability-Risk framework of the research and the notion of *risk paths* were generated [8]. Risk and vulnerability factors were identified and documented in a Vulnerability-Risk ontology-based database using data related to 75 international construction projects conducted by Turkish contractors in foreign countries [11]. A cost estimator agent is currently under development by means of Case Based Reasoning (CBR). In order to generate an independent agent supporting negotiator agents' arguments, a risk model comprising of a network of interactive scenarios was developed using SEM [10] . In this model, a total number of 82 vulnerability and risk factors are included as the model's observed variables. Using special features of SEM, 28 latent factors are identified to be indicated by these observed variables. The final

SEM-based Risk-Path Model includes a total of 36 interactive risk-path scenarios each of which deriving from one of the vulnerability sources inherent in project environment. Data related to 166 international construction projects are used for development of this model. The cross-impacts among risk paths are all estimated in a way that all are mutually significant at 5% level, and the whole model fits the data adequately.

SEM-based Risk-Path Model mitigates the aforementioned shortcomings of current risk models in that it possess a comprehensive and lifecycle look to the risk emergence pattern of projects by incorporating vulnerabilities, risk sources, risk events and risk consequences. Moreover, apart from considering causal relations among diverse risk factors, it includes the complex interactions among diverse risk-path scenarios. In this paper, a case study project will be given to demonstrate application of the SEM-based Risk-Path Model.

CASE STUDY

Overview of the project

A Bulgarian based company has awarded a contract for replacement and reconstruction of part of its power station. The scope of the project is defined as construction of circulating fluidized bed (CFB) boiler for an industrial power plant in Bulgaria. In 2006, as one of the subcontractors of this project, a Turkish company was engaged by the major contractor under four separate contracts. The first contract is the "Purchase Contract for the Delivery of Equipment and Steel Structure Fabrication and Delivery to the Site". This contract included manufacturing and delivery of steel structures, structural and miscellaneous steel, for Boiler Building, Silo Building, and for Crusher Building. The second contract is the "Subcontract for the Delivery of Erection works for Boiler Steel Structure". This contract included erection of steel structures, structural and miscellaneous steel, for Boiler Building, Silo Building, and for Crusher Building. The third contract is the "Subcontract for the Delivery of Boiler Erection". This contract included the erection of the boiler mechanical equipments/ components in accordance with the provided technical description. And finally, the fourth contract is an umbrella agreement entered into, in order to coordinate the three aforementioned contracts which are linked to each other. The total contract amount comprising of three initial contracts has been estimated about 7.5 million euro. The payment type of all contracts was lump sum. The works contracted to the Turkish company mainly included the fabrication of structural steel at a factory located at Turkey, followed by the delivery of fabricated material to the project site, and finally, erection of the boiler steel structure and the boiler itself.

In order to examine the initial vulnerabilities of the project, the problems and risks faced, and the occurred risk scenarios throughout the lifecycle of the project, one of the managers directly involved in all phases of the project, and in all of the claim preparation stages, was interviewed in separate sections.

Overview of the company

The firm under study is a Turkish company specialized in giving services in construction and steel structure fabrication. Since its establishment, the company have conducted diverse construction projects like power plants, refineries and petrochemical plants and civil works for both Turkish and international clients. In terms of fabrication, different products, ranging from heavy steel structures to many kinds of equipments, are being fabricated at the Steel Construction and Machinery Factory owned by the company.

The project that is going to be studied in this paper is the first experience of the company in Bulgaria. Although the technological complexity and the size of the project can be considered to be relatively low when compared with other projects conducted by the company in both domestic and overseas markets, the company faced lots of cost and time overruns, and numerous disagreements occurred among project parties. This project is used for examining the emergence pattern of risks that may affect performance of international construction projects.

Vulnerabilities of the project

Vulnerability sources representing the capacities, capabilities and characteristics of each project's environment are believed to trigger the occurrence of future risk scenarios. The vulnerability sources identified in previous stages of this research [8] and included in a Risk-Path Model [10] are examined for this project.

Design Problems:

This factor is mentioned as one of the most important and effective vulnerability sources of the project. The structural design of various elements of the project was contracted to another company located in a third country. The designer company, the manufacturing unit, and the erection team had to work in a highly coordinated manner since the design was not complete when the fabrication of the elements and the erection of the structures started. The drawings issued by the designer were to be sent to fabrications unit according to a predefined schedule. Then, the manufactured elements were to be sent to construction site in Bulgaria for montage and erection of the structure in accordance to the planned schedule. However, due to the lack of skills and experiences of the designer company in similar projects, and because of high levels of details and different types included, vast amounts of delays occurred in submissions of the drawings. These delays affected the planned schedules of both the manufacturing and the construction works. Due to the specific physical condition of the site (will be discussed in detail in subsequent sections of the paper), most of the activities have to be done in a finish-to-start pattern. That is, less parallel activities existed and most of the construction works had to be stopped in the case of significant delays in delivery of elements and equipments. Incomplete designs, late drawing submissions, the significant time losses in construction process of the project (approximately 1 year in some parts), and the loss of construction productivity, were some of the major subjects of the further disputes.

Existence of lots of design errors was the factor that affected the performance of the project more than late submissions. The structural elements were mostly unique, possessing different dimensions, shapes and technical specifications. Therefore, the elements fabricated based on such incorrect drawings became useless for other parts of the structure most of the time. The sudden escalation of steel price caused the additional costs of such wastes to substantially increase. The Turkish company faced problems like significant cost increase, negative cash flows, several reworks, decrease in productivity, and lots of time loss. For example, each type of the steel beams had holes and welds in different places with different dimensions that errors in specifying them correctly led to some additional work items such as 1) Additional holes were added, 2) Holes were removed, 3) Welds were added, 4) Weld were removed, 5) Dimensions were changed, and 6) Details were added.

Design revisions, most of which were sudden and without early notice, is the other factor having led to reworks, productivity losses, decrease in work quality, and further cost overruns.

Adverse Site Conditions:

One of the other most important vulnerability factors mentioned by the company representative is physical boundaries and working conditions prevailing the construction site of the project. The erection area at the project site was surrounded from three of its sides with the existing buildings. The erection works had to be started from the back side of the boiler unit which was adjacent to the existing building and had to be carried out from backward to the front direction. Moreover, the access to the erection area was only possible from the front side due to buildings surrounding other sides. The limited access and dangerous position of the erection area eventually imposed certain technical priorities and restrictions related to the erection process. Such physical limitations made the construction process very sensitive to the sequence of the activities. For example, the erection of some portions of 4th floor could not be started before the lifting of coal gallery, otherwise the coal gallery could never be lifted to its final position since there was existing building adjacent to it, which had made the lifting process impossible. The other example for the tasks having been affected by adverse site condition was the placement of the elements like supports for the coal and limestone silos that had to be placed on the beams of the 2nd floor. In the case that the steel structure erection was carried out without the installation of these supports, these silos could not be placed due to access limitations to the back side of the area. The Turkish company was only responsible for the erection, and the material supply of such supports and silos was under the responsibility of another company located in a third country. The procurement and delivery of such materials faced significant delays due to unexpected harsh sea storm. This caused substantial time loss in construction process since the erection had to be stopped until the installation of the supports. Also, the access limitations of the erection site limited the lifting radius of the tower crane. This caused difficulties in subsequent phases of erection in lifting of some bigger or heavier elements. Therefore, a mobile crane was hired. This brought about additional costs and some time losses due to problems like unavailability of crane and certified local operator, and also erection time of the crane. It is claimed that, although the occurred delays in supply and delivery of the material by either supplier party or the manufacturing unit would have probably caused time losses in erection process even if there had not been any site constraints, the finish-to-start relations of the activities resulted from the backward erection of the elements, and from access limitations, have significantly intensified the idle times.

Country Related Conditions:

Newly joined to European Union, Bulgaria was subject to lots of sudden and substantial changes in its laws and regulations. The first one was the visa requirement. Acquisition of visa for Turkish workers became obligatory. This resulted in significant delays in the supply of manpower from Turkey. The lack of local skilled manpower and certified technicians in some areas intensified this problem. According to the company's representative, this fact affected the construction productivity and quality of the work. For example, the company faced difficulties in finding a skilled operator for the newly hired mobile crane. This led to some idle times of the crane, and to delays in erection process. Finally, in order to prevent further losses, the company employed some uncertified workers resulting in conflicts with health and safety inspectors. Other notified problem was high levels of bureaucracy, especially in custom procedures that caused significant delays in the procurement of materials and equipment which were mostly outsourced from other countries. Lack of local material and equipment were other notified country related vulnerabilities of the project.

Contractor Related Vulnerabilities:
Besides the drawing errors, revisions and supplier delays, lack of coordination and poor communication among the erection team and manufacturing unit were other factors that affected the manufacturing process, supply and delivery of the structural elements, and erection process. For example, there were elements having been sent to the site long before their prerequisite parts were fabricated. Lack of managerial skills of contractor is the other notified vulnerability. Poor planning was one of the most important vulnerability that apart from its effects on project time and cost performances, caused the company to face difficulties in gathering the necessary documents for supporting their arguments in raised claims. Poor quality management for both manufacturing and erection parts can be considered as the other managerial vulnerability of the contractor. For example, there were some unnoticed differences among some fabricated beams and their specifications in the design drawings. Such quality deviations led to reworks and time losses. The site organization and management team of the contractor changed frequently throughout the project. The company representative believes that this factor mostly affected the productivity of the erection team. Contractor’s lack of experience with client, and with the general conditions of the country is other contractor related vulnerabilities mentioned by the company representative.

Unexpected Events:
Harsh and extreme weather conditions are mentioned as the most important unexpected events in this project. Unpredictable and exceptionally high speed of the wind during July and August months forced contractor to stop erection with cranes due to health and safety issues. Also, the erection process of the top floors had to be stopped for several weeks since their construction was postponed to winter’s freezing months because of delays, especially due to the design related delays.

Client’s high level of bureaucracy, negative attitude, and technical, managerial and organizational incompetency are client related vulnerabilities, and strict quality, and strict health and safety requirements are the vulnerabilities of the project mentioned by the interviewee.

Application of the SEM-based Risk-Path model

The identified SEM-based Risk-Path Model [10] comprises of 36 interactive risk-path scenarios each deriving from one of the project vulnerabilities. Using the prediction capability of SEM models, the magnitudes of the future risk factors and the probable risk paths can be estimated by inserting the known severities of the vulnerability sources as the inputs of the model.

For the project studied in this paper, the most significant vulnerabilities are mentioned above. The interviewee is asked to rate the severity of these critical vulnerabilities, and the others included in the model, in a 5 Likert scale: Very Low (1), Low (2), Medium (3), High (4), and Very High (5).
Based on these values, and using the estimated path coefficients, the probable magnitudes of risk factors, and the level of project cost overrun are estimated. Figure 1 shows all the 36 interactive risk paths, the inserted severities of the vulnerability sources, and the estimated magnitudes of the risk and cost overrun factors. This gives an overall picture of the complex risk emergence pattern of the project. The total effect of each of the 36 risk-path scenarios will be the product of coefficients of all paths underlying that scenario. Multiplying the total effect of the scenarios with the severity levels of their initiator vulnerability sources, the

impact of different vulnerabilities on the cost overrun will be calculated. Ranking these impacts, the most effective risk-path scenarios for the project will be obtained. Table 1 shows the risk-path scenarios, their impacts on project cost overrun, and the most critical ones for the project under study.

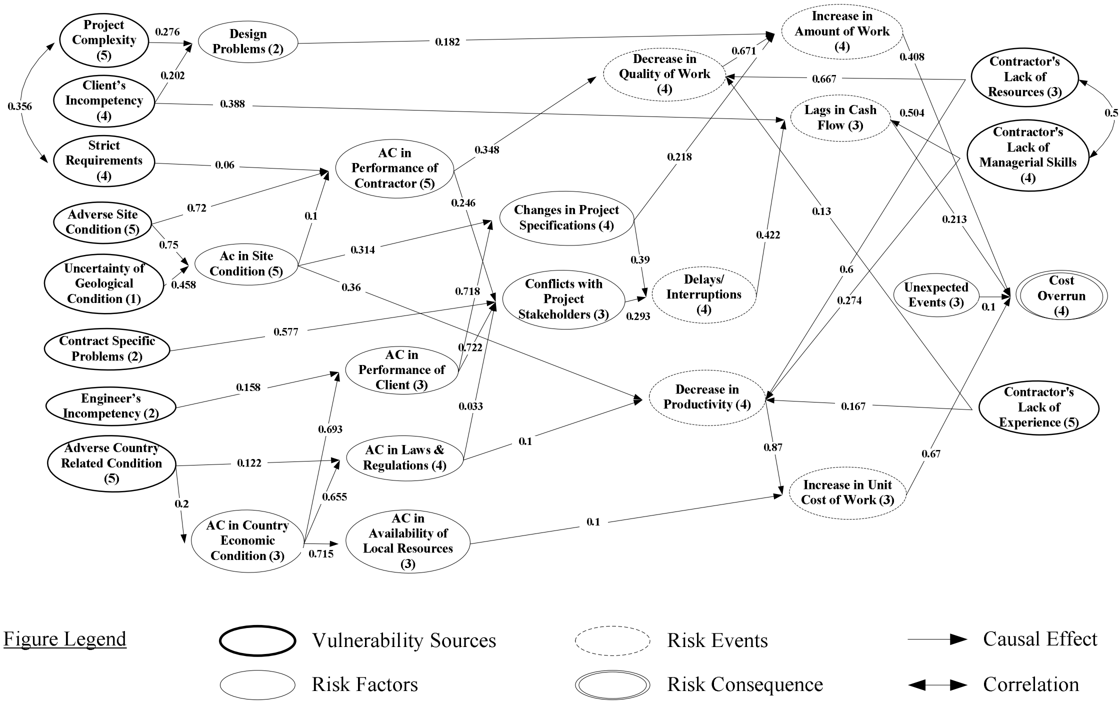

Figure 1: *Risk-Path Model for the case study*

Note: A) Values in parenthesis are inserted or estimated magnitudes of the vulnerability/risk factors in 5 scales. B) All paths are mutually significant at 5% level.

Discussion of findings

Figure 1 shows the general risk structure and the emergence pattern of the possible risk-path scenarios for the case study project. Such a comprehensive risk map gives a wider and more realistic view about the future when compared to that of common risk checklists. For example, as mentioned by company's representative, *adverse site condition* was one of the main vulnerabilities of the project the severity of which was known from the beginning of the project. If the company had considered the direct and indirect impacts of this source on other areas like *quality decreases*, *specification changes*, *delays*, *etc*., and at the same time the subsequent effects of these events, more effective strategies may have been made, and more realistic cost and time planning may have been possible. On the other hand, the influence of alternative mitigation strategies can be traced not only on a specific risk and possibly on its outcomes, but also on the whole network of interrelated risks. The statement of "*missed opportunity*", mentioned by Ward [19], being generated from the ignorance of such interdependencies, refers to the existing gap of various risk checklists that are improper in clarifying the effects of any response strategy on the whole system of risks. Moreover, the probable magnitudes of diverse risk factors, their cross-impacts on each other, and their impacts on project cost overrun are estimated (Figure 1 and Table 1). A total of 36 general risk-path scenarios are considered. Based on the specific conditions of different projects, these paths may have different impacts on project cost overrun, and hence, different scenarios may become critical.

Table 1: *Risk-path scenarios and their impacts on project cost overrun for the case study project*

Path	Identified Risk Paths Derived from Vulnerabilities →							Impact of Scenario	Total Impact
	Vulnerability	Risk 1	Risk 2	Risk 3	Risk 4	Risk 5	Risk 6		
1	(Conty-Cndtn)	(Conty-Econ)	(Avlb-Res)	(Unt-Cst)	(Cst-Ovrn)			0.008	
2	(Conty-Cndtn)	(Conty-Econ)	(Law-Reg)	(Prdcty)	(Unt-Cst	(Cst-Ovrn)		0.0064	
3	(Conty-Cndtn)	(Conty-Econ)	(Law-Reg)	(Coflt)	(Dely-Intrpt)	(Csh-Flw)	(Cst-Ovrn)	0.0001	
4	(Conty-Cndtn)	(Conty-Econ)	(Clt-Prfc)	(Coflt)	(Dely-Intrpt)	(Csh-Flw)	(Cst-Ovrn)	0.0024	
5	(Conty-Cndtn)	(Conty-Econ)	(Clt-Prfc)	(Prjt-Sps)	(Dely-Intrpt)	(Csh-Flw)	(Cst-Ovrn)	0.0024	
6	(Conty-Cndtn)	(Conty-Econ)	(Clt-Prfc)	(Prjt-Sps)	(Wrk-Amnt)	(Cst-Ovrn)		0.0072	
7	(Conty-Cndtn)	(Law-Reg)	(Prdcty)	(Unt-Cst)	(Cst-Ovrn)			0.0056	
8	(Conty-Cndtn)	(Law-Reg)	(Coflt)	(Dely-Intrpt)	(Csh-Flw)	(Cst-Ovrn)		0.0001	**0.0322**
9	(Pjt-Cmx)	(Dsgn-Prblm)	(Wrk-Amnt)	(Cst-Ovrn)				0.0434	0.0434
10	(Glgcl)	(Chng-Sit)	(Prdcty)	(Unt-Cst)	(Cst-Ovrn)			-0.1338	
11	(Glgcl)	(Chng-Sit)	(Prjt-Sps)	(Dely-Intrpt)	(Csh-Flw)	(Cst-Ovrn)		-0.007	
12	(Glgcl)	(Chng-Sit)	(Prjt-Sps)	(Wrk-Amnt)	(Cst-Ovrn)			-0.0181	
13	(Glgcl)	(Chng-Sit)	(Con-Prfc)	(Coflt)	(Dely-Intrpt)	(Csh-Flw)	(Cst-Ovrn)	-0.0004	
14	(Glgcl)	(Chng-Sit)	(Con-Prfc)	(Qlty)	(Wrk-Amnt)	(Cst-Ovrn)		-0.0056	-0.1649
15	(Strct-Rqr)	(Con-Prfc)	(Coflt)	(Dely-Intrpt)	(Csh-Flw)	(Cst-Ovrn)		0.0002	0.0026
16	(Strct-Rqr)	(Con-Prfc)	(Qlty)	(Wrk-Amnt)	(Cst-Ovrn)			0.0024	
17	(Cont-Prblm)	(Coflt)	(Dely-Intrpt)	(Csh-Flw)	(Cst-Ovrn)			-0.0128	-0.0128
18	(Eng-Incpt)	(Clt-Prfc)	(Coflt)	(Dely-Intrpt)	(Csh-Flw)	(Cst-Ovrn)		-0.0022	
19	(Eng-Incpt)	(Clt-Prfc)	(Prjt-Sps)	(Dely-Intrpt)	(Csh-Flw)	(Cst-Ovrn)		-0.0029	
20	(Eng-Incpt)	(Clt-Prfc)	(Prjt-Sps)	(Wrk-Amnt)	(Cst-Ovrn)			-0.0073	-0.0124
21	(Clt-Incpt)	(Csh-Flw)	(Cst-Ovrn)					0.0581	**0.0686**
22	(Clt-Incpt)	(Dsgn-Prblm)	(Wrk-Amnt)	(Cst-Ovrn)				0.0105	
23	(Sit-Condtn)	(Chng-Sit)	(Prdcty)	(Unt-Cst)	(Cst-Ovrn)			0.3549	
24	(Sit-Condtn)	(Chng-Sit)	(Prjt-Sps)	(Dely-Intrpt)	(Csh-Flw)	(Cst-Ovrn)		0.0181	
25	(Sit-Condtn)	(Chng-Sit)	(Prjt-Sps)	(Wrk-Amnt)	(Cst-Ovrn)			0.0475	
26	(Sit-Condtn)	(Chng-Sit)	(Con-Prfc)	(Coflt)	(Dely-Intrpt)	(Csh-Flw)	(Cst-Ovrn)	0.0113	
27	(Sit-Condtn)	(Chng-Sit)	(Con-Prfc)	(Qlty)	(Wrk-Amnt)	(Cst-Ovrn)		0.0158	
28	(Sit-Condtn)	(Con-Prfc)	(Coflt)	(Dely-Intrpt)	(Csh-Flw)	(Cst-Ovrn)		0.0113	
29	(Sit-Condtn)	(Con-Prfc)	(Qlty)	(Wrk-Amnt)	(Cst-Ovrn)			0.156	**0.6149**
30	(Con-Expr)	(Prdcty)	(Unt-Cst)	(Cst-Ovrn)				0.0603	**0.0827**
31	(Con-Expr)	(Qlty)	(Wrk-Amnt)	(Cst-Ovrn)				0.0224	
32	(Con-Res)	(Prdcty)	(Unt-Cst)	(Cst-Ovrn)				-0.0663	**0.101**
33	(Con-Res)	(Qlty)	(Wrk-Amnt)	(Cst-Ovrn)				-0.0347	
34	(Con-Mngt)	(Prdcty)	(Unt-Cst)	(Cst-Ovrn)				0.0701	**0.117**
35	(Con-Mngt)	(Csh-Flw)	(Cst-Ovrn)					0.0469	
36	(Unxpt-Evnt)	(Cst-Ovrn)						0.1011	**0.1011**

Note: A) All impacts are standardized estimates. B) Highlighted paths are the most effective scenarios.

In the Power Plant Reconstruction project, the standardized impacts of each risk-path scenario are estimated (Table 1) based on the severity levels of project vulnerabilities reported by the interviewee and discussed before through the paper. The total impacts of the vulnerability sources (i.e. the sum of the impacts of each scenario deriving from the vulnerability) are also reported in this table. The highlighted scenarios are the most effective ones deriving from each source. Also, the highlighted total impacts indicate the highest total impacts on project cost overrun, belonging to sources like adverse site condition, contractor's managerial incompetency, unexpected events, contractor's lack of resources, contractor's lack of experience, client incompetency, and adverse country conditions. Although some conclusions can be made by comparing the prediction results of the Risk-Path Model with the details discussed in the case study section, the identified paths and the predicted magnitudes were consulted with the company representative to ensure their compatibility with what happened in real project. All the identified critical risk paths were confirmed by the interviewee to be effective scenarios in the project.

According to company representative, the complex and interrelated nature of the occurred events was one of the factors having made the identification of responsible parties, and determination of their contribution rate on the raised overruns, a tedious task resulting in lots of time/cost consuming disagreements. According to the related clauses of the binding contract, each of the risk factors forming the project Risk-Path Model is under the responsibility of one of the project parties, or is shared among them based on their contribution to its occurrence. It is believed that integrating the identified risk paths with contract clauses will provide project parties with a supporting tool to facilitate their negotiations over the occurred cost overruns. Having knowledge about their approximate fault rate in the occurred scenarios will assist negotiators in determination of their reservation values, in getting ideas about the reasonable offers, and in forecast of the counter-offers during the negotiation process.

CONCLUSIONS

This paper reports a detailed case study for examining the complex risk emergence pattern of an international construction project. The results of the case study illustrates that incomplete design, errors in drawings, and sudden and frequent revisions have been some of the major problems of the project causing lots of time, cost, and productivity loss. Restrictions in accessibility of different construction areas and adverse site conditions were other main sources of poor time and cost performance in the project. Country, contractor, and client related vulnerabilities were other important fragility sources for the case under study. The results of the case study show that these vulnerabilities have caused a number of interrelated risks. In order to examine the discussed risk emergence pattern of the project in a systematic way, the Risk-Path Model developed in previous stages of this research is applied. Knowing the severities of project vulnerabilities, which are the most certain knowledge sources at early stages, the probable magnitudes of risk factors, and possible risk-path scenarios and their impacts on project cost overrun were predicted. The results of the Risk-Path Model are identified to be highly compatible with what have happened in the real project. Finally, it should be noted that, the aim of this case study is not to test the reliability of the model and predictive capability, but it is to demonstrate that how the proposed model may be used to assess risk paths in international construction projects.

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