sASSESSMENT OF PROJECT VULNERABILITY AS A PART OF RISK MANAGEMENT IN CONSTRUCTION

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The main purpose of risk management is to identify risks, quantify their impacts and develop strategies to mitigate them to succeed in project objectives. Project risk assessment is usually about quantification of the statistical link between the risk events and their consequences. However, this approach has a limitation as the influence of the "system" is neglected during modeling the relation between risk sources and consequences. The word "vulnerability" is used to describe internal characteristics of a system which influence this relationship. In this study, it is proposed that risk management should cover assessment of project vulnerabilities as well as risk factors. A case based methodology is used to investigate the relationships between risk events, project vulnerabilities and project performance. By referring to two international construction projects, the impact of project vulnerability on performance is demonstrated and a list of factors that can be used for vulnerability assessment is presented. Case study findings point out that an integrated structure that takes into account of cause-effect relations between risk and vulnerability factors must be developed and an integrated procedure should be used for risk and vulnerability assessment rather than individual risk and vulnerability ratings.

KEYWORDS: Risk, vulnerability, international construction.

INTRODUCTION

Risk is the probability of occurrence of a risk event, which triggers undesirable outcomes. Magnitude of risk depends on its probability and potential consequences (Brooks, 2003). Risk management process mainly comprises of identification of risk events, assessment of their influence on project outcomes and developing response strategies to mitigate them. Within this process, the consequences are determined only by considering likelihood of risk events. However, as emphasized by Zhang (2007), giving more importance to the statistical link between risk events and risk consequences neglects the effect of project system on the process.

The rules, structures, actions, behaviors, cultures within the project system have influence on the risk process. Barber (2005) considers these types of risks as internally generated and mentions the fact that imperfect organizations or systems generate new risks. Dikmen et al. (2007) describe the factors that determine the relationship between risk source and consequence as factors about manageability. In this paper, the term “vulnerability” will be used to characterize the influence of project system on risk consequences as suggested by Zhang (2007) and Lewis (1999). The traditional risk management process should be enhanced to cover vulnerability management, which deals with the fragility of a system to probable risk events.

VULNERABILITY AND RISK

Crichton (1999) defines risk as the probability of a loss, which depends on three elements: hazard, vulnerability and exposure. Changing any one of these three elements changes the risk consequence. According to Agarwal and Blockley (2007), risk is the production of hazard and vulnerability. To illustrate, hazard is the earthquake, exposure is the facility on earthquake zone and vulnerability changes due to the design, construction and maintenance of the facility. It is clear that the combination of a hazard with a vulnerable system results in disasters.

The term “vulnerability” is used to explain inborn characteristics of a system. Project vulnerabilities create the potential for harm but are independent from the probability of occurrence of a risk event (Sarewitz et al., 2003). Vulnerability indicates the degree to which a project is susceptible to adverse effects of change (Brooks, 2003). It exists within systems independently of external hazards and depends on organization’s capability to manage risks, and can be internally created by organizational, social and economic factors.

The social, political and economic conditions of nations, regions and systems have been investigated considering the concept of vulnerability. Focusing on different types of risks and their outcomes leads to the emergence of different definitions of vulnerability (Alwang et al., 2002). Table 1 presents some of the different definitions of vulnerability within the literature.

Table 1: Definitions of Vulnerability in the Literature

Author(s)	**Definitions**
Agarwal and Blockley (2007)	**“Vulnerability is a particular form of hazard- a hazard which is internal to the system.”**
Allen (2003)	**Vulnerability refers to “the set of socio-economic factors that determine people’s ability to cope with stress or change.”**
Blaikie et al. (1994)	**Vulnerability is “the combination of characteristics of a person or group in terms of their capacity to anticipate, cope with, resist, and recover from hazard impacts that threaten their life, well-being and livelihood.”**
Buchanan (1991)	**“Vulnerability refers to the scale and complexity of the problems facing the project manager, the degree of uncertainty and risk involved, and to the anticipated degree of contention and resistance which the change is likely to generate.”**

Buckle et al. (2001)	**“Vulnerability is a measure of the exposure of a person to a hazard and indicates the type and severity of the damage that is possible.”**

Table 1: Vulnerability Definitions in the Literature (continued)

Author(s)	**Definitions**
Council for International Organizations of Medical Sciences cited in Levine (2004)	**“Vulnerable persons are those who are relatively or (absolutely) incapable of protecting their own interests because they may have insufficient power, intelligence, education, resources, strength, or other needed attributes”.**
Nicholls et al. (1999)	**“The likelihood of occurrence and impacts of weather and climate related events.”**
Oksuz (2003)	**Vulnerability assessment is for the prediction and identification of the seismic performance and safety level of the building, which might be exposed to severe damage during an expected earthquake.**
Winslow (1998) cited in Levine (2004)	**Vulnerable populations are the “social groups who experience limited resources and consequent high relative risk of morbidity and premature mortality.”**
Zhang (2007)	**“A system’s vulnerability represents the extent or the capacity of this system to respond to or cope with a risk event.”**

Vulnerability is often confused with risk (Ezell, 2007). However, vulnerability concept has several distinctions from risk and management of vulnerability is based on a different perspective than the traditional risk management. Vulnerability is the concept of being susceptible to a risky situation, whereas risk is used for defining the severity of consequences within a scenario. While risk management is applied to estimate the likelihood and consequences of risks, vulnerability management is used to define the characteristics of a system that will change the possibility for harm. (Ezell, 2007; Brooks, 2003; Adger, 1999). Project vulnerabilities exist before the occurrence of risk events (Zhang, 2007), but they will not become significant until the risk event occurs. For instance, the existence of an escalation clause will not become momentous until there is a change in inflation. Reducing vulnerability is an important way of managing risk, but any reduction in the impact of a risk is not related with reducing the vulnerability of system (Agarwal and Blockley, 2007; Sarewitz et al., 2003). For example, theft of materials at site will cause both time and money loss. Insurance, as a risk response strategy, will prevent cost overrun. However, insurance will not change the vulnerability of system. Vulnerability can only be reduced by improving site conditions, such as building secure storages at site. A vulnerability parameter cannot generate a risk consequence without a risk event; however, a risk event may lead to a risk consequence on its own (Zhang, 2007). Vulnerability is the condition or inherent characteristic of a system, which influences the amount of damage. For example, project size will not cause any risk. However, in case of any change in quality of a material, project size will change the degree of cost overrun.

If a system has enough strength to handle a risk (low vulnerability), the occurrence of risk may not cause any deviation from pre-defined objectives. As Buckle et al. (2001) mentioned, “the higher the resistance, the less likely damage may be, and the faster and more effective recovery is likely to be. Conversely, the higher the vulnerability, the more exposure there is to loss and damage." This reveals out that vulnerability is not related with the probability and severity of the risk event. Vulnerability is a function of internal properties of a system. In spite of not being a function of severity and probability of occurrence of a risk event, some characteristics of a system will make it more vulnerable to certain risks (Brooks, 2003). For example, if the project's construction technology is complex and if the company does not have enough experience than the risk of project failure will be high.

Determination of vulnerabilities and managing them is important for increasing the capability to deal with risks and improving adaptation capabilities (Prowse, 2003). Through vulnerability management, the weakness of a project system can be identified and the project may be adapted to probable risks to minimize their impact on project outcomes.

According to Brooks (2003), "adaptation is the adjustments in a system's characteristics that improve its ability to cope with risks and adaptive capacity of a system is the ability of a system to modify or change its characteristics so as to cope better with existing external stresses." Vulnerability will be reduced through adaptation. For example, if a company is not familiar with the construction technology used in the project, then an experienced partner may be found to perform the construction. Then the company may reduce the vulnerability generated from the lack of experience and decrease the probability of project failure.

Managing vulnerability shows the ways of limiting uncertainty through achieving enough capacity to deal with risk and vulnerability (Prowse, 2003). Effective planning for risk consequences requires that the vulnerability associated with specific processes be understood in parallel with understandings of probabilities of risk, so that decisions can be taken by achieving the appropriate balance between risk and vulnerability management (Sarewitz et al., 2003). Integrated vulnerability management into risk management process may help companies to better understand threats, determine acceptable levels of risk, and take action to mitigate identified vulnerabilities.

In this paper, it is suggested that the level of vulnerability should be assessed so that it can effectively be managed. Thus, a framework that consists of vulnerability parameters applicable to construction business should be developed.

Vulnerability Parameters

As Twigg (2001) mentioned, in order to understand the factors that increase a system's vulnerability, one should diverge from the risk event itself and consider a set of influences. For international construction projects the factors related with the contract, company, project and project participants come together to create the influencing factors. Table 2 summarizes the vulnerability factors, which were identified as a part of this study.

According to Katz (2004), "the contract is the contractor's first line of defense in dealing with risks", because responsibility and risk allocation between project parties are defined through contractual clauses. Ineffective risk sharing or the misunderstanding of risk distribution between project parties generally leads to a dispute after the occurrence of a risk event (Hartman and Snelgrove, 1996). Unfair or poorly defined contract clauses may lead severe risk consequences. Table 2 shows the most significant contract clauses that will make the projects more or less vulnerable to risk events.

Project characteristics basically include project requirements, restrictions, standards, project size, duration, site and country conditions (Table 2). Fan et al. (2008) mention that project characteristics could change the impact of risk event by affecting the risk handling strategy. As discussed by Han et al. (2007), many risks of international construction projects are closely related with fairness of construction laws and regulations of host country, local material supplies, the cultural issues and the attitude of government.

Table 2: Vulnerability Parameters

Category	Sub-category	Factors
Contract	Clauses	Rights and obligation of parties, payment method, escalation, taxation, warranty, default of owner, force majeure, cost compensation, time extension, liquidated damages, change orders, variation of work, valuation of variations, disputes, codes and standards, etc.
Project	Project-requirements	Technical, technological, managerial, quality, health and safety, environmental impact
	Project-conditions	Design maturity, constructability, geotechnical conditions, location, site conditions, contract clarity, scope clarity, size, duration, payment type, project delivery system
	Country-market conditions	Labor, material, equipment, local supplier, local subcontractor, infrastructure
	Country-requirements	Import-export rules, customs procedures, social security law, requirements from foreign firms
	Country-conditions	Political and economic stability, legal system maturity, socio-cultural differences, international relations, bureaucracy, significance of the project for the country, geography and climate conditions, government attitude toward foreign investors.
Company	Company-resources	Financial and technical resources, staff, managerial capability, experience, relations (with client,etc.)
	Company-conditions	Objectives, management capability (such as planning, organization, documentation, control and monitoring, leadership etc.), risk response strategy, workload, business style, management style, top management support, location of management (headquarter vs. regional branch)
Project parties	Client-resources	Financial strength, staff, experience
	Client-conditions	Significance of the project, clarity of objectives, management capability, risk response strategy, relations with contractor
	Other parties (Partner, designer, engineer, supplier etc.) -resources	Financial strength, experience, staff, cultural differences, Management capability, risk response strategy, relations with the client and government

Company characteristics such as project management system's maturity, project managers and team's abilities, experience and strength have also influence on the risk consequences.

Chan et al. (2004) mention that the project managers should be able to plan and execute their construction projects to maximize the project's chances of success. They should use management tools effectively, which include adequate communication, control mechanisms, feedback capabilities, monitoring, project organization structure, plan and schedule followed, etc.
Key project participants include client, partner, subcontractor, supplier, designer and engineer. As Chan et al. (2004) state, "a construction project requires team spirit; therefore team building is important among different parties." Thus, the abilities, workload, financial strength of each party and the relations between these parties will influence project outcomes.
Table 2 presents a set of factors and a categorical structure for vulnerability assessment. Although it is based on an extensive literature survey, it has to be validated by referring to real cases. In this paper, two interviews carried out to test the validity of vulnerability parameters are discussed.

CASE STUDIES

This research is built on cases to demonstrate the relationships between risk events, project vulnerabilities and project performance. The initial cases are chosen so that they are carried out in the same country and the projects are technically very similar. This enables the investigation of impacts of contract and country conditions as well as the parties involved in the project.

The Company that carried out both of the projects has been designing, manufacturing and undertaking the construction works of steel structures for energy and telecommunication industries since 1955. The Company employs around 1 000 personnel and exports to more than 100 countries in five continents. In 2007, the total sales of the Company were around 180 million USD and the Company exported nearly 70 000 metric tons of towers. The projects investigated for this research were technically very similar and performed in different regions of the same country in the same year.

Information about the projects was collected through interviews. Managers taking part in both of the projects were interviewed, each lasting for 1-1.5 hours. They were asked to give information about the project progress and their experiences. Project failures, their causes and actions taken were discussed. Some information about the projects and findings are as follows:

1. Project A – The Company was responsible for design and manufacturing of the steel structure for the energy transmission line constructed in the south region of the country. The construction phase of the project was under the responsibility of a local firm who is the JV Partner of the Company. As a part of their competitive strategy, the Company managers did not want to introduce an experienced firm to the Owner to sustain their competitive advantage in the market and therefore, they chose an inexperienced partner. However, because of the technical complexity, Partner could not complete the construction. The Company had to undertake the responsibility of the Partner and performed the construction themselves due to its significance for them. This caused several revisions in organizational structure of the Company and allocation of required resources to project took more time than expected and caused delays. In addition to technical issues, the quality requirements of the

project were also heavy. The chosen local suppliers and subcontractors were not capable enough to maintain these requirements. Low quality of materials resulted in repetitive tests and reworks. Heavy constraint in quality also required several suppliers from different countries, which made the communication and coordination a critical issue for the Company. In the south side of the country where the project was performed, there was a conflict between different ethnic groups. Because of the social instability, the Company faced with obstacles in finding personnel who is willing to work there. Finally, they had to employ a site manager who does not have enough experience in similar works. Site manager's insufficient technical competence resulted in a new crisis due to improper selection of suppliers. Project required a detailed geotechnical investigation, but at tendering stage, the Company made several assumptions about soil data instead of a detailed site survey. Being inexperienced in the region, not having a detailed geotechnical report and wrong quantity estimation at the tendering stage resulted in significant deviations from the initially assumed quantities regarding the pile foundations. Large-scale of the project and contract type (lump sum) influenced the severity of this event and resulted in severe financial losses. The company tried to overcome this issue by making a claim. However, the frequent change of project managers and team members slowed down the claim preparation progress. Complex managerial requirements of the project and unfamiliarity with contract requirements also caused some financial problems. According to the contract, progress payments were not made unless all the reporting was done according to the format defined in the contract. The owner assigned a consulting firm to examine the submitted documents to accelerate the approval process. The project was delivered with two months delay and with a lower profit than expected.

2. Project B – It has very similar technical characteristics with Project A. This time, the Company was responsible for design, manufacturing and construction. The Company did not have any partner. The Company had previously completed several projects for the same client and chose subcontractors and suppliers that they worked together before. The project manager, who was an expert in this type of projects, controlled the project at site, which eliminate the communication problems with parties and accelerate the approval process. The project was performed in the North side of the same country, where there was more stability in social life. The company performed several projects in this region and did not face with any unexpected conditions affecting the project execution. The managerial complexity of the project was lower when compared with Project A. Team turnover rate in the project was very low, and there were no changes in the organizational structure. The most critical issue was the consulting company who assigned only one engineer to the project. The engineer did not have enough technical capacity; therefore, he slowed down the process. The project was delivered on time and within budget.

It is clear that although the company is the same, different strategies were utilized in the projects. Different parties involved in the projects and contract clauses significantly affected the level of vulnerability. Some examples of project vulnerabilities identified through case studies are summarized in Table 3.

Table 3: Examples of Risks and Project Vulnerabilities from the Case Studies

Case	Risk Event	Project Vulnerability

Project A	Poor Performance of Partner	Partner could not fulfill his responsibilities because of his insufficient capacity and lack of enough experience.
Project B	-	The Company performed the project on his own. It had enough experience and resources to complete project successfully.
Project A	Poor competency of staff	Because of the social instability in South region, the Company could not find an experienced manager willing to work there and had to choose an inexperienced site manager.
Project B	-	In Northern side, there were not any security problems; so the Company could easily find a very qualified manager.
Project A	Delay in approvals	Project is directed from the headquarter; communication through e-mails on critical issues took much time.
Project B	-	Project was directed at site, there were not any communication problems. In addition since they worked together before, relations between parties were good.

Table 3: Examples of Risks and Project Vulnerabilities from the Case Studies (continued)

Case	Risk Event	Project Vulnerability
Project A	Delay in progress payments	Owner made payments when progress reports were completely submitted. Because of the unfamiliarity with this system, company could not submit the required documents on time.
Project B	-	The managerial requirements were very low. Submitting photos proofing the progress at site was enough for Owner.
Project A	Delay in logistics	Due to heavy quality requirements, several suppliers from different countries were selected which result in coordination problems.
Project B	-	The chosen suppliers were all in the host country, and the relations with suppliers were good.

It is clear from the case study projects that vulnerability factors may affect different stages of the risk emergence process. Some vulnerability parameters affect the probability of occurrence of risk. For example, in Project A, heavy technical requirements of the project caused an unexpected change in partner’s performance, which is considered as a low probability risk at the first stages. Thus, “technical complexity” is a potential vulnerability factor that may increase the risk of poor performance. Another vulnerability factor mentioned in the case studies was “unfamiliarity with FIDIC type of contract” which resulted in “conflict between project participants”. Some vulnerability factors may affect manageability of risk. For instance, in Project B, an experienced site manager controlled the project at site, which minimized delay risk for the company. Vulnerabilities may also influence the impact of risk events on project success. In other words, those are the factors, which affect the magnitude of risk consequences. For instance, wrong quantity estimation during tendering stage caused severe financial losses for company because the contract/payment type was lump sum.

CONCLUSION

In this paper, the concept of vulnerability as a part of risk assessment was introduced and factors that can be used for vulnerability assessment were presented. A hierarchical structure that comprises of factors related with the contract, company, project and parties involved in the project were developed. Validity of these factors was discussed by referring to findings of two case studies. The major conclusions derived as a result of case studies are as follows:

1. The vulnerability factors affect project success by interfering with the risk events in different ways. Some vulnerability parameters affect the probability of occurrence of risk, some of them affect manageability of risk and some vulnerability factors may influence the impact of risk events on project success.

2. Vulnerability should be assessed within the context of risk scenarios. Vulnerability assessment should be done simultaneously with risk assessment. Risks should be examined through paths (risk source- risk event- risk consequence paths) and vulnerabilities should be added to those paths for estimation of risk impacts on project success. A hierarchical vulnerability structure that excludes risk factors and a multi-criteria vulnerability assessment process that does not consider risk paths may give unreliable results if used for quantification of level of vulnerability in a project. Thus, an integrated risk-vulnerability assessment procedure has to be developed.

This paper presents the initial findings of an ongoing research. It is evident that only two case studies are not enough to understand the risk-vulnerability relations and validate the identified vulnerability factors. In the forthcoming stages of this research, more case studies will be carried out to finalize the vulnerability parameters and define generic risk-vulnerability paths that can be used for risk modeling of international construction projects.

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