EVALUATING PROJECT RISKS OF PROJECT DELIVERY SYSTEMS IN CONSTRUCTION PROJECTS

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Abstract: This paper investigates two different project delivery systems in Taiwan and Japan, and presents a pilot study to evaluate the effectiveness of risk reduction of these systems in construction projects. Basically, Fault Tree Analysis is used to assess the probability of risk occurrence and to identify the importance of risk factors contributing to risk occurrence. Facilitating dual structure between Fault Tree Analysis and Reliability Graph Analysis, the comparison for the effectiveness of risk reduction between project delivery systems for stakeholders was evaluated. In the same time, the project management in Japan is discussed from the viewpoint of risk management.

Keywords: project risk, risk factor, project delivery system, Fault Tree Analysis, Reliability Graph Analysis

1. INTRODUCTION

The procurement systems and project delivery systems are focused due to the complexity and large-scale of construction projects. The projects' participants (called "stakeholder" in this paper) should assess which project delivery system [1] should be developed in their risk response system [11]. In this paper, the data obtained by an investigation is analyzed from the viewpoint of the international comparison in consideration of the different backgrounds of the projects. And, the features and the project risks of the delivery systems are derived from this comparison.

The major purposes of this paper are:

1) To derive the features of the delivery systems of construction projects from the investigation of real construction projects.

2) To develop an effective method of risk evaluation for delivery systems of construction projects by the qualitative/quantitative analysis.

In order to present the real life span of construction projects, the three major phases of the project are quoted from IMEC [7]. Those are Front-End Debates (FED), Strategic Project Definition (SPD) and Engineering, Procurement and Construction (EPC). The major risk strategies are classified and simplified as Contingency Planning, Mitigation, Allocation and Deflection [11].

2. ANALYSIS APPROACH

The approach of this study is shown in Figure 1. In chapter 3, the difference of construction industries between Taiwan and Japan and the reasons why the projects are specified in Taiwan and Japan are discussed. Then, the risk data of these two projects are investigated for the analysis in next step. In chapter 4, the authors use the data to do qualitative and quantitative analysis of these project delivery systems. Fault Tree Analysis (FTA) is used to build and evaluate the general model of project risk that describes the causal scenario among risk causes. The concept of dual structure between FTA and Reliability Graph Analysis (RGA) is used to make the comparison of the effectiveness of risk reduction between project delivery systems for stakeholders. And, the result of analysis is examined to explain the project risk of these two project delivery systems.

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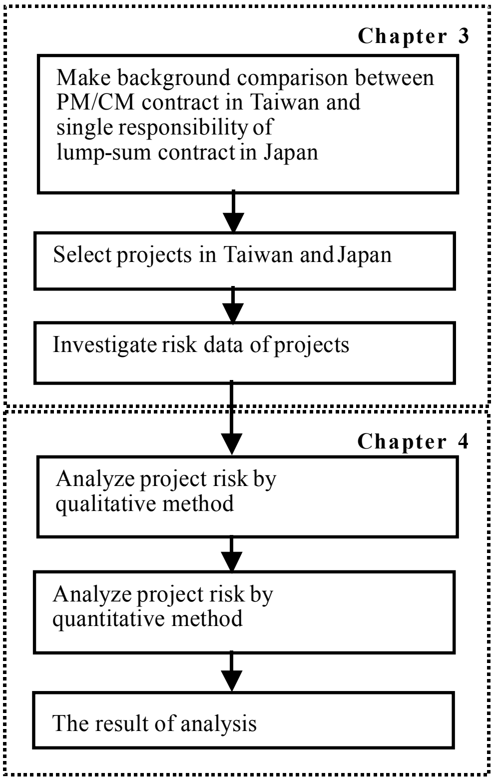

Figure 1. Analysis approach of this study

3. COMPARISON OF BACKGROUNDS AND INVESTIGATION OF PROJECTS

3.1 Project delivery systems in Taiwan and Japan

From the following two reasons the authors choose the project to which the project management & construction management (PM/CM) is adopted in Taiwan and the one to which the single responsibility of lump-sum contract is adopted in Japan for the large-scale construction projects [2][3][6][8].

1) Construction market:

The gross domestic product for one people of Taiwan became 8,000-10,000 U.S. dollars in the latter half of 80's, and demand for the high-rise building is increasing. A lot of investors who did not have the knowledge of construction entered the construction market. And, this caused the motives of these investors to use PM/CM for each project.

On the other hand in Japan, the single responsibility of lump-sum contract is used in 60% to 70% of construction projects. And, the design-build contract is used in the remainder of construction projects. The PM/CM contract is not well prepared and not established in institutional regulation, only few private projects are trying to be operated by this delivery system. Until now, most of the clients in Japan can not understand the advantages of the PM/CM contract, and only recognize the merits of the single responsibility of lump-sum contract.

2) Technology:

The building projects of Taiwan become high-rise and large-scale from the latter half of 80's. For instance, the proportion of 15 meters or more in the height of the building in building permits which is 62.0% in 1996 and 63.4% in 1997 respectively. The judgment whether all should depend on a designer or a contractor for the investor makes the needs for the PM/CM as another alternative.

On the other hand in Japan, large general contractors are assumed to have a high construction and management ability, which is one of the reasons why the single responsibility of lump-sum contract is trusted by the clients. For example, the ratio of research expenses versus sales of the entire Japanese construction industries is about 0.4%, but the ratio reaches about 1.0% and research expenses exceed 10 billion yen in one year for some large construction companies. From an international comparison viewpoint, the research and development desire of the large construction companies pushes the evolution of the construction technology of Japan.

3.2 Investigation of projects in Taiwan and Japan

1) The project of PM/CM in Taiwan

Project: High-rise building of multi-functions in Taipei City (T-Project as follows)

Investigation time: February, 2000

Investigation method: Interview, questionnaire, and literature review

Investigation purpose: Detailed analysis of current situation of new project delivery system and ideology analysis of project risk

Investigation entity: Main stakeholders of the owner, the designer, the PM/CM, and the general contractor (GC) (Nationality of each stakeholder is different respectively)

Project phase: In consideration of the timing of participation in the project, the owner is for FED/SPD/EPC, the designer is for SPD/EPC, the PM/CM and the GC are for EPC

Investigation content: Ideology and evaluation of project risk and management

2) The project of single responsibility of lump-sum contract in Japan

Project: High-rise building of office in Osaka City (J-Project as follows)

Investigation time: December, 1998

Investigation method: Interview, questionnaire, and literature review

Investigation purpose: Probability analysis and ideology analysis of project risk

Investigation entity: Main stakeholders of the owner, the consultant, the designer, and the GC (All stakeholders are local)

Project phase: In consideration of the timing of participation in the project, the owner and the consultant are for FED/SPD/EPC, the designer is for SPD/EPC, the GC is for EPC

Investigation content: The probabilities and evaluation of 29 risk causes and concerning risk strategies (Table 1)

4. RISK ANALYSIS

4.1 The qualitative analysis

For T-Project, major stakeholders were definite to the owner, the designer, the PM/CM, and the GC. The owner contracted with the designer, the PM/CM and the GC directly (Figure 2). The PM/CM is as a representative of owner to provide some advises for the design and supervise the construction. For J-Project, major stakeholders were definite to the owner, the consultant, the designer and the GC. The owner contracted with the consultant and the GC directly, and the consultant who is as a general supervisor contracted with the designer (Figure 3).

From the viewpoints of owners, Table 1 shows the result of risk strategies and other parties for 29 risk causes in EPC through the contract relationship and the local investigation of both projects. There are only mitigation and deflection of risk strategies that are used by the owner who depends on the consultant and the GC very much in J-project. On the other hand, there are various risk strategies that are used by the owner who does not rely on specific other party alone in T-project. As for the evaluation of management situation, Figure 4 shows the result of six items about the complexity of the project. Every stakeholder evaluates with a high score for "PM/Coordination are vague, and complex".

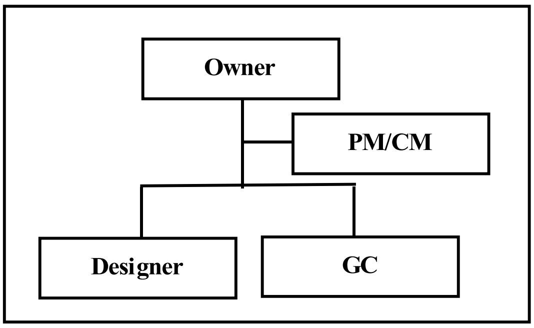

Figure 2. Contract relationship in T-Project

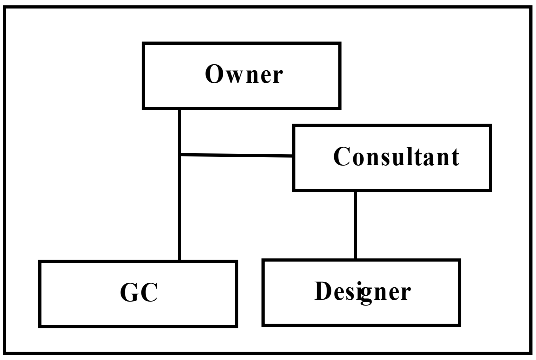

Figure 3. Contract relationship in J-Project

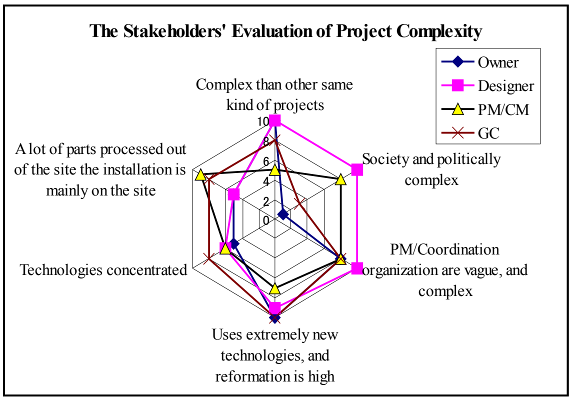

Figure 4. Project complexity for T-Project

As the local investigation and literature review [11][14][15], the risk factors of the projects can be categorized into internal risks and external risks. So the project risk for each stakeholder associates to two major risk modes. Applying the concept of FTA, as shown in Figure 5 [12], they are "A1: Failure of Project Management" and "A2: Failure of Adaptation to External Environment".

These risk modes can be divided into subsequent risk modes and risk causes. For example, the risk mode of A1 can be divided into "Failure of Project Execution " and "Failure of Management". The risk mode of A2 can be divided into "Failure of Adaptation to Predictable Factors" and "Failure of Adaptation to Unpredictable Factors" [11]. The risk cause X6 can be further divided into risk causes such as failure of adaptation to postulate, natural hazards, unanticipated government intervention, unexpected side effects and completion failure. Following the general model of project risk, the 29 risk causes for normal construction projects were identified for X1 to X6 in hierarchy as Table 1.

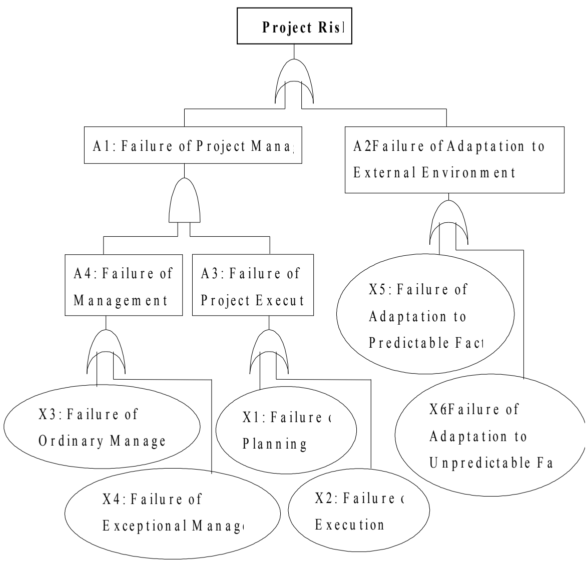

Figure 5. General model of project risk [12]

Table 1. Risk strategies and other parties in EPC for Owner

Risk Cause		J-Project		T-Project	
Item (1)	Description (2)	Strategy (3)	Other Party (4)	Strategy (5)	Other Party (6)
1. X111	Failure of Project Definition	D	C		
2. X112	Failure of Resource Allocation	D	C		
3. X121	Failure of Concept Design	D	C	A	D
4. X122	Failure of Detail Design	D	C	A	D
5. X131	Failure of Labor Acquirement				
6. X132	Failure of Material/Equipment Acquirement			D	G
7. X211	Failure of Labor Execution	D	G	D	G
8. X212	Failure of Material Supply				
9. X213	Failure of Equipment Execution				
10. X311	Failure of Quality Planning	D	C	A	P
11. X312	Failure of Quality Control	D	C	A	P
12. X321	Failure of Cost Planning	M		A	P
13. X322	Failure of Cost Control	M		A	P
14. X331	Failure of Schedule Planning	D	G	D	G
15. X332	Failure of Progress Control	D	G	D	G
16. X411	Failure of Scope-Change Management	D	G	A	P
17. X412	Failure of Design-Change Management	D	G	A	P
18. X413	Failure of Technology-Change Management	D	G	A	P
19. X511	Failure of Adaptation to Inflation	D	C	M	
20. X512	Failure of Adaptation to Currency Change	M			
21. X513	Failure of Adaptation to Environmental Impact	D	C	D	G
22. X514	Failure of Adaptation to Market Change	D	C	M	
23. X515	Failure of Adaptation to Social Impact				
24. X516	Failure of Adaptation to Tax Change	D	C	M	
25. X611	Failure of Adaptation to Postulated				
26. X612	Failure of Adaptation to Natural Hazards	M		M	
27. X613	Failure of Adaptation to Unanticipated Government Intervention	D	C		
28. X614	Failure of Adaptation to Unexpected Side Effects	D	C	D	G
29. X615	Failure of Adaptation to Completion Failure	D	C	D	G

Remark:
1. Strategy: C: Contingency Planning, M: Mitigation, A: Allocation, D: Deflection
2. Other Party: C: Consultant, D: Designer, G: General Contractor, for J-Projects
3. Other Party: D: Designer, P: PM/CM, G: General Contractor, for T-Project

4.2 The quantitative analysis

Because the T-Project is just in the beginning of the construction phase, there are a lot of uncertain conditions that make the stakeholders difficult to answer the probabilities of risk causes, risk strategies and other parties. So the data of J-Project is applied to make the quantitative analysis of both projects, which is to assume the J-Project is operated by these two delivery systems in Japan, and to simulate how much project risk will be for stakeholders. There are three steps in the quantitative analysis as follows.

Step 1: In order to calculate the probability of project risk, FTA is used to build the general model of project risk as Figure 5. Logic gates of “AND gate” and “OR gate” are to describe the relationship of failure factors by Fault Tree (FT). FT is composed of failure interactions among devices, software, material, and human [10]. The quantitative definition of project risk in FTA is as below.

Probability of risk occurrence: When every risk cause Xi in every minimal cut-set *Kj* (*j=1,…,k*) occurs, the probability of project risk is obtained from Equation (1).

$$g(\boldsymbol{q}) = \coprod_{j=1}^{k} \prod_{i \in K_j} q_i \qquad (1)$$

where

$$\prod_{i=1}^{n} x_i = min\{x_1, x_2, \ldots, x_n\} = x_1 x_2 \ldots x_n \qquad (2)$$

and

$$\coprod_{i=1}^{n} x_i = max\{x_1, x_2, \ldots, x_n\} = 1 - (1 - x_1)\ldots.(1 - x_n) \qquad (3)$$

$g(q)$: Probability of risk occurrence

q_i : Probability of risk cause Xi

Step2: In order to evaluate the effectiveness of risk strategies, dual structure between FTA and RGA is used to compare the difference of risk strategies in project delivery systems. Every FT can be mutually transferred to a Reliability Graph (RG) [9]. “OR gate” of FT is the series allocation of RG and “AND gate” of FT is the parallel allocation of RG. The risk strategies in RG are shown in Figure 6 [12]. OP is assumed to be other party to which the job is issued. Contingency planning cannot reduce the probability of risk factor, but mitigation can reduce some of the probability. Allocation is to put some redundancy on risk factor but deflection is to replace this risk factor.

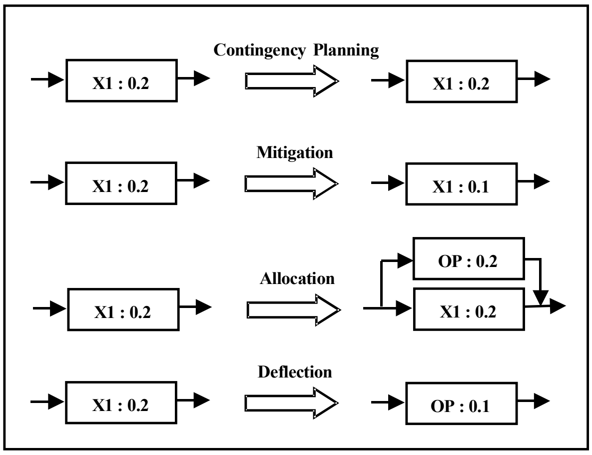

Figure 6. The meaning of risk strategies in RG

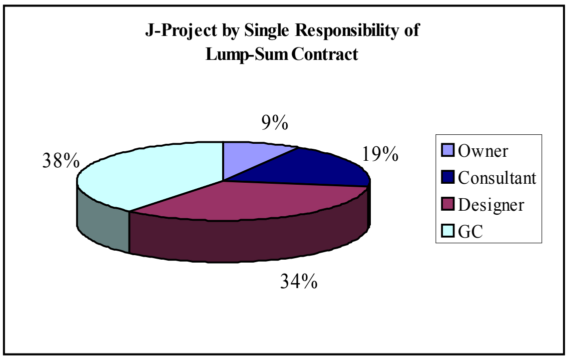

Figure 7. Probability proportion of project risks before adopting risk strategies in EPC

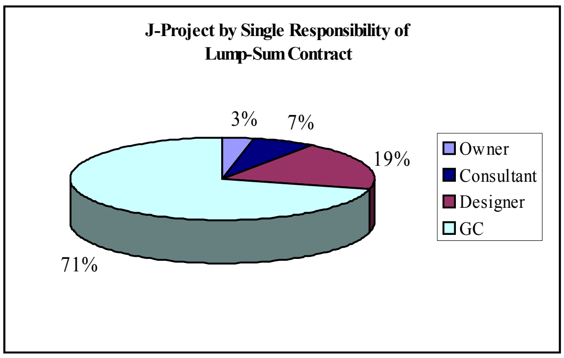

Figure 8. Probability proportion of project risks after adopting risk strategies in EPC

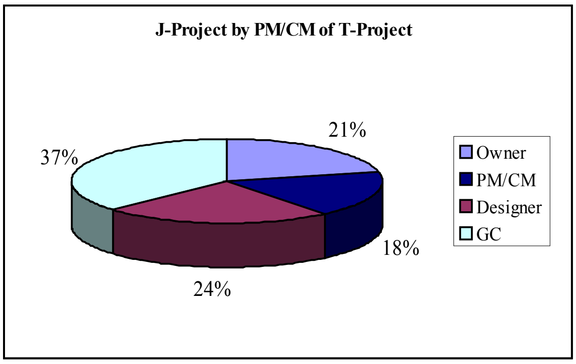

Figure 9. Probability proportion of project risks before adopting risk strategies in EPC

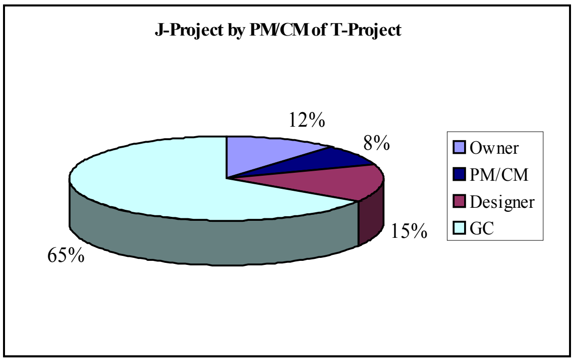

Figure 10. Probability proportion of project risks after adopting risk strategies in EPC

Step 3: Input the probabilities of 29 risk causes into the Equation (1), the probability of project risk before adopting risk strategies can be obtained (Figure 7, 9). And, the probabilities of risk strategies and other parties are incorporated to the probabilities of 29 risk causes by the concepts of Figure 6, then the probability of project risk after adopting risk strategies can be assessed by Equation (1). For example, the column of J-Project in Table 1 is used to evaluate the probability of project risk after adopting risk strategies for J-Project is operated by the single responsibility contract in EPC (Figure 8). And, the column of T-Project in Table 1 is used to evaluate the probability of project risk after adopting risk strategies for J-Project is operated by the PM/CM of T-Project in EPC (Figure 10).

Figure 7, 8 show the probability proportion of project risks for stakeholders in EPC when J-Project is operated by the single responsibility of lump-sum contract. Figure 9, 10 show the probability proportion of project risks for stakeholders in EPC when J-Project is operated by the PM/CM of T-Project. From the viewpoint of risk, there is not obvious difference between these two delivery systems for the GC to take large proportion about 65% to 71% of risk probabilities in EPC. But, it is totally different to the owner who takes only 9% and 3% of risk probabilities in Figure 7, 8 when J-project is operated by the single responsibility of lump-sum contract. The values are smaller than 21% and 12% of risk probabilities in Figure 9, 10 when J-Project is operated by the PM/CM of T-Project. Also, the proportion of risk probabilities for the designer can be reduced very radically, from 34% to 19%, when J-project is operated by the single responsibility of lump-sum contract. If we consider the nature of the role for the consultant and the PM/CM is similar in construction projects, especially when the projects are operated in Japan, we can find out the proportions of risk probabilities for both stakeholders are very similar in these two delivery systems.

5. CONCLUSIONS

In this paper, the project risks of delivery systems were analyzed from the local investigation based on the proposed analysis model. As for the reduction of the risk, the single responsibility of lump-sum contract is clear and more effective for the client in Japan than the PM/CM. And, it is understood from the analysis result that the owner should realize his/her own role in the project, and do more efforts to accomplish his/her responsibility, when project is operated by the delivery system of the PM/CM. In order to improve the accuracy of analysis, it is necessary to continue the investigation, and compare with other delivery systems. The next study will be the comparison between these two delivery systems by the environmental conditions of Taiwan.

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REFERENCES

[1] American Institute of Architects, “ Handbook on Project Delivery. ” AIA California Council., 1996

[2] Chang, W.N., “Building Law in Taiwan”, Jen Publish, Inc., 1999

[3] Construction and Planning Administration Ministry of Interior, Taiwan, “Statistical Analysis of Construction”, Ministry of Interior, Taiwan., 1999

[4] Endoh, K., Furusaka, S. and Sasaki, Y., “ Studies on Organization of Sub-package for Building Construction (7), Organizational Behavior Under Uncertainty.” Proceedings of Sixth Symposium on Organization and Management of Building Construction, pp.247-252, Architectural Institute of Japan., 1990

[5] Evans R. E., Olson D.L., “Introduction Simulation and Risk Analysis”, Kozo Keikaku Engineering, Inc., 1999

[6] Hisatomi, Y., “PM/CM for Japanese General Contractors”, The reports of situations and themes of PM/CM in Japan, JIA., 1996

[7] IMEC. (International programme on the Management of Engineering and Construction), “ Imec Benchmarking Handbook.” IMEC., 1995

[8] Japan Federation of Construction Contractors, “1999 Handbook of construction industry”, JFCC., 1999

[9] Inoue, I., “ FTA Safety Engineering.” Research Institute of Safety Engineering., Tokyo, Japan., 1979

[10] Kumamoto, H., and Henley, E. J., “ Probabilistic Risk Assessment and Management for Engineers and Scientists.” IEEE PRESS., 1996

[11] Project Management Institute Standards Committee, “ Project Management Body Of Knowledge.” PMI, USA.., 1987

[12] Tsai, T.C., Furusaka, S., Kaneta, T., "Evaluating Risk Factors and Risk Strategies of Procurement Systems in Construction Projects", Proceedings of the 2nd International Conference on Concurrent Engineering in Construction, pp.357-366, 1999

[13] Tsai, T.C., Furusaka, S., Kaneta, T., " International Comparative Study on The Management of Large-Scale Engineering Construction, Part 2: The Trends of Construction and Building Production System in Taiwan ", Proceedings of 16th Symposium on Organization and Management of Building Construction, (Accepted), Architectural Institute of Japan., 2000

[14] Williams, T. M., “ Using a risk register to integrate risk management in project definition.” International Journal of Project Management Vol. 12, No. 1, pp.17-22., 1994

[15] Yeo, K. T., “Strategy for risk management through problem framing in technology acquisition.” International Journal of Project Management Vol. 13, No. 4, pp. 219-224, 1995

[16] Zhi, H., “ Risk management for overseas construction project.” International Journal of Project Management Vol. 13, No. 4, pp. 231-237, 1995