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ADDRESSING COST OVERRUNS THROUGH RISK PATH MODELING

Tamima S. Elbashbishy[13], Ossama A. Hosny[1], Ahmed F. Waly[2], and Elkhayam M. Dorra [1].
[1] Department of Construction Engineering, The American University in Cairo, Egypt
[2] Faculty of Engineering at Mataria, Helwan University, Egypt
[3] telbashbishy@aucegypt.edu

Abstract: Whether forced by economic conditions or internal motivations, contractors may choose to minimize their mark-up margins in order to maximize their chances of winning a bid. Such drastic bidding conditions render contractors sensitive towards all types of project risks. This is why it is important for contractors to fully understand intricate risk dynamics for effective and efficient risk management. This paper explores risk identification and classification using the risk path approach as a substitute for the traditional risk source-risk factor approach mostly used nowadays. The risk path identified in this paper consists of risk elements and vulnerability factors, where risk elements are project uncertainties categorized according to their role in the risk path while vulnerability factors are project conditions that determine the project's capacity to resist risk elements. Risk elements consist of risk sources, risk events, and risk consequences, while vulnerability factors consist of robustness factors, resistance factors and sensitivity factors. An artificial neural network (ANN) is then constructed based on the identified risk path with training and testing cases retrieved from surveying construction experts in Egypt. Simulations are conducted using the ANN algorithm to establish the sensitivity of cost overruns to each of the identified risk path elements with the aim of identifying risk path elements with the greatest impact on projects' costs. Following this enhanced understanding of risk path elements, their relation, and their effect on cost overruns, research findings allows contractors to account for such risks, thus enabling them to minimize their contingency estimates and, consequently, reduce their bid prices.

1 INTRODUCTION

The construction industry's sensitivity towards events that may take place either inside or outside project boundaries render it a highly dynamic environment. This is why contractors are always faced with a new challenge each time they are estimating a project's price. Further, contractors often encounter situations where they are forced to submit the lowest bid possible. This can be due to a number of reasons ranging from relevant economic conditions of the country where the project is executed, to bidding conditions, such as bidding on a public project where the project is usually rewarded strictly to the lowest bidder. As a result, contractors may choose to minimize their mark-up margins in order to maximize their chances of winning a bid. In such cases, they are often more focused to submit bids with the lowest price possible with less regard to the proper profit or contingency margins needed to execute the project. Some contractors, even, resort to more extreme measures of submitting bids at zero percent profit and/or zero percent contingency.

Such drastic bidding conditions render contractors sensitive towards all types of potential risks associated with executing a project. This is why it is important for contractors to always be motivated to learn new risk management techniques and how to apply them effectively and efficiently in projects in which they are involved. However, the process of effective risk management proves to be challenging for a number of reasons. First, lack of comprehensive understanding of the interrelated relations between projects risks, which may lead to inaccurate risk identification and assessment. Typically, risk is defined as isolated factors that are independent of one another. Each risk factor is derived by a particular risk source and its magnitude is measured through traditional approaches such as the severity of impact approach. Such traditional approaches understate the dynamic nature of risks by not taking into account the interdependency of their relations.

A second reason why implementing effective risk management techniques can be a challenge is lack of project based data. Due to the difficulties most researchers face when collecting comprehensive project based information, a large number of studies focusing on the construction industry in Egypt are based primarily on data collected through surveys. While such surveys target field experts and professionals, the collected data is often subjective and based on experiences. Such subjectivity undermines research's findings, weakens its accuracy, and limits its applicability. On the other hand, project based data enables researchers to impartially analyze and understand important industry trends. It allows them to realize educated estimations and reliable predictions. Since risk management practices depend vastly on predictions and estimations, the outcomes of such practices are greatly affected by the subjectivity, quality, and comprehensiveness of collected information.

2 LITERATURE REVIEW

Risk management is a process of identifying risks, assessing their impacts, and developing mitigation strategies to ensure project success (Fidan, et al. 2011). Risk Identification is considered to be one of the most known and practiced steps of Risk Management worldwide (Uher and A.R. 1999). One reason why is because risks often have direct impact on projects goals namely cost, time and quality. Therefore, lack of effective and comprehensive risk identification results in ineffective risk management, which leads to failure in achieving project goals (Beltrão and Carvalho 2019). One study that focuses on public projects in Europe and North America shows that of the 258 projects examined 86% suffered from cost overruns due to poor risk management during cost estimation (Flyvbjerg, Holm and Buhl 2002).

Another practice that is closely associated with risk identification is risk categorization. Risk classification is an imperative risk management practice as it provides an indication of the categories of risks where common approaches to risk analysis, risk treatment, and risk monitoring and control can be utilized (Bing, et al. 2005). There can be numerus ways to classify risks associated with construction projects. Thus, selecting the suitable categorizing methodology depends the intended purpose of classifying project risks.

Smith, et al. (2014) identify 15 types of risks according to their sources as characterized by each project's nature. These sources of risk, or risk drivers, can include both engineering and non-engineering project-specific risks. They are generic and boundary-less to allow for a project-based risk management process that is more flexible and tailored compared to a typical risk management process. Similarly, LY et al. (2001) opted to classify project risks according to their nature into six main categories: Financial, Legal, Management, Market, Policy and political, and Technical risks. Alternatively, Bing et al. (2005) proposed to classify project risks based on the relation between risks and their impact, and the project itself. This technique is comprosed of three levels of risk categories, where risks in each level share the same source and relation to the project. The three levels are macro level risks, meso level risks, and micro level risks. Macro level risks are risks that take place outside the project boundaries, but whose consequences take place inside the project boundaries. While meso level risks are risks related to project's constructability risks, design risks, and operation risks. Finally, micro level risks are risks related to the relationship between the stakeholders and the various parties involved in the project. Both meso and micro risks take place inside the project boundaries. Another technique used to identify and classify project risks is the Potential Risk Breakdown Structure (PRBS), where project risks are identified and classified in accordance with a project's Work Breakdown Structure (Mojtahedi, Mousavi and Makui 2010). Since WBS is the most used structuring method in project management practices, it was deemed by the authors as suitable for providing the basis for identifying and categorizing risks to ensure that all the important information is generated and processed.

Building on both LY et al and Bing et al.'s work, One study further developed their risks list to include the most identified project risks across several countries (Chou and Pramudawardhani 2015). Their surveyed countries include the United Kingdom, Singapore, Taiwan, China, Australia, Iran, and India. A total of 69 risks has been identified across the 7 surveyed countries. This study illustrates that while some of the identified risks were country based, meaning that they are not common worldwide, but rather prevail in certain countries as a result of specific homebased characteristics, others such as inflation and interest rates volatility, changes in legislation and tax regulations, and delays in project approvals and permits from authorities having jurisdiction have been found to be common across most countries included in the study.

As can be seen, advances have been made in identifying and categorizing projects' most significant risks. However, this alone is not sufficient to understand project risks. Work remains to be done in identifying the relations between those risks as well as developing risk paths that explain those relations. Contrary to traditional risk management approaches that define risks as separate factors independent of one another, in practice project risks are found to be interconnected through a series of relations throughout a project's life (Fidan, et al. 2011, Charkhakan and Heravi 2018, and Liu, Zhao and Yan 2016). The statistical link between risk events and their consequences is limited for two main reasons. First, it ignores the cause-and-effect relationships among the various risk elements. Second, it neglects the influence of a "Project System". Also known as project vulnerabilities, a project system is a set of project characteristics that influence the severity of project risks (Fidan, et al. 2011).

To overcome these shortcomings, Fidan et al. (2011) developed a risk path that integrates both risk relations mapping and project vulnerabilities. Risk elements are categorized according to their role within the risk path as either risk sources, risk events, or risk consequences. Similarly, project vulnerabilities are also categorized based on their effect on risk elements of the risk path into Robustness factors (V1), Resilience factors (V2), and Sensitivity factors (V3).

Alternatively, Charkhakan and Heravi (2018) focus on the observability of risk drivers as an indication of potential risk scenarios. They use the DEMATEL technique to create a risk path, determine its main components, and establish the features of the risk path according to each of the identified risk scenarios. The developed risk path is composed of observed risk drivers and risk scenario's sources and events. Similarly, Liu et al. in their study rely on the concept of risk observability to construct risk paths and examine their effect on project objectives. The authors established a list of 60 risks, divided into three levels: country, market, and project; and 21 categories. Their risk path is composed of two types of variables: observable variables and latent variables. Observable variables are measured variables, while latent variables are hypothetical variables inferred from the observable variables.

As demonstrated in this paper, researchers from numerous countries have been working on identifying the most significant risks in the construction industry in their countries over the years. Yet, despite the booming of the Egyptian construction sector, contributing approximately 11.2% to Egypt's national GDP in 2015/2016 (Central Bank of Egypt 2017), such research has not been given appropriate attention in Egypt.

3 OBJECTIVES

The main objective of this paper is to identify risk elements with the greatest impact on projects' costs in the Egyptian construction industry. This objective is fulfilled by developing a risk path that models project risk elements, their interdependencies, and their effect on cost overruns in order to be able to simulate the various project's risk scenarios and estimate their corresponding cost overruns.

4 METHODOLOGY

The methodology described in this paper aims to fulfill the research objectives through both qualitative and quantitative approaches and is divided into three phases: Literature review, surveying professionals, and modeling the risk path.

In the first phase, a literature review is conducted to identify construction project's most significant risks, explore relevant categorization methods, as well as explore common risk mapping approaches. Following in phase two, industry professionals are surveyed to collect information regarding patterns of dependencies amongst the identified risk elements as well as the degrees of significance of these dependencies in terms of their effect on projects' cost in the Egyptian construction industry. Concluding with the third phase, a series of models is constructed to investigate risk path elements and their dependencies with the purpose of identifying the elements that have the greatest impact on cost overruns.

5 RISK PATH ELEMENTS

A total of 131 significant construction project risks were found based on common risks identified in 8 countries including UK, China, India, and Egypt. The identified risks were classified into five levels based on their driver or relation to the project as Country level, Project level, Owner level, Contractor level, and Project participants level. Then, each of the five levels was further divided into categories based on their nature. The first level is the Country level and it is composed of risks that materialize due to the conditions of the country in which the project is executed. Typically, these risks usually take place outside the project boundaries. However, their consequences take place inside the project boundaries and affect its objectives. Country level risks are divided into four categories: Economic, Political, Social, and Legal conditions. Whereas, the second level is Project level and it is composed of risks that materialize as a result of the specific project characteristics such as its type, location, or size. Project level risks are divided into five categories, which are Design, Construction, Management, Contract, and Market, and they can take place either inside project boundaries such as design and construction risks or outside project boundaries such as market risks.

As for the third, fourth, and fifth levels, they are concerned with risks related to the main parties involved in the project and their relationship to the project. These three levels take place and affect a change inside the project boundaries and they are: Owner level, Contractor level, and project participants level. Owner level risk are further divided into three categories which are Objectives, Resources, and Managerial abilities. Likewise, Contractor level risks are divided into three categories which are Experience, Resources, and Managerial abilities. Lastly, Project participants level risks are divided into two categories: Designer and Engineer.

6 RISK PATH

The created risk path as well as the main elements forming it shall constitute the base model upon which risk simulations are conducted to investigate the impact of various combinations of risk elements on project cost overruns. The risk path developed in this paper is greatly influenced by the risk path developed in Fedan et al.'s work (2011). It takes on the concept of project vulnerabilities and combine risk elements and project vulnerability factors in one integrated risk path that accounts for and describes the relation between both components. It also utilizes the same risk elements as well as the relationships governing the cause-effects relations between them. However, it introduces an enhanced paradigm for the relationship between vulnerability factors and risk elements. Regardless, these attributes are the reason why a risk path approach was opted for in the research.

The developed risk path is comprised of two main components: risk elements and vulnerability factors. Elements of the risk path can be described by one or more of three properties: probability of occurrence, magnitude of occurrence, and impact of occurrence, where probability of occurrence is the likelihood of a certain event to take place, while magnitude of occurrence is the measure of the size of a certain element when it actually occurs. As for impact of occurrence, it is the extent of the magnitude of occurrence of a certain element on subsequent elements in the risk path.

6.1 Risk Elements

Risk elements are risk factors that are identified, monitored, and controlled before project initiation as part of a project's risk management plan. Naturally, risk elements are project specific and thus may differ from one project to the other depending on project characteristics such as project size, location, or delivery method. Three subgroups of risk elements were created and defined according to their role and sequence in the risk path. These are risk sources, risk events, and risk consequences.

Risk sources are defined as changes or uncertainties in a project's system or properties, which have the potential to cause variance in project proceedings. These uncertainties can be attributed to project circumstances either within or outside of project boundaries, or changes in the relation between both. Risk sources are observable risks that may lead to one or more risk events. Likewise, risk events can be due to one or more risk sources. However if realized, risk sources can help effectively manage a risk scenario and thus prevent a risk event from taking place. As for risk events, they are defined as incidents that take place within project boundaries and cause variations in project proceedings. Such variations have the potential to alter the project's original program upon which project goals (time, cost, and quality) were decided. Risk events may lead to one or more risk consequences. Lastly, risk consequences are defined as the impact of one or more risk events that took place in the project on one or more project outcomes, namely cost, time or quality. Therefore, risk consequences may be changes in the project's total cost, duration, or quality of work. Since this research focuses on the effect of project risks on cost overruns, risk consequences in this case are limited to changes in project cost, while the remaining project outcomes (time and quality) are ignored.

Generally, only risk events are described by all three properties defined earlier: probability, magnitude, and impact of occurrence. Whereas, risk sources are described in terms of magnitude and impact of occurrence, while risk consequences are described only in terms of probability and magnitude of occurrence. Reasonably, risk sources cannot be described in terms of their probability because they are either recognized as project risk sources with identified magnitudes or not in which case they have a magnitude of zero. Likewise, risk consequences cannot be described in terms of their impact as they are an impact themselves. Also due to their position as the last element in the risk path, there are not followed by any other elements to have an impact on.

6.2 Vulnerability Factors

As for the second component of the risk path, vulnerability factors are the innate characteristics of a project's system. They define the project system's ability to either drive or resist risks. Unlike risk elements, vulnerability factors are a set of influences that cannot be controlled or managed since they describe independent, known project conditions that are established either before or at project initiation. However given their influence on all three categories of risk elements, vulnerability factors should be identified, monitored and taken into consideration in a project's risk management plan. Similar to risk elements, vulnerability factors are also project specific and therefore may change from one project to the other depending on two aspects. The first is project properties such as size, location, or delivery method, while the second aspect is project circumstances such as involved parties abilities or country conditions. In this research, three subgroups of vulnerability factors were created and defined according to their role and sequence in the risk path. They are robustness factors, resilience factors, and sensitivity factors.

Robustness factors are defined as project system characteristics that stem from country, project, owner, designer, and engineer conditions. Accordingly they include factors found within as well as outside of project boundaries. Generally, robustness factors determine the project's vulnerability towards the occurrence of risk sources and thus they are concerned with issues such as the financial, technical, and managerial abilities of each of the project parties as well as the relationship between them. In other words, the higher the number of weak robustness factors in a project system the higher the probability of occurrence of associated risk sources. As for resilience factors, they are similar to robustness factors. However, they are concerned with project system characteristics that stem from contractor conditions such as the contractor's technical abilities, financial resources, and relation with the rest of the project parties. They determine the project's ability to resist the occurrence of risk event. In other words, the better the contractor's conditions, the more resistant is the project to potential risk events. The last category of vulnerability factors is sensitivity factors. As suggested by the name, sensitivity factors determine how sensitive a project is to risk events. They are concerned with the magnitude of the risk consequences following a risk event taking place in the project. Sensitivity factors describe project properties such as scale, type, contract type, and delivery method.

As for the vulnerability factors' properties, all vulnerability factors are defined in terms of two properties only: magnitude of occurrence and impact of occurrence. The reason why none of the vulnerability factors can be attributed by their probability of occurrence is that by definition vulnerability factors cannot be controlled or monitored. They are either recognized as project system conditions, in which case their probability of occurrence is a hundred percent, or not in which case their probability of occurrence is zero. Therefore, they cannot be described in terms of probability of occurrence.

6.3 Developed Risk Path

The path starts with robustness factors as its initiation point, where the magnitude of robustness and resilience factors are identified based on recognized project system characteristics. These magnitudes are then materialized into impacts of occurrence that influence the magnitude of a risk source. Following, the magnitude of the risk source is materialized into an impact of occurrence that influence the magnitude and probability of occurrence of a risk event. Further along the path of materialization of the risk source's magnitude into impact, the magnitude of occurrence of the resilience factor is also materialized into an impact of occurrence that influences the impact of the risk source as well. In other words, the impact of a resilience factor can affect not only the magnitude of a risk source but also either increase or decrease the impact of a risk source on the probability and magnitude of a risk event. Moving to risk event, it is connected to the risk consequence in two ways. First, the probability of occurrence of a risk event has an effect on and is directly proportional with the probability of occurrence of a risk consequence. As for the second, the magnitude of the risk event is materialized into an impact of occurrence that influence the magnitude and probability of occurrence of the risk consequence. Meanwhile, the magnitude of occurrence of the sensitivity factor is also materialized into an impact of occurrence that also influences the impact of a risk event on the probability and magnitude of a risk consequence, thus concluding the risk path with risk consequence as its last element. Figure 1: The Developed Risk Path demonstrates the developed risk path and the relationship between its elements as described above.

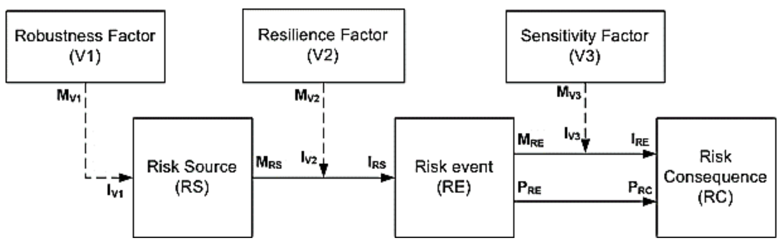

Figure 1: The Developed Risk Path

After defining the risk path's risk elements, vulnerability factors, and relations between them, the identified 131 common construction projects risks were re-categorized and distributed as per established definitions according to their role in the risk path. First, risk sources were classified based on their nature into eleven categories: Financial, Contractual, Legal, Political, Social, Environmental, Communications, Geotechnical, Market, Project, and Construction risks. Further, 14 risk events were identified and grouped in one group as Risk Events. Lastly as mentioned hereinafter regarding the risk consequences, this research is concerned with only cost as one of the project outcomes. Therefore, cost overruns is the only risk consequence taken into consideration.

As for the vulnerability factors, they were selected and re-categorized is a manner similar to the previously described. First, the identified factors were classified into levels based on their driver or relation to the project. Then, factors in each level were further divided into categories based on their nature. Robustness factors were divided into four levels: Country conditions, Project conditions, Owner conditions, and Project participants conditions, while Resilience factors comprised of only one level: Contractor Conditions. Lastly, sensitivity factors were grouped in one group as Sensitivity Factors.

7 SURVEYING PROFESSIONALS

A project based survey was conducted to collect information regarding the patterns of dependencies amongst the identified risk path elements (risk elements and project vulnerabilities) as well as the degrees of significance of these dependencies in terms of their effect on projects' cost overuns in the Egyptian construction industry. Notably, using surveys to collect project performance data has been widely utilized in research of similar nature. (Liu, Zhao and Yan) (Bing, Akintoye and Edwards) (LY, GWC and CSK).

The survey was conducted through a questionnaire where respondents are asked to provide information pertaining to a specific project in which they have been involved with a maximum of two projects per questionnaire. The questionnaire consists of three sets of questions. The first set asks respondents to rank the identified vulnerability factors with respect to their relevance to the project's conditions using a five-point scale (1= Not relevant; 2= Slightly relevant; 3= Relevant; 4= Very relevant; 5= Extremely relevant), while the second set asks respondents to rank the identified risk elements with respect to their effect on the project's cost overruns using a five-point scale as well (1= Not significant; 2= Slightly significant; 3= Significant; 4= Very significant; 5= Extremely significant). As for the third section, it asks respondents specific project information including project type, contract type, delivery method, contract form, project budget estimate and cost overrun percentage.

The questionnaire was created using Google Forms, where sharable links were sent out to respondents through emails, LinkedIn and other social media platforms. Also, hardcopies of the questionnaire were printed out and filled by hand when applicable. A total of 80 questionnaires were sent out to professionals at different positions ranging from engineers and architects to manager and executive level personnel with varying roles in the Egyptian market including Owners, Developers, Project Managers, Consultants, Domestic and International Contractors, and Sub-Contractors. A total of 34 complete responses pertaining to 40 projects were received and considered in the study, thus constituting an acceptable sample size as specified using Cochran's sample size formula. According to the formula and typical equation parameters, the minimum sample size required is 31 respondents.

8 MODELING THE RISK PATH

A model composed of a chain of three sub models was designed to simulate the relations between the risk path elements on one another and on cost overruns as prescribed in this research's risk path. Two of the sub models are optimization models, while the third is an Artificial Neural Network (ANN) model. The database for this model was developed based on project-based data collected from the survey responses mentioned in the previous section.

The rankings collected using the survey are assumed to be the magnitudes of the risk path elements, while the probability of risk events and consequences are assumed to be a hundred percent given that the surveyed projects are completed or in progress and therefore the risk events in question have taken place and their consequences have been witnessed. As for the impact, the purpose of the model is to investigate the impact of the identified risk path elements on one another and on project cost overruns.

The first optimization model simulates the impact of the magnitudes of the Robustness factors on the magnitudes of the Risk sources. Whereas, the second optimization model simulates the impact of the magnitudes of both Resilience factors and Risk sources on Risk events. Lastly, the third and only ANN model simulates the impact of the magnitudes of both Sensitivity factors and Risk events on Risk consequences, which in this case is cost overruns.

Starting with the first model, which represents the relation between Robustness factors and Risk sources, each of the robustness factors is assigned an arbitrary value. These values are considered the weights of the factors when forming the model's objective function. Following, an objective function of two equations is created. The first equation is the weighted average of the robustness factors' ratings, while the second equation is the sum of the squares of the difference between the weighted average of the robustness factors' ratings (independent variables) and sum of the risk sources ratings (dependent variables) for each of the database scenarios. The model runs to find the smallest possible value for this sum by calibrating the assigned factors weights given that none of them can be equal to zero. The second model follows the same logic established in the first one. However, it represents the relation between Resilience factors and Risk sources and Risk events.

The third model is an ANN model and it represents the relation between Sensitivity factors and Risk events and cost overruns. It is constructed such that Sensitivity factors ratings are its independent variables, and Risk events ratings are its independent variables. Whereas, percentage cost overruns are the dependent variable. By running the model, its net data is developed and the variables impact analysis is calculated.

Outputs generated by the three models comprise of five sets of calibrated weights: Robustness factors, Resilience factors, Risk sources, Sensitivity factors, and Risk events. Each set represents the effect of a risk path element on another. Collectively, the five sets quantitatively demonstrate the relations established in this study’s risk path. Tables 1 and 2 show all risk path elements identified in this research sorted according to their corresponding weights. Elements are sorted in descending order from highest to lowest in terms of their effect on one another.

9 RESULTS

Out of the 44 identified Robustness factors, Lack of enforcement of legal judgment, Low constructability of design, and Managerial incompetency of Owner's project team are the top three factors in terms of their effect on the magnitude of Risk sources. On the other hand, Incomplete contract terms and Complexity of construction method are among amongst the lowest. As can be seen in Table 1, 35 percent of the top 20 factors are related to project design whether they are Project Design Conditions such as Low Constructability or Errors in Design/Design Drawings, or Designer Conditions such as Technical incompetency of Designer's project team or Change in Designer's project team.

Out of the 19 Resilience factors included in this study, Lack of Contractor's experience in delivery system, and Contractor's lack of project procurement management are of the top factors in terms of their effect on the magnitude of Risk events. While Technical incompetency of Contractor's project team, Lack of Contractor's experience in country, and Managerial incompetency of Contractor's project team are at the bottom of the list. Unlike Robustness factors, Resilience factors do not follow any clear patterns or recognizable trends. However, it is worthy to note that, generally, contractor’s financial matters such as Contractor's lack of project cost management and Lack of Contractor's financial resources do not rank amongst the top five factors. Further, Lack of contractor’s technical resources rank higher than Lack of contractor’s financial resources in terms of their effect on Risk events. As for the Sensitivity Factors, Project type has the most impact on a project cost overrun, followed by Project delivery method.

Out of the 58 identified Risk sources, Change in availability of labor, Change in site conditions, and Change in project design are the top three factors in terms of their effect on the magnitude of Risk events. While Change in project scope, Change in relations with government, Change in work quality are of the bottom five sources according to the same measure. It is important to note that Change in the financial situation of owner is amongst the sources with the lowest influence on Risk events. Even though the Lack of Contractor's financial resources has a low rank amongst the rest of the resilience factors, a Change in financial situation of contractor is amongst the top 25 percent of Risk sources with the greatest effect on Risk events.

Of the 14 risk events identified, Delay in owner interim payments, Increase in quantity of work, and Decrease in productivity are the three greatest risk events in terms of their impact on the magnitude of risk consequences (cost overruns). As can be noticed, none of the three top risk events are essentially project cost items. Nonetheless, they are directly followed by events related to project cost such as Increase in labor costs, Increase of materials prices, and Increase in project overheads costs as can be seen in Table 1. Delays due to bureaucracy whether from the owner or the government’s side rank at the bottom of the list.

Table 1: Sorted Robustness Factors, Resilience Factors, Risk Events, and Sensitivity Factors.

Robustness factors	Resilience factors
Lack of enforcement of legal judgment	Lack of Contractor's experience in delivery system
Low constructability	Change in Contractor's company organizational structure
Managerial incompetency of Owner's project team	Contractor's lack of project procurement management
Technical incompetency of Designer's project team	Contractor's lack of project communication management
Instability of economic conditions	Contractor's lack of project scope management
Change in Designer's project team	Contractor's lack of project cost management
Errors in Design/Design Drawings	Lack of Contractor's technical resources
Instability of government	Lack of contractor staff
Instability of international relations	Lack of Contractor's experience in similar projects
Change in Engineer's project team	Lack of Contractor's experience with Owner
Lack of Designer's technical resources	Change in Contractor's project team
Lack of Engineer's financial resources	Contractor's lack of project time management
Inadequate geotechnical investigation	Lack of Contractor's financial resources
Lack of Engineer's technical resources	Lack of Contractor's experience with other project parties
Managerial incompetency of Designer's project team	Contractor's lack of project risk management

Complexity of design	Contractor's lack of project human resources management
Technical incompetency of Engineer's project team	Technical incompetency of Contractor's project team
Incomplete design	Lack of Contractor's experience in country
Immaturity of legal system	Managerial incompetency of Contractor's project team
Restrictions for foreign companies	**Risk Events**
Managerial incompetency of Engineer's project team	Delay in Owner payments
Errors in Contractual agreement	Increase in quantity of work
Lack of Designer's financial resources	Decrease in productivity
Lack of Owner's financial resources	Increase of labor costs
Level of bureaucracy of Owner	Increase of accessory facilities prices
Change in laws, policies, or regulations	Increase of materials prices
Change in Owner's company organizational structure	Increase in project overheads costs
Technical incompetency of Owner's project team	Decrease in quality of work
Strict environmental management requirements	Delay in work progress
Vagueness in contract clauses	Increase in site overheads costs
Poor accessibility of site	Increase of resettlement costs
Instability of social conditions	Delays due to government bureaucracy
Unknown site physical conditions.	Delay in project logistics
Negative attitude of Owner	Delays due to Owner bureaucracy
Strict safety management requirements	**Sensitivity Factors**
Change in Owner's top management	Project type
Strict quality management requirements	Project delivery method
Strict project management requirements	Project budget
Change in Owner's project team	Project contract type
Lack of Engineer's staff	
Incomplete contract terms	
Unclarity of Owner's objectives	
Inadequate climate conditions	
Complexity of construction method	

Table 2: Sorted Risk Sources

Risk **Sources**	
Change in availability of labor	Change in level of bureaucracy
Change in site conditions	Change in weather conditions
Change in project design	Hazards of environmental regulations
Poor quality of procured accessory facilities	Improper selection of project type.
Increase in site overheads	Change in relation between parties
Change in performance of designer	Difficult convertibility of Local Currency
Low credibility of Owner	Disputes between project parties
Change in availability of subcontractor	Inadequate project organization structure
Change in construction method/technology	Improper project planning and budgeting
Problems associated with culture difference	Change in tax rates
Breach of contracts by Owner	Change in interest rates
Change in level of bribery and Corruption	Competition from other similar projects.
Incompetence of transportation facilities	Improper project feasibility study
Change in performance of engineer	Change in availability of equipment
Change in financial situation of contractor	Fall short of expected income from project use
Change in currency exchange rates	Poor quality of procured materials.
Improper selection of project location	Change in performance of Owner
Inadequate forecast about market demand.	Change in geological conditions
Increase in project overheads.	Difference in practices amongst project participants
Change in original schedule	Change in communication between parties
Obsoleteness/failure of Equipment	Change in performance of contractor
Low credibility of Contractor	Change in public reaction
Low credibility of Subcontractor	Unfairness in tendering
Change in availability of material	Shortage in supply of water, gas, and electricity
Uncertainty and unfairness of court justice	Change in site organization
Accidents on site	Change in project scope
Breach of contracts by Contractor	Change in financial situation of owner
Change in inflation rates	Change in relations with government
Change in availability of accessory facilities	Change in work quality

In order to verify the model, a sample of twenty percent of the model cases is selected for testing with a thirty percent tolerance interval for bad predictions. Around eleven percent of the tested cases are bad predictions. Moreover, the values of the Root Mean Square Error, Mean Absolute Error, and Std. Deviation of Abs. Error are within acceptable ranges. Thus, it can be concluded that the model is an accurate representation of risk path elements relations. Accordingly, weights calculated by the model are reliable and can be considered an indication of the relative effect of each of the risk path elements on projects cost overruns.

10 CONCLUSION

As the findings show, vulnerability factors, specifically contractor and Owner conditions, rank the highest in terms of their influence on project overruns. Of the 30 risk path elements with the greatest impact on cost overruns, 50 percent were found to be risk sources. Besides, 58 of the 131 risk elements identified at study initiation were also found to be risk sources. Thus, it can be concluded that risk path elements with the highest impact on project cost overruns are observable and can be identified at project initiation which encourages effective and efficient risk management practices. Throughout the project, watching for observable risk sources can help prevent or alleviate the impact of a risk scenario on project outcomes. Lastly, Owner’s readiness to commence a project is as important as selecting a suitable contractor.

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