Doctor of Philosophy

Risk Event Management for International Construction Project Using Case-Based Learning

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Abstract

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International construction projects normally involve high level of risks because of the differences in construction practices, working conditions, cultures, and political, legal, and economic conditions between domestic and overseas markets. The risks (e.g., Knowns, Known-unknowns, and Unknown-unknowns) from uncertainties of international construction projects cause risk events during construction execution, which arise losses in project cost and schedule. To manage the risks from their project's uncertainties, the construction contractors have introduced the risk management with its principles and framework to their projects for its success. Based on the risk management process including risk identification, analysis, and evaluation, the construction contractors propose a financial and

other risk treatments such as removing or avoiding the identified risks in planning phase, planning response strategies for predictable risk events in advance, and estimating a contingency covering potentially required changes (i.e., contingency reserve).

However, the risk management process based approach still has limitations for managing risk events of construction execution. In other words, the current practices of risk management cannot cover the entire risk events, and unexpected risk events still remain in construction execution because of a complexity of the interrelationship between risks, a limitation of risk identification, and difficulties in predicting risk value. As a result, the estimated contingency reserve and planned response strategy cover only predictable risk events. For instance, despite its role and importance, the contingency for unplanned changes (i.e., management reserve) is often estimated as a percentage of the estimated project cost baseline (i.e., deterministic point estimation). In addition, the response strategies for recovering risk events are still determined based on the experiences of contractors when the unpredictable risk events occur, which has no theoretical and scientific foundation. These weaknesses have raised the need for a more robust and systematic approach to manage the risk events in international construction projects.

As an effort to address these challenging issues, this research proposes a risk event management framework for international construction projects. In particular, a management reserve estimation method and a response strategy decision-making support model are developed using pertinent or similar instances with an application of case-based learning. It starts by analyzing backgrounds on risk management of international construction projects and methodologies applied in this research for developing the case-based learning. Then, variables are selected by considering uncertainties of international construction projects. Based on the extracted variables, the management reserve estimation method and response strategy decision support model are developed by applying the Case-Based Reasoning (CBR) for retrieving pertinent cases. In addition, this research also adopts Genetic Algorithm (GA) and Analytic Hierarchy Process (AHP) for variable weighting and as a result, improves the performance of CBR classifications. Finally, to clarify the developed management reserve estimation method and response strategy decision support model, case studies are conducted to validate retrieval performance of the proposed methods and test its applicability in international construction projects.

This research contributes to a risk event management with a consideration of its unpredictable characteristic until realized as outcomes. Specially, the management reserve is estimated as a budget set aside in addition to the specific risk provision (i.e., the contingency reserve) to achieve the project objectives in the face of as yet unidentified risks. With this, the response strategies and solutions can support decision-making of contractors for determining an appropriate and immediate recovery plan

when the risk events are caused. As a result, this research enables construction contractors to cope with emergent risk events during construction execution, and then minimizes a likelihood of project cost increase and losses in time of international construction projects. Academically, this research proposes a more robust, systematic, and suitable approach for estimating the management reserve and developing case-based decision-support model for managing international construction risk events.

Keywords: International Construction Project; Risk Management; Management Reserve; Response Strategy; Case-Based Learning

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Chapter 1 . Introduction

International construction projects normally involve a high level of risks, and the likelihood of project cost increases and losses in time is considerably higher than domestic construction projects. To manage the risks, construction contractors applies the risk management process including risk identification, analysis, and evaluation. Based on the analysis, it estimates a contingency as a provision covering potentially required changes and plan response strategies for predictable risk events. However, the estimated contingency and planned response strategies cannot cover the entire risk events occurring during construction execution. For instance, the risk events from interrelationship between Unknown-unknowns and other risks is not predictable due to its complexity of the interrelationship, a limitation in risk identification, and a difficulty in predicting and managing risk values. These weaknesses have raised the need for a more robust and systematic approach to manage the unpredictable risk events of international construction projects.

This chapter presents a brief overview of research background and motivation. For this, the cost and schedule performance of international construction projects are first analyzed to comprehend its current states and significance of risk management application. The problem statement, research objective and scope, and research significance are then discussed. Finally, the research procedure is provided at the end of this chapter.

1.1 Research Background and Motivation

The construction projects became more complex according to the its increasing scale, nature of the different activities, and involvement of many equipment and materials. This complexity increases the uncertainty of construction projects steadily (Imbeah and Guikema 2009; Liu et al. 2013). In particular, the international construction projects normally involve a high level of risks because of the differences in construction practices, working conditions, cultures, and political, legal, and economic conditions between domestic and overseas markets (Bu-Qammaz et al. 2009; Zhi 1995). The higher risk expands a likelihood of arising larger project costs and losses in time compared with domestic projects (Xiang et al. 2012).

In these contexts, this research first analyzes the performance of construction projects undertaken in overseas country to understand its current state. According to the historical data from the International Contractors Association of Korea (ICAK), construction contractors in Korea executed the 2196 international projects from 1990 to 2010, which are composed of 890 architectural contracts, 579 civil contracts, and 727 plant contracts (Table 1-1). For architectural contracts, the number of contracts with profit greater than zero are 611 which is 68.7% of total architectural contracts. Also, the number of contracts with profit equal to zero are 211 which is 23.7% of total architectural contracts. Finally, the number of contracts with profit less than zero are 68 which is 7.6% of total number of contracts. In case of contracts for civil construction, the number of contracts with profit greater than zero are 386 with 66.7% of total civil contracts. For profit equal to zero and less than zero, the number of contracts are 135 and 58 each, with a percentage of 23.3 and 10.0. Finally, the number of plant contracts with profit greater than zero are 422, which is 58% of total plan contracts. Furthermore, the number of contracts with profit equal to zero and less than zero are 247 and 58 respectively, with 34% and 8% of total plant contracts. In conclusion, the number of international construction projects with profit less than zero had 184 cases with a percentage of 8.4 compared to the total number of contracts.

Table 1-1. Cost performance of international construction projects

Classification		Number of contract (Ratio)	Number of Profit>0 (Ratio)	Number of Profit=0 (Ratio)	Number of Profit<0 (Ratio)
International construction projects		2196 (-)	1419 (64.6%)	593 (27.0%)	184 (8.4%)
Construction type	Architecture	890 (40.5%)	611 (68.7%)	211 (23.7%)	68 (7.6%)
	Civil	579 (26.4%)	386 (66.7%)	135 (23.3%)	58 (10.0%)
	Plant	727 (33.1%)	422 (58.0%)	247 (34.0%)	58 (8.0%)

Although the number of projects with profit less than zero is 184 (i.e., 8.4% of total number of international construction projects), this research understood the cost and schedule performance indexes (CPI and SPI, respectively) (Fig 1-1). This research comprehends the international construction projects indicating big size of losses in their cost and schedule. These projects should be managed not to cause a liquidity crisis of construction companies.

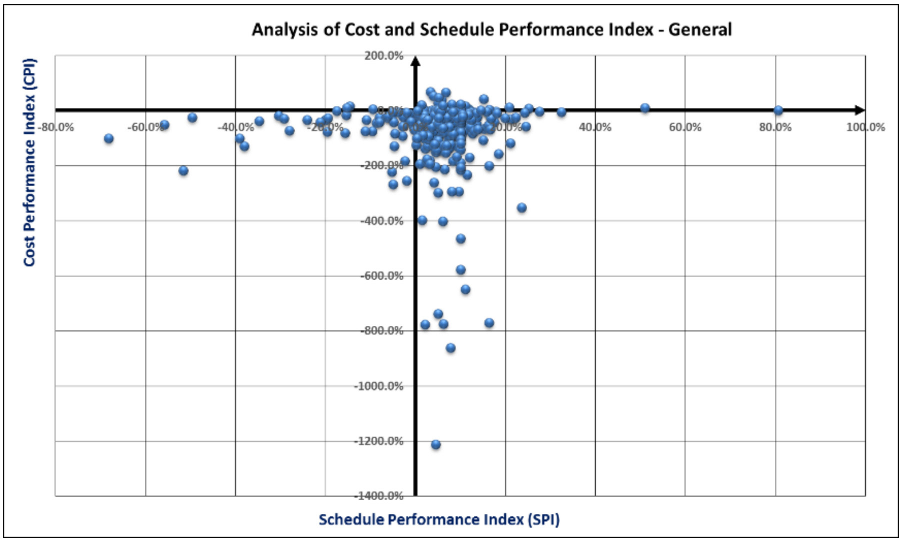

Figure 1-1. Cost and schedule performance indexes of international construction projects

In addition, this research also analyzes the contract cost and duration of international construction projects to comprehend its changes along the passage of time. Fig 1-2 shows the cost and duration changes of international construction projects. The average contract cost increases gradually, and average contract duration decreases. In other words, the average construction cost per day increases. This indicates that the likelihood of project costs increase and drops in time become considerably higher than its past state because of its increased uncertainty for construction execution (i.e., increased construction cost per day).

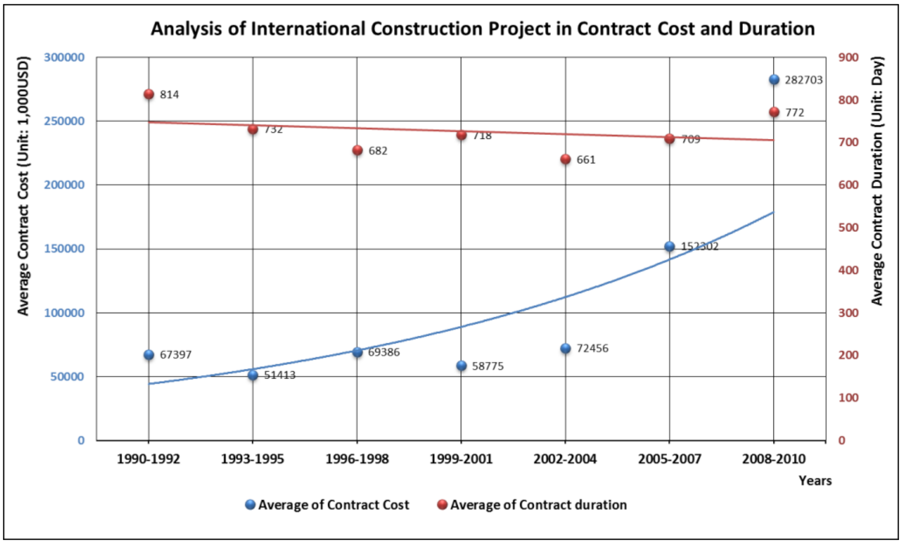

Figure 1-2. Contract cost and duration of international construction projects

To mitigate the likelihood of arising larger project cost and time losses, the construction companies analyze the causes incurring losses in their project cost and schedule by considering the life-cycle of construction project and recognize the unexpected risk events during international construction execution (Fig 1-3). For instance, the risks from uncertainty of construction projects cause unexpected risk events during construction execution and it causes the cost increase and time delay. To minimize the losses from risk events, the construction companies have introduced the risk management to their projects for its success by managing risks from their project's uncertainties (Monetii et al. 2006; Zhi 1995; Zou et al. 2010).

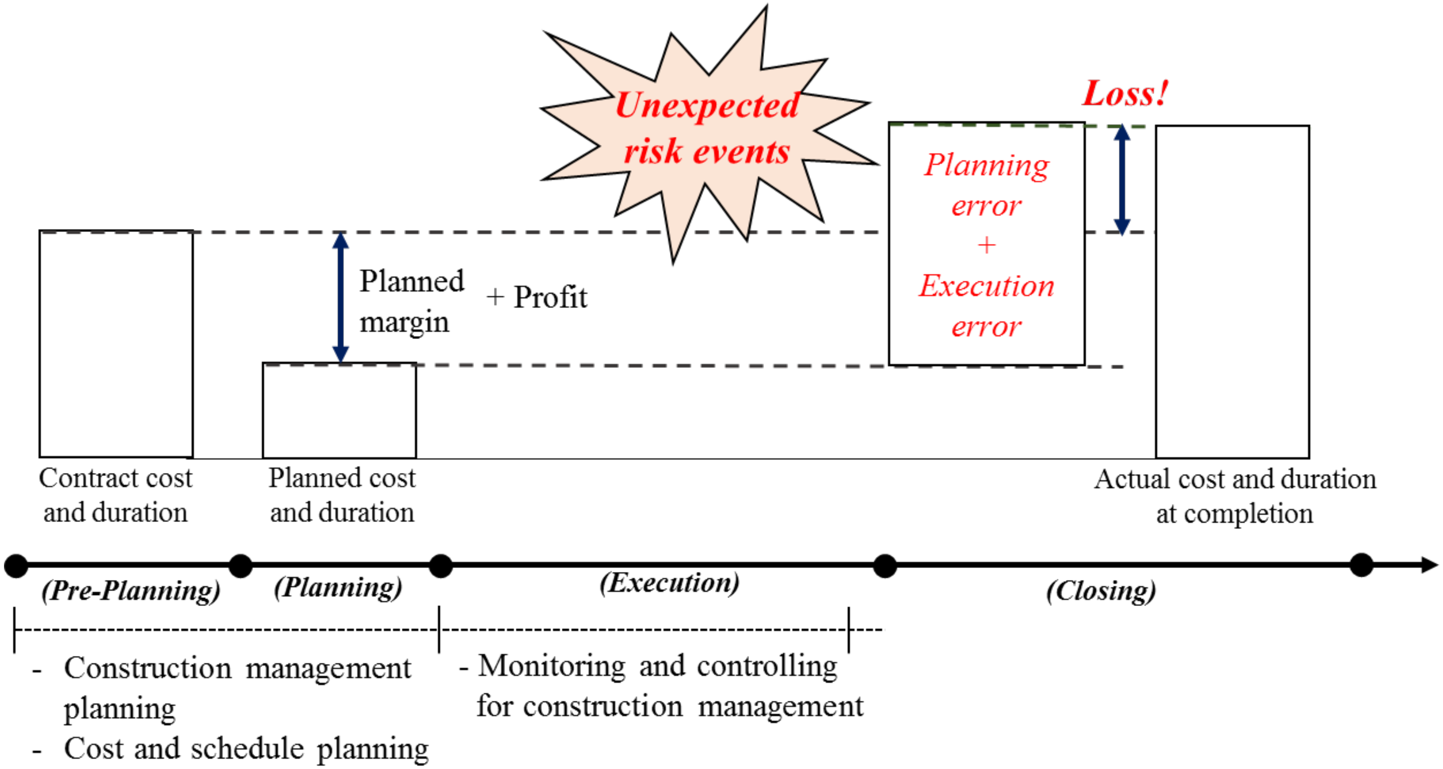

Figure 1-3. Losses in project cost and schedule

1.2 Problem Statements

The construction contractors applies the risk management process with its principles and framework to their projects (Monetii et al. 2006; Zhi 1995; Zou et al. 2010), which generally includes establishment of the context, risk assessment, and risk treatment [Berkeley et al. 1991; Institute of Risk Management (IRM) 2002; International Organization for Standardization (ISO) 2009; Jia et al. 2013; Office of Government Commerce (OGC) 2006; Project Management Institute (PMI) 2013; Smith et al. 2006; Wang et al. 2004]. Based on the risk management process, the construction contractors assess the risks by conducting risk identification, risk analysis, and risk evaluation. As a result, they could manage the risk events from the identified risks (i.e., specific risks related with a project's threat) through removing or avoiding the risk events, planning response strategies and solutions for the risk events, and estimating a contingency covering potentially required changes (i.e., contingency reserve).

However, the risk management process based approach still has limitations for managing risk events of construction execution. To manage the risks more effectively, the following problems should be discussed.

(1) The current risk management practices cannot cover the entire risk events and as a result, unexpected risk events still occur during construction execution due to the following reasons (Fig 1-4).

- A complexity of the interrelationship between risks - the risks are generally classified into three categories in accordance with its characteristics related to identification and probability of occurrence: (1) Knowns, (2) Known-unknowns, and (3) Unknown-unknowns [Berg and Tideholm 2012; Construction Industry Institute (CII) 1989]. These risks causes the risk events through interaction between the risks in construction projects. In this situation, there are difficulties to find out the interrelationship of risks and predict the risk events due to a complexity from different environmental factors of international construction projects. For instance, different environmental factors cause a different interaction procedure leading to risk events.
- A limitation in risk identification - there are risk factors which has have not been identified in advance and therefore the probability cannot be known (i.e., Unknown-unknowns). Therefore, the risk events related with the Unknown-unknowns cannot be predicted in initiating and planning phase owing to the unidentifiable nature of Unknown-unknowns.
- A difficulties in predicting risk values – the construction contractors can remove or avoid the risk events by managing the variability of risk values. However, the prediction of risk factor’s value is difficult because many of risk factors are microscopic variable related with the country’s economic, political, social, and cultural environments.

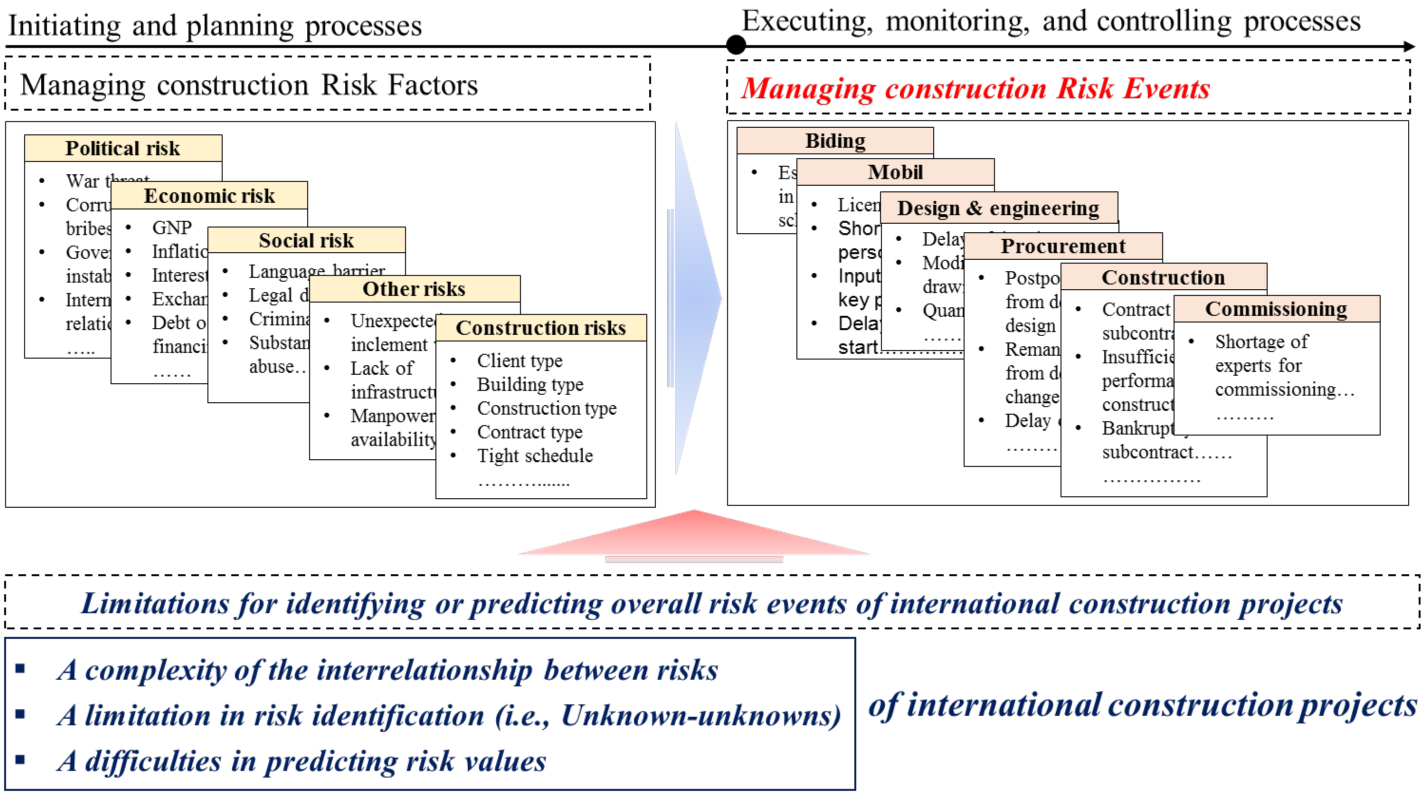

Figure 1-4. Current construction risk management practices and limitations

(2) Another issue related to unexpected risk events during construction execution can influence project cost and schedule performance markedly (Berg and Tideholm 2012). For instance, it is hard to respond to such unpredictable events immediately. Therefore, a likelihood of project cost increase and losses in time is greater compared with those of predicted (and thus planned) risk events. This weaknesses have raised the need for a more robust and systematic approach to managing the unexpected risk events of international construction projects.

(3) To mitigate negative effects from the risk events, the construction contractors typically include a reserve (i.e., contingency) in their project costing, which can be classified into two categories: (1) contingency reserve covering potentially required changes (i.e., specific risk events relating to a project's threat) and (2) management reserve covering unplanned changes (i.e., emergent risk events). In these contexts, previous research has estimated the CR and MR (Baccarini 2004; Eldosouky et al. 2014; Mak and Picken 2000; Thal et al. 2010; Touran 2003; Xie et al. 2012; Yeo 1990). First, the contingency reserve can be estimated by considering the cost of the identifiable risk events. As a result, various estimation techniques have been developed to assess the contingency reserve (e.g., traditional percentage method, method of moments, Monte Carlo simulation, factor rating method, range estimation method, regression

analysis, artificial neural networks, fuzzy sets, influence diagrams, analytical hierarchy process) (Baccarini 2005). (Fig 1-5).

- On the contrary, few investigations have proposed to estimate the management reserve based on the cost of the unidentifiable or unpredictable risk events.
- As a result, despite its role and importance, the management reserve is often estimated just as a percentage of the estimated project cost baseline (i.e., deterministic point estimation), which is typically derived from intuition and experience (Baccarini 2005; Kumas and Ergonul 2007).
- The traditional percentage estimation method has been criticized as an unscientific approach (Thompson and Perry 1992), and it is considered to be one reason why many projects have shown losses in their cost performance (Hartman 2000).
- With this, the traditional percentage estimation method implies a determinate prediction (Mak et al. 1998) despite the uncertainty of international construction projects in a different host country and under diverse project conditions. These weaknesses of the traditional percentage estimation method have raised a need for a more robust and systematic approach for estimating the contingency for unplanned changes.

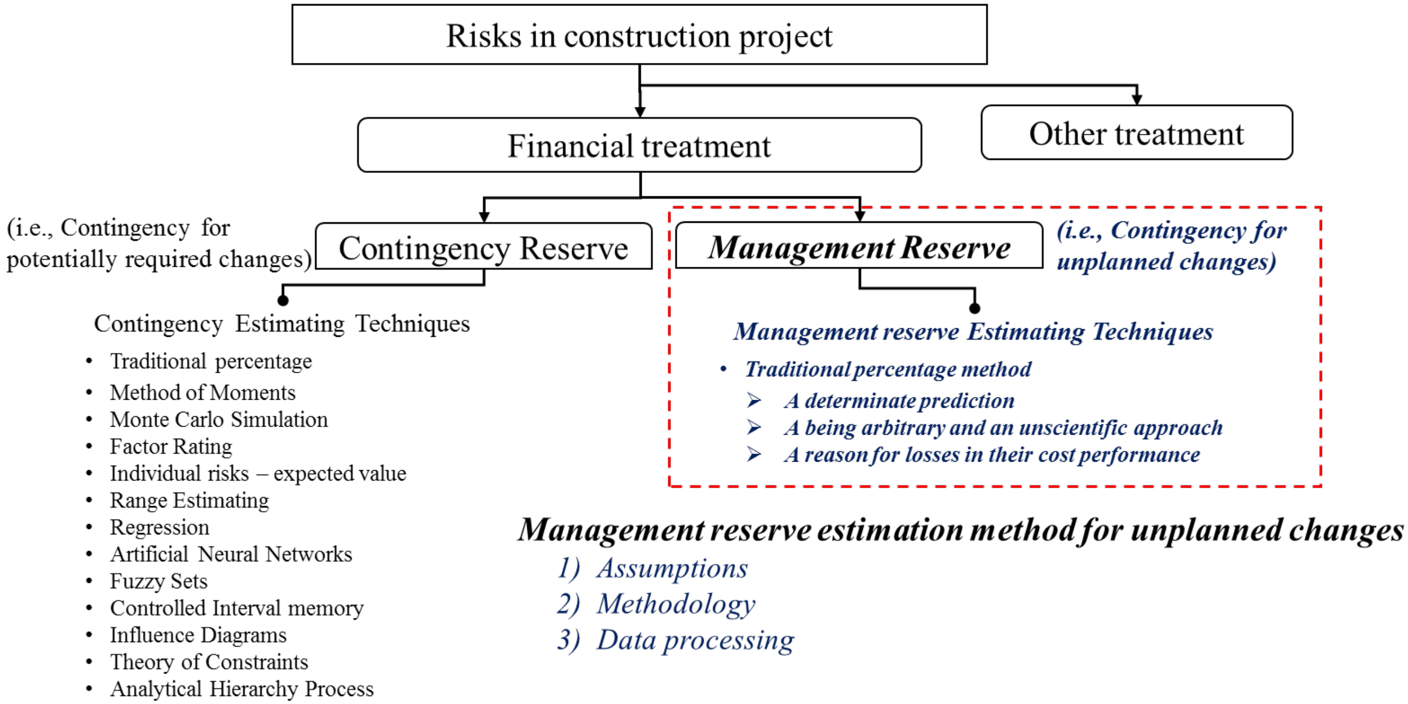

Figure 1-5. A contingency estimation method for risk events

(4) In construction execution phase, the construction contractors should decide appropriate response strategy and solution in time when the risk events occur. For this, the response strategies and solutions are determined based on the intuition and experience of contractors, which has no theoretical and scientific foundation (Frandsen and Johansen 2010) (Fig 1-6).

- This experience-based intuitive decision-making for recovering the risk events causes perception of bias (Syal et al. 2014) and regarded as a subjective or isolated decision-making, which does not consider characteristics of the risk events regarding country, market, and project environments or conditions.
- Another issue related to the experience-based intuitive decision-making can only respond to the risk events, which the contractors have experienced. As a result, these weaknesses of the contractors' experience-based decision-making have raised the need for a more robust and systematic approach to support the decision-making on response strategy and solution for recovering the risk events (Sahin et al. 2015; Srinivasan and Nandhini 2015).

In these contexts, efforts for managing the construction risk events of international construction projects are required to minimize the likelihood of larger project costs and losses in time. As an effort to address the challenging issues, this dissertation proposes a method for managing the risk events of international construction projects. For achieving the objective of this dissertation, research backgrounds and methodologies are required for developing the method, and then variables should be established by considering uncertainty of international construction projects. Based on the selected variables, this research proposes a management reserve estimation method and a response strategy decision-making support model by considering the purpose of this dissertation. Subsequently, case study approaches should be conducted to validate the proposed method and test its applicability.

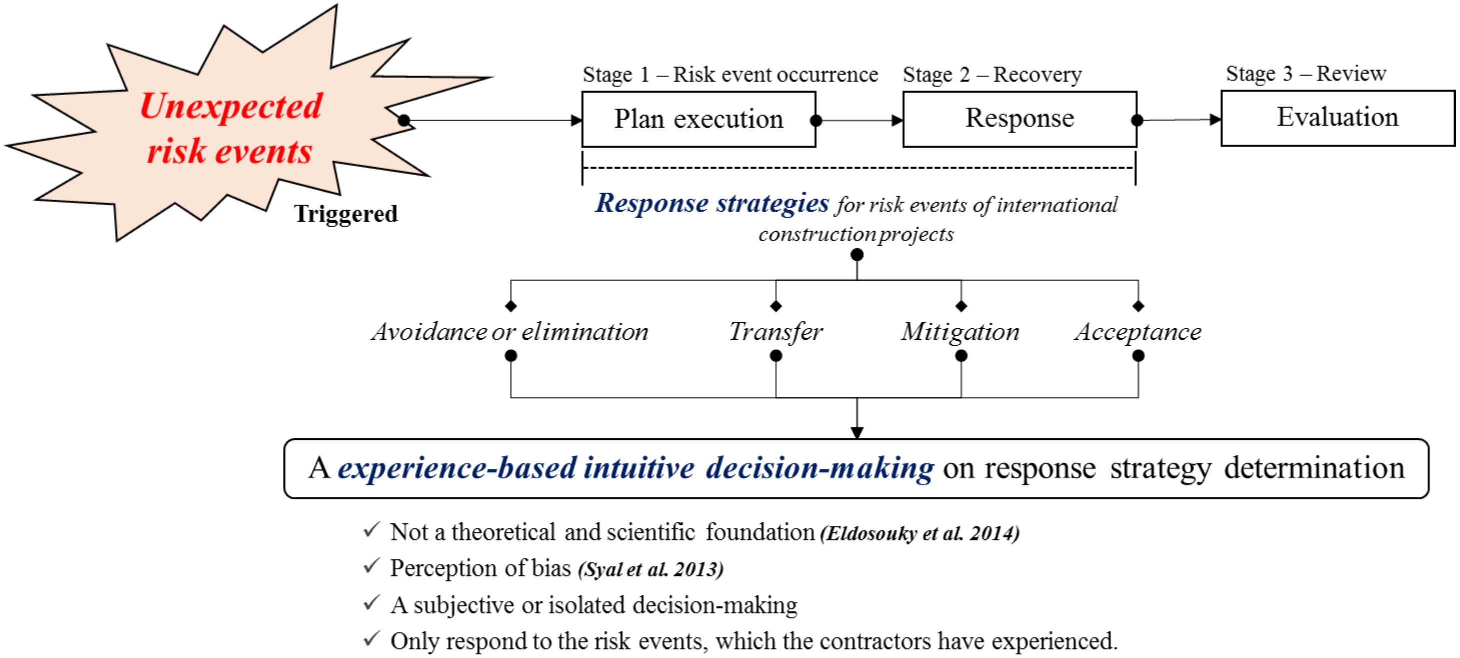

Figure 1-6. Response strategy for recovering construction risk events

1.3 Research Objective and Scope

The contractors of international construction projects desire to minimize the likelihood of project cost increase and losses in time. For this, the contractors estimate the contingency for potentially required changes and plan response strategies recovering expected changes. However, these could not cover overall risk events and as a result, did not minimize likelihood of losses in project cost and schedule fully. For instance, to estimate the management reserve realistically for this purpose, an arbitrarily chosen change of ±10% may be applied. In addition, response strategies and solutions recovering risk events is determined only depending on experience and intuition of construction contractors. Aspects of the current practices still have limitations for managing risk events of international construction execution

In these contexts, as an effort to address these challenging issues, this research proposes a systematic management reserve estimation method and a response strategy decision-making support model for managing the risk events in international construction projects. For this, a case-based learning and reasoning is applied to achieve the goals of this dissertation by considering the unpredictable characteristic of risk events (Fig 1-7). The objective and goals of this dissertation are conducted according to the following procedure:

(1) This research first conducts preliminary studies for developing risk event management method. It starts by analyzing project risk management to understand the risk related concepts, risk management process, and previous research about international construction projects. With this, methodologies applied in this dissertation are described to develop the case-based learning algorithm.

(2) Then, variables are selected for applying the case-based learning algorithm. For this, a relationship between uncertainty and risk management competence in construction projects is analyzed, and the configurations of selected variables are established for data collection.

(3) Based on the selected variables, the management reserve estimation method and response strategy decision support model are proposed by applying Case-Based Reasoning (CBR). For achieving the goals of this research, K-Nearest Neighbor (K-NN) algorithm is adopted for retrieving pertinent cases with the application of Genetic Algorithm (GA) and Analytic Hierarchy Process (AHP) to improve the performance of CBR classifications.

(4) Finally, to clarify the proposed method and model, case studies are conducted to validate retrieval performance of the proposed method and test its applicability.

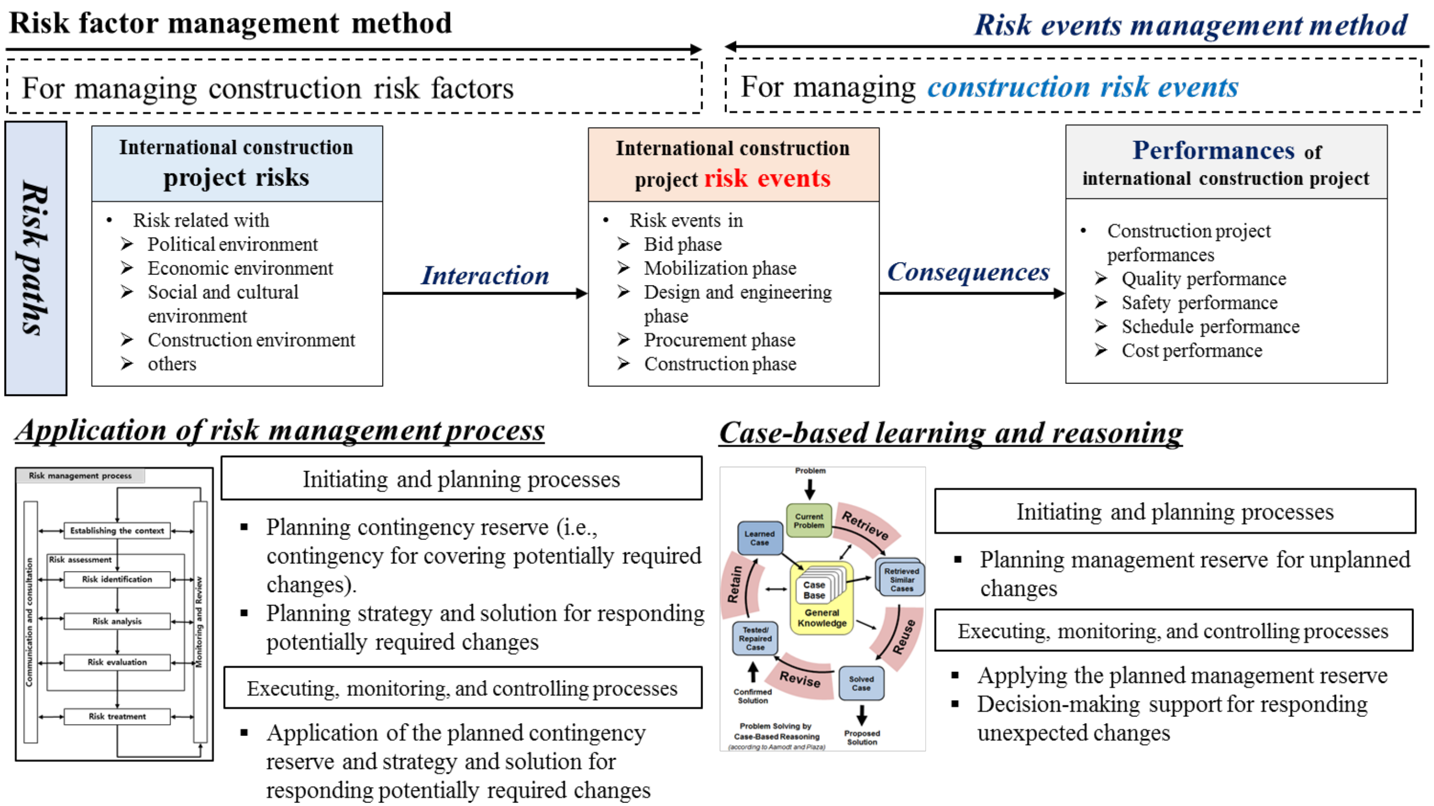

Figure 1-7. Research objective and scope

Considering the objective of managing risk events, this research describes the primary goals of this dissertation more in details, as follows:

(1) To select and configure variables for developing the management reserve estimation method and response strategy decision-making support model by analyzing uncertainty of international construction projects. A three-step approach is carried out to achieve this goal:

- Step 1 - To analyze uncertainty in international construction projects thorough previous literature reviews related to Risk Breakdown Structure (RBS) of international construction projects
- Step 2 - To establish the risk management competences for construction projects, one of variables for developing case-based learning, including skills and individual behavior competences. For this, this research analyzes practical activities of construction project risk management and applies Exploratory Factor Analysis (EFA) and reliability test.
- Step 3 - Subsequently, to select 30 variables and define its configurations for retrieving pertinent instances by applying the case-based learning and reasoning.

(2) To propose a management reserve estimation method for risk events of international construction projects, which provide a provision to

deal with emergent changes with consideration of their unpredictable characteristic. A four-step approach is carried out to achieve this goal:

- Step 1 - To explain considerations required for proposing the management reserve estimation method, such as the characteristics of management reserve, Liquidated Damages (LDs) clause in contract, and the cost and schedule performance ratios (CPR and SPR, respectively).
- Step 2 - To describe methodologies for applying case-based learning, such as Case-Based Reasoning (CBR), K-Nearest Neighbor (K-NN) algorithm, and Genetic Algorithm (GA).
- Step 3 - To estimate the CPR and SPR based on the optimized retrieval results (i.e., cost and schedule performance of similar construction projects).
- Step 4 - Subsequently, to propose management reserve calculation by using the estimated CPR and SPR.

(3) To develop the response strategy decision-making support model for coping with unexpected risk events of international construction projects. A four-step approach is conducted to achieve this goal:

- Step 1 - To analyze considerations for proposing the response strategy decision support model, such as risk paths in construction projects and applicable risk response strategies.

- Step 2 - To establish breakdown structure of risk events in international construction projects through previous research reviews on the risk events and interviews on experienced professionals of international construction risk management.
- Step 3 - To determine the relative importance of variables for improving the effectiveness of CBR retrievals by applying the AHP.
- Step 4 - Subsequently, to retrieve pertinent risk events with its response strategies and solutions adopted in previous by applying the variable–weighted K-NN algorithm.

(4) To validate the proposed management reserve estimation method and response strategy decision-making support model by conducting case studies. A three-step approach is carried out to achieve this goal:

- Step 1 - To describe validation strategies for evaluating the suggested management reserve estimation method and response strategy decision support model.
- Step 2 - To collect data sets related with the selected variables and cases related to international construction projects and risk events.
- Step 3 - Lastly, to conduct case studies for validating retrieval performance and testing an applicability of proposed method and model.

Consequently, this research would contribute to risk management of international construction projects by proposing method for managing unexpected risk events occurring during construction execution. Specially, the management reserve estimation method could have a potential benefit for construction companies to calculate a provision for the risk events. With this, the response strategy decision-making support model may help construction contractors determine appropriate response strategy and solution in time when the risk events occurs. Based on the research goals, construction contractors could finally minimize the likelihood of project cost increase overrun and schedule delay. Academically, this research proposes a more robust, systematic, and suitable approach for estimating the management reserve and supporting construction contractors' decision-making for dealing with the risk events of international construction projects.

1.4 Organization of the Dissertation

This dissertation is organized into six chapters—including the introduction— and a set of appendices containing additional information and data on variables, case projects, and risk events. Fig. 1-8 describes an overall research procedure and its components for managing the risk events of international construction projects. The dissertation begins with the introduction in Chapter 1, briefly describing research backgrounds and problems. Then, this research explains the need for the systematic management reserve estimation method and response strategy decision-making support model for recovering unexpected risk events in international construction projects.

Following the research background and objective in Chapter 1, reviews on project risk management is conducted to comprehend the risk-related concepts, definitions, risk classification, and risk paths in construction projects. Then this research analyzes the risk management process with its principles and framework and describes an overview of international construction risk management. As a result, a need for managing risk events in international construction projects is provided in Chapter 2.1. Next, in Chapter 2.2, this research explains methodologies for developing case-based learning. For this, EFA and reliability test using Cronbach alpha coefficient are first described for developing the risk management competences for construction projects as one of variables. In addition, the

Case-Based Reasoning (CBR) is introduced as an instance-based problem solving method with the K-Nearest Neighbor (K-NN) algorithm for retrieving similar instances. Subsequently, the Genetic Algorithm (GA) process and its applications in construction projects are analyzed for optimization of CBR classifications.

In Chapter 3, this research selects variables for achieving the objective of this dissertation. For this, the international construction risks are analyzed through the previous literature reviews and interviews on experienced professionals, and this research also develops the risk management competences for construction projects as one of variables. To develop the risk management competences, the practical activities related to managing construction risks are analyzed for developing risk management skills, and the personalities are examined by applying EFA and reliability test described in Chapter 2.2.1. Based on the analysis results, this research develops a breakdown structure of international construction risks, and from the classification, selects 30 variables for developing the case-based learning. Subsequently, data on the selected variables are collected by considering the configurations of selected variables.

In Chapter 4, the management reserve estimation method are proposed using the case-based learning algorithm. For this, it starts by defining considerations such as the characteristics of management reserve, CPR and SPR of construction projects, and LDs in contract. Then the CPR and SPR are estimated based on the results of similar construction projects. For this, using the selected variables, the k-NN is applied as an instances-based learning algorithm for retrieving similar projects, and a GA is adopted to optimize the retrieved instances. Subsequently, the management reserve estimation method is proposed by applying the estimated CPR and SPR. Finally, to evaluate the effectiveness of the developed management reserve estimation method, case study approaches are conducted.

In Chapter 5, this research develops a response strategy decision-making support model for recovering emergent risk events in international construction execution. For this, available response strategies for coping with the risk events are described with the overview of risk events management framework. This research then classifies the risk events through investigation of previous research efforts and experts' opinions. Next, relative importance of variables is determined by applying the AHP, and as a result, a variable-weighted K-NN algorithm is proposed to retrieve pertinent instances of a new risk event. Based on the retrieved similar cases, its applied strategies and solutions are proposed, and these would support the contractor's decision-making for recovering a new risk event. Lastly, to clarify the suggested model, case studies are conducted to evaluate its retrieval performance.

Finally, in Chapter 6, the research results and contributions to the body of knowledge in the field of construction management and project risk management are described. Then this research provides the limitations of proposed management reserve estimation method and response strategy decision-making support model. Subsequently, the recommendations and required future research are explained to enable the research contributions to be applied to the real world situations in the future.

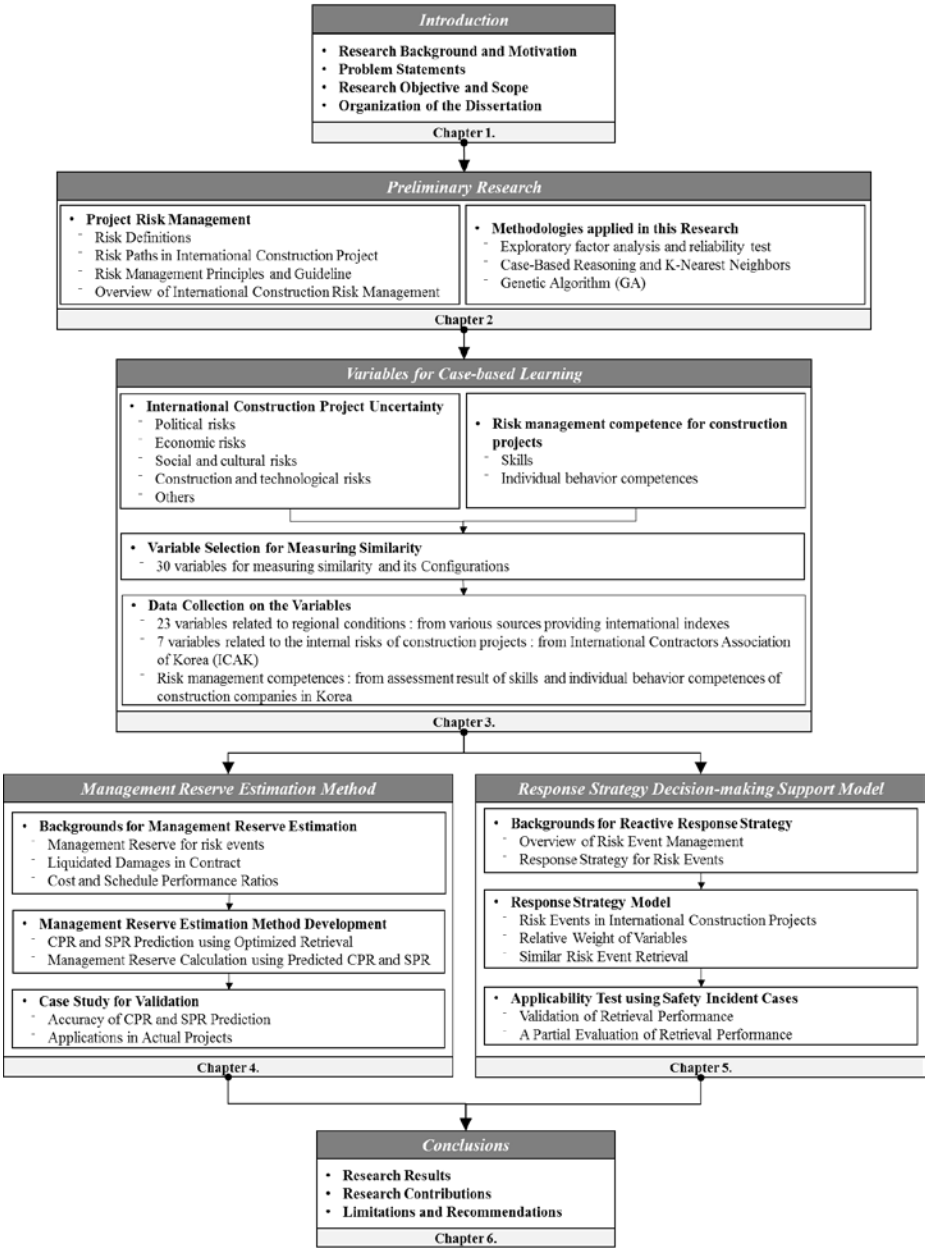

Figure 1-8. Organization of this Dissertation

Chapter 2 . Preliminary Research

In this chapter, this research explains academic backgrounds of this dissertation to describe the limitations of current risk management practices and requirements for developing the objective of this research. For this, literature reviews on project risk management are first conducted to comprehend risk events in international construction projects and process for managing risks with its principles and framework. Besides, this research analyzes previous research efforts for managing international construction risks and emphasizes a need for a systematic management reserve estimation method and a response strategy decision-making support model for managing the risk events occurring during construction execution.

Next, methodologies required for achieving the objective of this dissertation are presented to develop case-based learning. The Exploratory Factor Analysis (EFA) and reliability test using Cronbach alpha coefficient is first described as required methodologies for developing risk management competences for construction project (i.e., one of variables). This research then explains a Case-Based Reasoning (CBR). With this, the K-Nearest Neighbors (K-NN) is introduced as a retrieval algorithm for CBR application. Subsequently, the Genetic Algorithm (GA) are analyzed for optimizing the K-NN retrievals.

2.1 Project Risk Management

The construction companies implement the risk management to their projects for accomplishing the project goals (e.g., cost, schedule, quality, and safety). Although main objective of the risk management is to reduce project's uncertainty, there are still limitations in managing risk events of international construction projects. In these contexts, this research presents the fundamentals of risk management and international construction risk management to comprehend the limitations of current practices for managing the risk events. For this, the risk related concepts and its definitions are first described with the risk paths in construction projects, and then risk management process are also analyzed with its principles and framework. Subsequently, previous research reviews on managing international construction project risks are conducted.

2.1.1 Risk Definition

For comprehending the project risk management, this research first defines the risk by investigating the various definitions of risks and its related concepts such as uncertainty, crisis, hazard, and opportunity. For instance, regarding concepts of risk and uncertainty, Schumpeter (1934) and Lindley (1972) described that if the probability distribution is known or can be rationally derived, it could be defined as risk, and if the probability is not known, it should be defined as uncertainty. Smith (1998) also defined the risk and uncertainty that uncertainty is a circumstance where the possibility is not quantified, whereas risk is a case where the possibility can be quantified with information regarding loss.

With this, regarding the risk, crisis, and hazard, Wideman (1992) compared the risk with crisis. The crisis could be defined as the potential or possible risk factor’s actual affection causing damage to projects, whereas the risk is an ambiguous situation or case where the risk factor’s affection is probable. Edward (1995) also made a comparison between the risk and hazard by defining hazard as causing casualties or damage and risk as multiplication of the economic cost and the probability of hazard occurrence. Besides, Rothcorf (1975) defined the risk as follows, “the risk is the possibility of loss, injury, disadvantage, or destruction”.

In addition, many professional organizations and institutes also have defined the risk, uncertainty, hazard, and opportunity. According to the PMI (2008), the risk is a certain condition that, if it occurs, has a positive or negative effect on a project’s objectives, and the opportunity is a condition or situation favorable to the project such as a positive set of circumstances, a positive set of events, a risk enabling a positive impact on objectives, or a possibility for positive changes. The International Organization for Standardization (ISO) (2009) also defined the risk, uncertainty, and hazard. The risk is defined as the “effect of uncertainty on objective”, the uncertainty is defined as “the state or partial state of deficiency of information related to knowledge such as consequence and likelihood of an event”, and the hazard is defined as the “source of potential harm”. In AS/NZS 4360 (Standards Australia 2004), the risk is also defined as “the chance of something happening that will have an impact on objectives”.

Table 2-1. Definitions of risk, uncertainty, crisis, hazard, and opportunity

Classification	Descriptions
Risk	• Conditions or chance of something happening that will have a positive or negative effects on a project’s objective.
Uncertainty	• Circumstances which is the state or partial state of deficiency of information related to knowledge such as consequence and likelihood of an event, and the probability or possibility is not quantified.
Crisis	• Potential or possible risk factor’s actual affection causing damage to the project.
Hazard	• Source of potential harm such as casualties or damage
Opportunity	• Conditions or situations which are favorable to the project such as a positive set of circumstances, a positive set of events, a risk causing positive impacts on objective, or a possibility for positive changes

Based on these previous definitions, this research briefly summarizes the definitions of risk, uncertainty, crisis, hazard, and opportunity as shown in Table 2-1. From the summarization, this research defines the risks that is conditions or chance of something happening such as a positive or negative effects on a project's objective.

With the definitions of risk, previous research have broadly classified the risks in several types according to their characteristics for managing the risk effectively. Fig. 2-1 shows the risk classification. For instance, Flanagan and Norman (1993) categorized the risk as controllable and uncontrollable risks, and Chapman (2001) also classified the risk into two categories according to their relationships: dependent risk and independent risk. Furthermore, the PMI (2000) categorized the risk as external risk and internal risk. The internal risk is technical risks related to project management which can be controlled within the project, and the external risk is environmental risks such as governmental policy, regulation changes, social disorder, and environmental disaster which cannot be controlled within the project. In addition, the CII (1989) and PMI (2008) also classified the risk into three following categories: (1) Knowns that have been identified in planning stage and assessed with a probability of occurrence, (2) Known-unknowns that have been also identified in planning phase but for which a probability of occurrence cannot be assigned, and (3) Unknown-unknowns that have not been identified in advance and therefore the probability cannot be known. This classification from CII and PMI is generally applied to construction industry for analyzing the risks, and therefore, this research also applies the cognitive risk classification for developing the objective of this research.

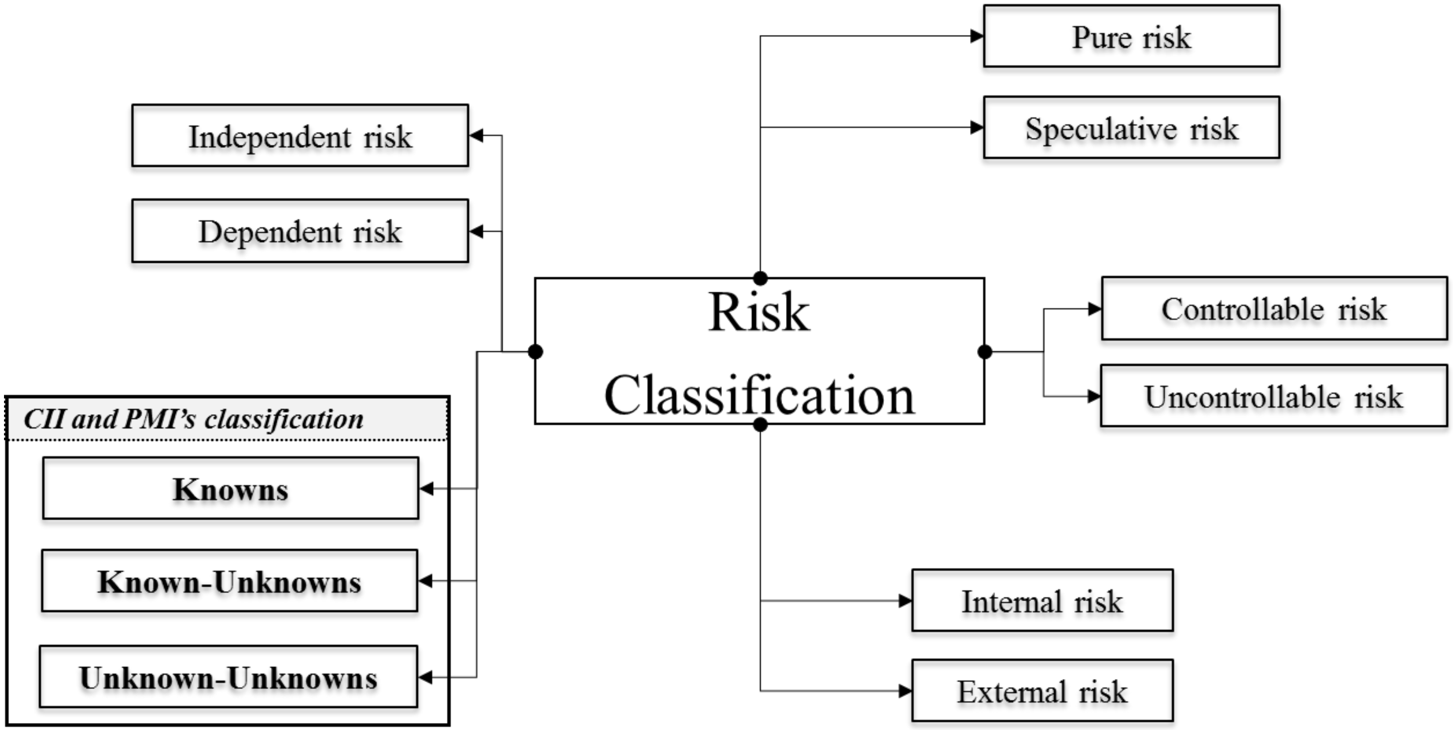

Figure 2-1. Risk classification (Revised from previous literatures)

2.1.2 Risk Event in International Construction Projects

The risks such as Knowns, Known-unknowns, and Unknown-unknowns are defined as risk sources or factors, and the risks can cause some risk events through their interrelationship or interaction (Dikmen et al. 2008). The risk events could be defined as an occurrence of negative happenings to construction project performances (e.g., cost and schedule) (AS 4360). For instance, the risk events influence the performance indicators such as quality, schedule, productivity, and health and safety (Eybpoosh et al. 2011). In line with the risk source and risk event, risk consequences can be briefly described as outcomes of the risk events (Al-Bahar and Crandall 1990). For instance, the risk consequence is an effect or impact of the risk events on construction project goals such as cost, schedule, quality, and client satisfaction (Al-Bahar and Crandall 1990; Tah and Carr 2000). The risk consequence finally influences the project cost and schedule performances.

Within the context of this research, the unexpected risk events can be realized from interrelationship or interaction between risk sources during construction execution, and then, it cause a negative influences (i.e., risk consequences) to construction project performances. In this circumstance, an effective risk event management is significant for minimizing the negative effects on cost and schedule performance of construction projects. For this, this research proposes a systematic management reserve estimation method and a response strategy decision-making support model

2.1.3 Risk Management Principles and Guidelines

Many institutes and study groups have widely proposed relationship between risk management principles, framework, and process for managing the risks described in Chapter 2.1.1 [PMI 2009; Office of Government Commerce (OGC) 2007, ISO 2009, Institute of Risk Management (IRM) 2002]. For instance, the ISO proposed principles and guidelines of risk management as shown in Fig. 2-2.

Based on the principles and guidelines, many researchers have also proposed the generic risk management process for its effective implementation (Berkeley et al. 1991; Jia et al. 2013; Smith et al. 2006; Wang et al. 2004). Berkeley et al. (1991) proposed the project risk management process as follows: risk classification, risk identification, risk assessment, and risk response. Wang et al. (2004) and Smith et al. (2006) suggested more simplified process such as risk identification, risk analysis and evaluation, and risk response. Jia et al. (2013) also presented the risk management process including risk management planning, risk identification, risk analysis and assessment, risk response, risk monitoring, and reporting. Table 2-2 shows the comparative summary of these risk management process.

From the comparative analysis, this research regards that the generic risk management process includes planning for risk management, risk identification and classification, risk analysis and evaluation, risk response, risk monitoring, risk control, reporting, and review. Based on this process, the skills for implementing risk management in construction projects are analyzed and established to develop the risk management competences as one of variables.

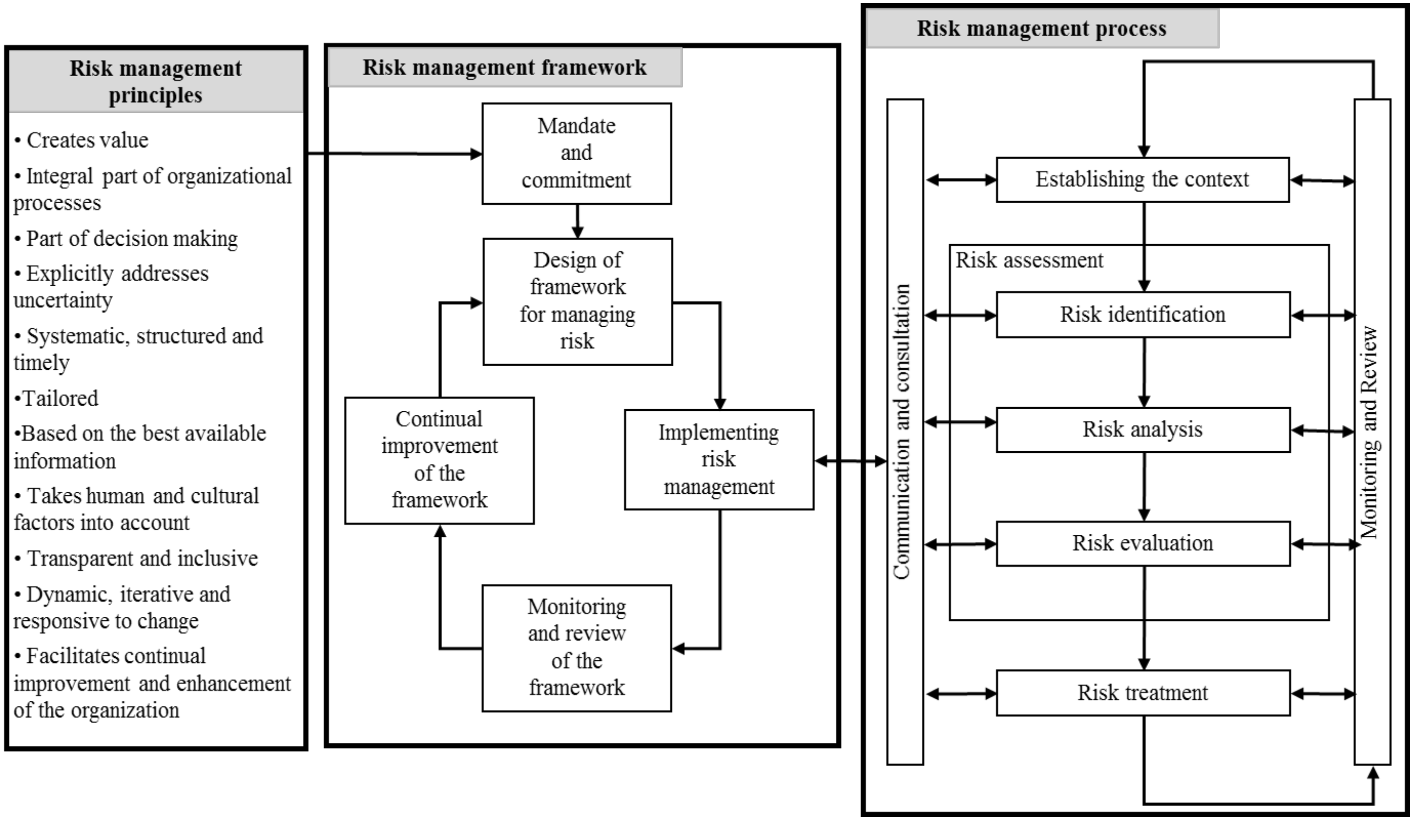

Figure 2-2. Relationships between the risk management principles, framework and process (ISO 2009)

Table 2-2. A comparative summary on risk management process

Risk management process	Professional organizations				Research in construction			
	IRM (2002)	OGC (2007)	ISO (2009)	PMI (2009)	Berkeley et al. (1991)	Wang et al. (2004)	Smith et al. (2006)	Jia et al. (2013)
Risk management planning			✓	✓				✓
Risk classification					✓			
Risk identification		✓	✓	✓	✓	✓	✓	✓
Risk analysis			✓	✓			✓	✓
Risk assessment	✓	✓	✓		✓	✓		✓
Risk evaluation						✓		
Risk responses	✓	✓	✓	✓	✓	✓	✓	✓
Risk monitoring	✓	✓	✓	✓				✓
Risk control				✓				
Risk reporting	✓		✓					✓
Risk review	✓		✓					

2.1.4 Overview of International Construction Risk Management

Based on the risk management process with its principles and framework, previous research have been widely proposed for managing risks in construction projects. The research efforts regard on as follows: (1) research on various methods or technologies for developing risk management process (Baker et al. 1999; PMI 2013; Ren 1994); (2) research on dynamic connection with other primary project management areas or fields (e.g., cost, schedule, quality, and safety management) (Barraza and Bueno 2007; Chan and Au 2009; Sousa et al. 2014); (3) research on the risk perceptions and attitudes of stakeholders (Al-sobiei et al. 2005; Kim and Reinschmidt 2011; Wang and Yuan 2011; Zou and Zhang 2009); (4) research on the critical risks associated with delivery systems (Pantelias and Zhang 2010; Thomas et al. 2003; Tiong 1995); and (5) research on improving maturity and competence of risk management (Jia et al. 2013; Zhao et al. 2013, 2014; Zou et al.2010).

Furthermore, research on risk management for international construction projects have been also performed recently according to consideration of globalization such as Uruguay Round in the General Agreement on Tariffs and Trade (GATT) (Ashley and Bonner 1987; Bing and Tiong 1999; Bu-Qammaz et al. 2009; El-Sayegh 2008; Han and Diekmann 2001; Hastak and Shaked 2000; Messner 1994; Kalayjian 2000; Walewski et al. 2004; Zhi 1995). For instance, Ashley and Bonner (1987) analyzed the political risks of international construction projects and proposed risk management model for managing the political risks, as follows: (1) labor cost model, (2) material cost model, (3) overhead cost model, and (4) revenue model. Besides, Zhi (1995) developed a comprehensive risk management method for overseas construction projects by proposing a useful risk assessment and vital risk response techniques. Fig. 2-3 shows the Zhi's risk assessment model for managing international construction risks. Bing and Tiong (1999) also presented the effective risk management measures for International Construction Joint Ventures (ICJVs) through case studies.

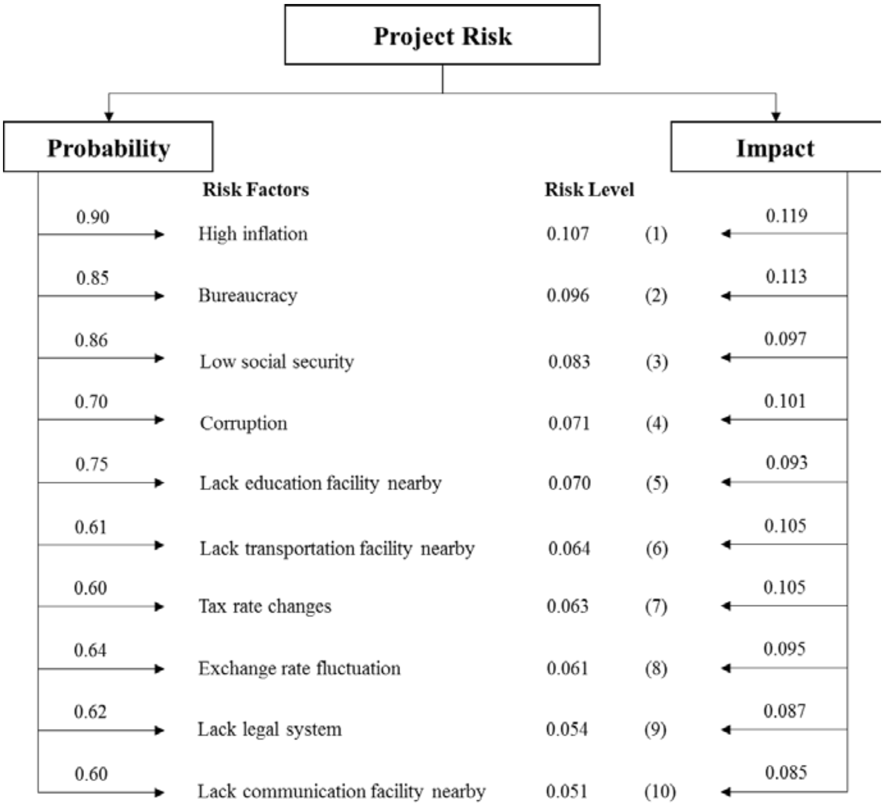

Figure 2-3. Risk assessment for overseas construction project (Zhi 1995)

With this, Hastak and Shaked (2000) developed an International Construction Risk Assessment Model (ICRAM-1). The model enables the user to evaluate the potential risks involved in expanding operations of international market by analyzing a macro (or country environment), market, and project risks. Fig. 2-4 shows the framework of ICRAM-1. Han and Diekmann (2001) introduced a formal entry decision procedure for international market by considering uncertainties from international risks such as political risk, economical risk, cultural risk, legal risk, and construction risk.

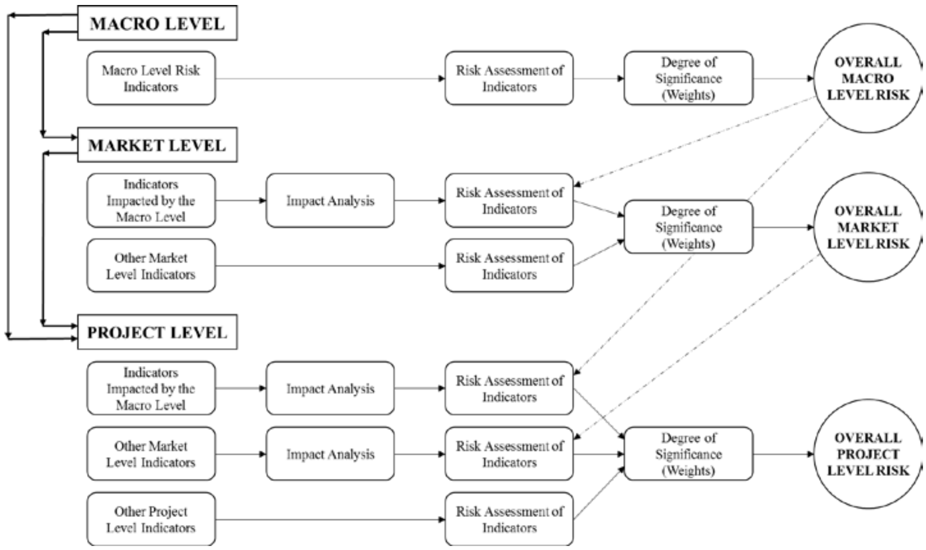

Figure 2-4. Framework of ICRAM-1 (Hastak and Shaked 2000)

In addition, as a representative risk assessment model for international construction project, Walewski (2003) proposed an International Project Risk Assessment (IPRA) tool with a systematic method for identifying, assessing, and determining relative importance of the international risks (Fig 2-5). Dikmen and Birgonul (2004) also developed a neuronet model as a decision support tool based on the experiences of Turkish contractors in overseas markets, which can classify the international projects with respect to attractiveness and competitiveness.

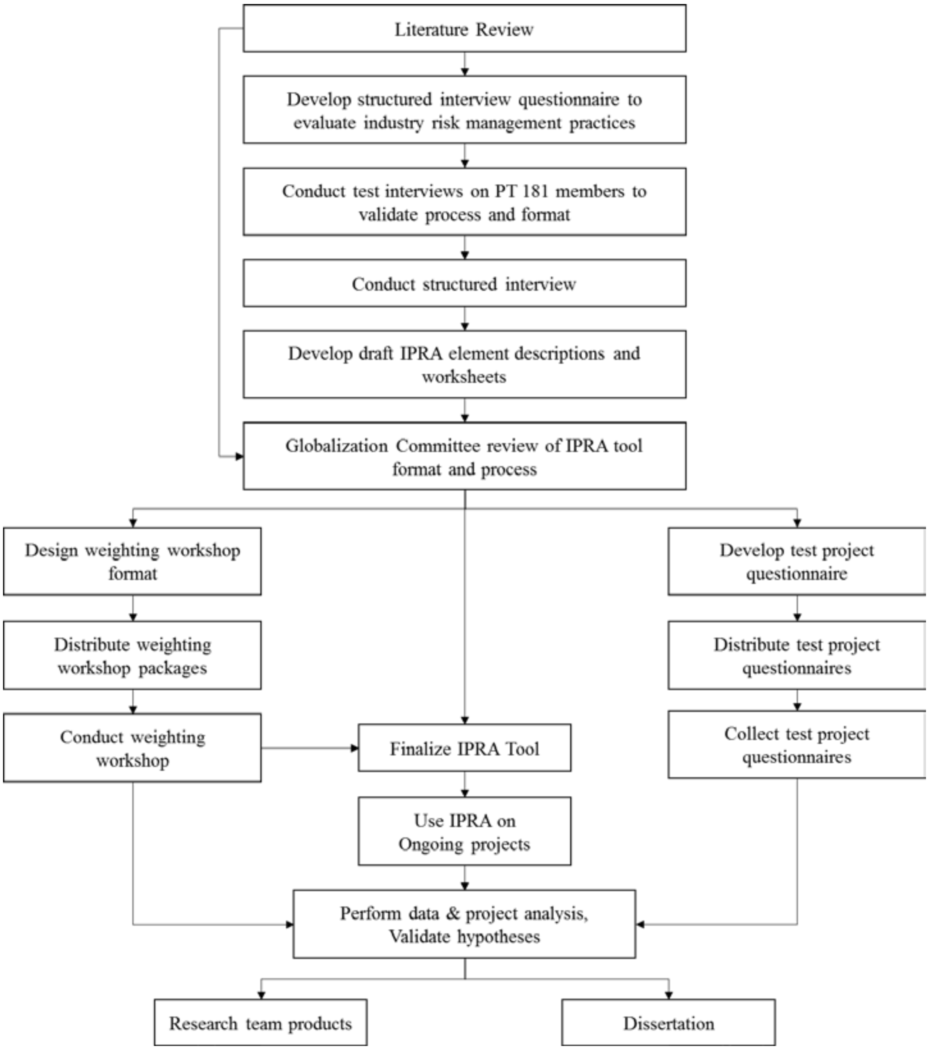

Figure 2-5. IPRA development methodology (Walewski 2003)

In recent, Dikmen et al. (2007) presented a decision-support tool for estimating bid mark-up values by applying a case-based reasoning (CBR) methodology. Han et al. (2008) also developed a web-based integrated system for international project risk management by considering a decision-making processes and construction life-cycle. The web-based integrated system comprises three modules as follows: (1) bid-decision model, (2) profit prediction model, and (3) risk scenario analysis and contract management guideline. Fig. 2-6 shows the integrated risk management process.

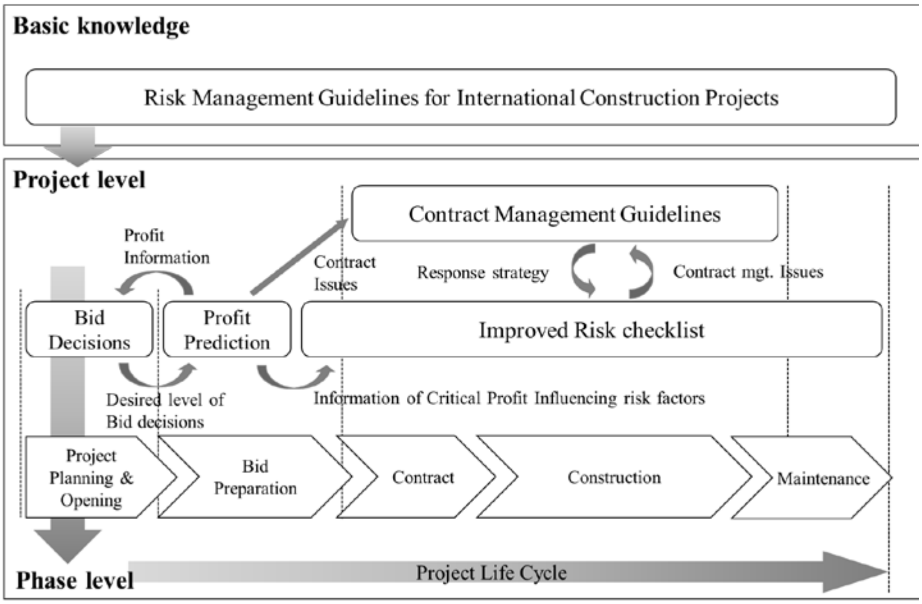

Figure 2-6. Integrated risk management process (Han et al. 2008)

Although those aforementioned research have contributed to the body of knowledge in the field of risk management for international construction projects, the entire aspects of managing international project risks have not yet been fully addressed. The previous research efforts have focused on developing method or model for managing international risks by using risk management process based approach. For instance, the models could only analyze the identifiable risks at the macro (or country environment), market, and project levels. As a result, the risk assessment methods or techniques are only applicable to estimating contingency reserve covering potentially required changes and planning response strategies and solutions for predictable risk events during construction execution.

However, current risk management practices cannot cover or manage the emergent risk events in international construction execution due to its unidentifiable characteristic. These weaknesses have raised the needs for a more robust and systematic approach for managing the risk events in international construction projects. In these academic contexts, this research proposes method for managing the risk events of international construction projects. In specific, a management reserve estimation method is developed for calculating cost for unplanned changes, and a response strategy decision-making support model is suggested for recovering risk events occurring during construction execution.

2.2 Research Methodologies for Case-Based Learning

In line with the analysis of international construction risk management, this research describes methodologies to develop the case-based learning. For this, the EFA and reliability test using Cronbach alpha coefficient is first explained as methodologies to develop the risk management competences for construction projects, which is one of variables required for retrieving similar instances. In addition, this research presents the CBR method which has a sophistication of experience-based human problem-solving. For applying CBR classification (i.e., CBR retrieval), the K-NN algorithm is briefly introduced to retrieve pertinent cases by using Euclidean distance. Besides, this research analyzes the GA process and applications in construction projects for optimizing the K-NN retrievals.

2.2.1 Exploratory Factor Analysis and Reliability Test

This research applies EFA and reliability test to develop the risk management competence as one of variables. The EFA is commonly applied to examine the construct validity using the Principal Components Analysis (PCA) and varimax rotation. With this, the reliability test measures the internal consistency using the Cronbach alpha coefficient. Before applying these methodologies, Kaiser-Meyer-Olkin (KMO) and Bartlett's test of sphericity should be measured to test sampling adequacy and multivariate normality, which evaluate the suitability of collected data.

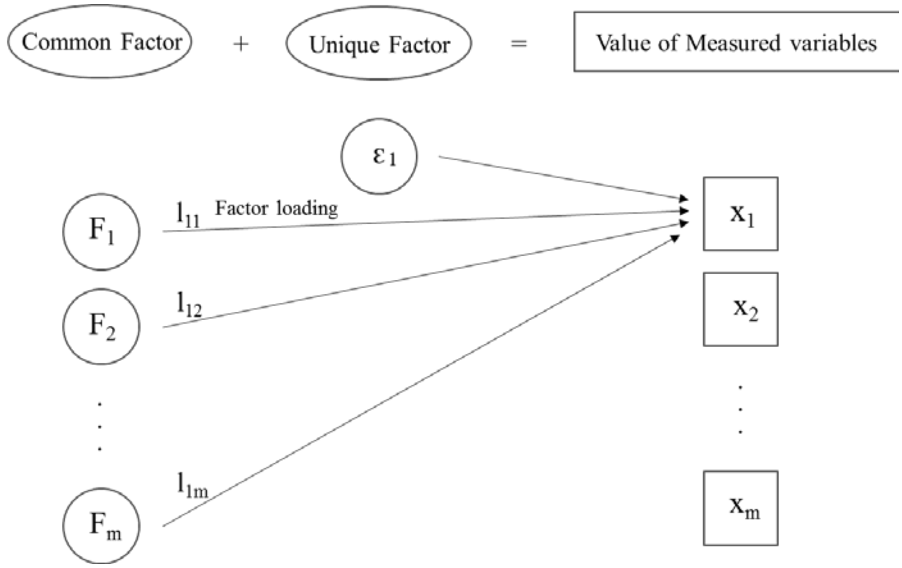

Figure 2-7. The concept of EFA

The EFA is a multivariate analytical technique to extract a smaller number of underlying variables or factors from the observed variables (Alroomi et al. 2011; Karami 2014). The objectives of EFA are as follows: (1) reduction the number of variables, (2) examination of structure or relationship between variables, (3) detection and assessment of unidimensionality of a theoretical construct, (4) evaluation of the construct validity of a scale, test, or instrument, (5) development of simple analysis and interpretation, (6) elimination of multi-collinearity in correlated variables, (7) development of theoretical constructs, and (8) verification of proposed theories (Pearson 1901; Pett et al. 2003). Based on the objectives, this research applies the EFA for evaluating the construct validity, eliminating the multi-collinearity, and examining the theoretical construct validity of risk management competences for construction projects. Fig. 2-7 explains the concept of EFA.

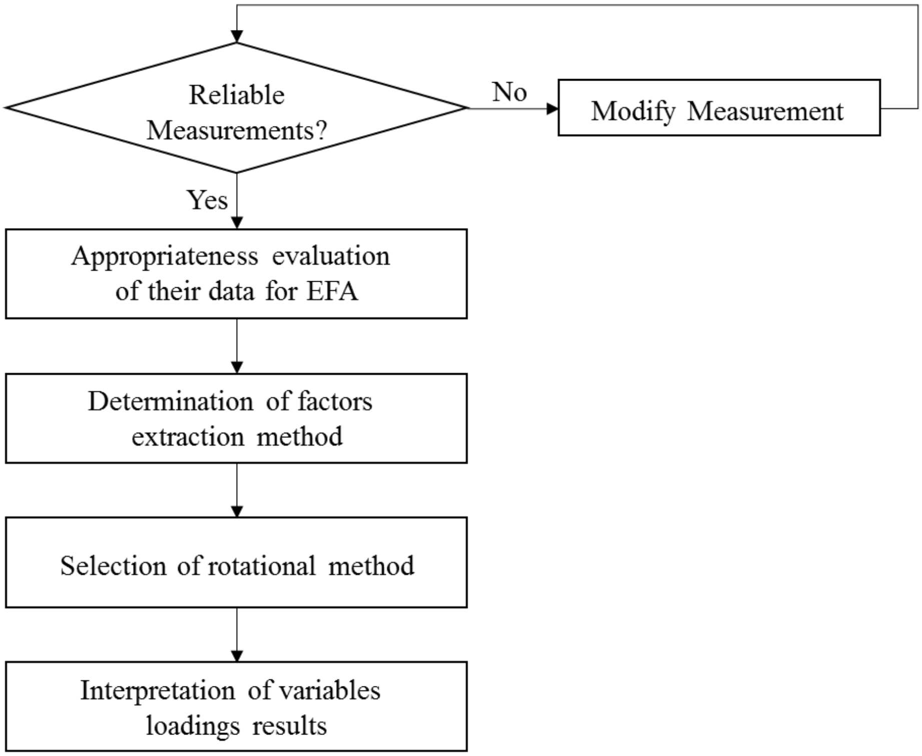

Figure 2-8. Procedure of EFA (Alroomi et al. 2011)

The EFA is generally conducted through several stages. Fig. 2-8 shows the stages of EFA. The fundamental of first stage is to design considerations such as appropriateness evaluation of specific statistical technique (Alroomi et al. 2011). For instance, the sample size for EFA analysis and quality of measurement instruments for data collection are evaluated. After evaluating the suitability of collected data, a method for extracting factors should be decided in second stage. Regarding this, PCA and Principal Axis Factoring (PAF) are the most frequently applied (Thompson, 2004). In third stage, factor axes are rotated in the multidimensional space to make the results more interpretable (Fabrigar et al., 1999). There are commonly two types of factor rotation method: (1) orthogonal rotation that the correlation between any two factors is zero; and (2) oblique rotation that the factors are allowed to be correlated (Conway & Huffcutt, 2003). After conducting these stages, the researcher can interpret the factor loadings (i.e., EFA results). The descriptions of each stage are as follows in details:

(1) Sampling Adequacy and Multivariate Normality

Prior to the principal components extraction of EFA, sampling adequacy and multivariate normality should be measured to evaluate the suitability of collected data (Bryant and Yarnold 1995; George and Mallery 2006; Lattin et al., 2003). For instance, KMO can be used to test whether the sample size and the number of variables are acceptable for applying EFA (Alroomi et al. 2011). KMO is calculated as the ratio of squared correlation between variables to squared partial correlation between variables, as shown in following Eq. (2-1) (Field 2005):

$$Kaiser - Meyer - Olkin(KMO) = \left(\frac{Correlation\ between\ variables}{Partial\ correlation\ between\ variables}\right)^2 \quad (Eq. 2$$

where correlation between variables means the degree of relationship between competences or elements, and partial correlation between variables means the degree of relationship between two competences or elements (Alroomi et al. 2011). The KMO value ranges from 0 to 1, with 0.50 considered suitable for factor analysis (Hair et al. 1995; Tabachnick and Fidell 2007). With this, Bartlett's test of sphericity is also applied to measure the multivariate normality of selected variables and tests whether the correlation matrix is an identity matrix (George and Mallery 2006; Lattin et al. 2003). When the Bartlett's Test of Sphericity is high enough with its associated p-value smaller than 0.05, the collected data are considered approximately multivariate normal, and the correlation matrix of the variables is not an identity matrix (Chan 2012).

(2) Principal Component Analysis and Varimax Rotation

The EFA with the principal component extraction is a linear transformation of the data into a new axis structure. The first axis is in the direction of the largest variance in the data, and the second axis is in the direction of the second largest variance, and so on (Alroomi et al. 2011). Using this concept, the Principal Component Analysis (PCA) reduces the number of variables into a smaller number of factors using eigenvalues representing the variance of the factor. Based on the eigenvalues, the number of factors is decided using the Kaiser's criteria which is most common criterion considering the minimum eigenvalue criteria. This criterion requires the eigenvalues of the principal components and selects principal components obtaining eigenvalues greater than 1.00.

Another consideration for deciding factors is rotation technique. The rotation technique maximizes high factor loadings and minimizes low factor loadings, and thereby providing a more interpretable and simplified solution (Williams 2012). For this, Orthogonal Varimax rotation developed by Thompson is commonly applied as rotational technique for EFA, which provides factors that are uncorrelated (Thompson 2004). Subsequently, the loading values less than ±0.4 are removed because they are considered as insignificant factor for interpretation (Rencher 2002).

With the EFA, the reliability test should be applied to examine internal consistency of variables (Cramer 1994). For this, Cronbach alpha coefficient is calculated using Eq. (2-2), as follows:

$$Cronbach\ alpha\ coefficient = \frac{kCov/Var}{1+(k-1)Cov/Var} \qquad Eq.(2-2)$$

where k = number of factors, Cov = average covariance between factors, total k(k−1)/2 factors, and Var = average variance of the factors, total k factors. The Cronbach alpha value from 0.6 to 0.7 is regarded as "sufficient", "good" with a value higher than 0.7, and "reliable" with a value higher than 0.8 (Cramer 1994; Sharma 1996).

Based on the EFA and reliability test, many previous research in construction industry classifies variables into a manageable number of factors and verify their construct validity and internal consistency. For instance, Alroomi et al (2011) developed a competency model for the cost estimation, and the EFA was applied to develop seven core estimating competency factors among identified 23 estimating competences. Chan (2012) investigated the principal factors affecting project overheads by applying the EFA, and Hon et al. (2012) determined safety climate factors of repair, maintenance, minor alteration, and addition (RMAA) sectors using the EFA. In recent, Chen et al. (2016) applies the EFA to identify the number and nature of factors for measuring Building Information Modeling Maturity (BIMM).

2.2.2 Case-Based Reasoning and K-Nearest Neighbors

This research proposes a management reserve estimation method and a response strategy decision-making support model for managing risk events in international construction projects. The objective and goals of this dissertation could be achieved using pertinent instances undertaken in previous with consideration of risk events' unidentifiable or unpredictable characteristic until they occur. By considering the unidentifiable characteristic of risk events, CBR method is adopted to retrieve pertinent instances as a similar solution.

For this, this research first explains an overview of CBR in construction projects and its problem solving process to convince the necessity of CBR and its suitability in this research. Subsequently, the K-NN, an instances-based learning algorithm, is described for developing the CBR classification.

CBR proposed and developed by Schank and Abelson (1977) is a method for solving problems by using or adapting solution from pertinent cases (Watson 1999). The original inspiration of CBR method came from the process of reminding in human reasoning (Aamodt and Plaza 1994; Schank 1982; Leake 1996), and an assumption of CBR is that the similar problems have similar solution (Ji et al. 2011). For instance, the CBR concentrates on situations such as how humans learn a new skill and how people generate hypotheses about a new problem using the bases of past experiences (Pal and Shiu 2004).

In problem solving process of CBR, the primary knowledge sources for solution are generated by experience-based memory, and thus the solution can be proposed by retrieving most pertinent case and adapting it to new problem situations (Ji et al. 2011). For instance, a set of training instances are stored to classify a new instance (problem). When a new query instance is encountered, its relationships to the stored examples are examined to retrieve similar cases (Burkhard 2001). Based on this concept of CBR, Aamodt and Plaza (1994) has proposed the process of CBR using four steps: (1) retrieve, (2) reuse, (3) revise, and (4) retain. In addition, Watson (2001) also proposed the CBR-cycle comprising six activities (the six-Res), as shown in Fig. 2-9: (1) retrieve, (2) reuse, (3) revise, (4) review, (5) retain, and (6) refine. The descriptions of each process are as follows:

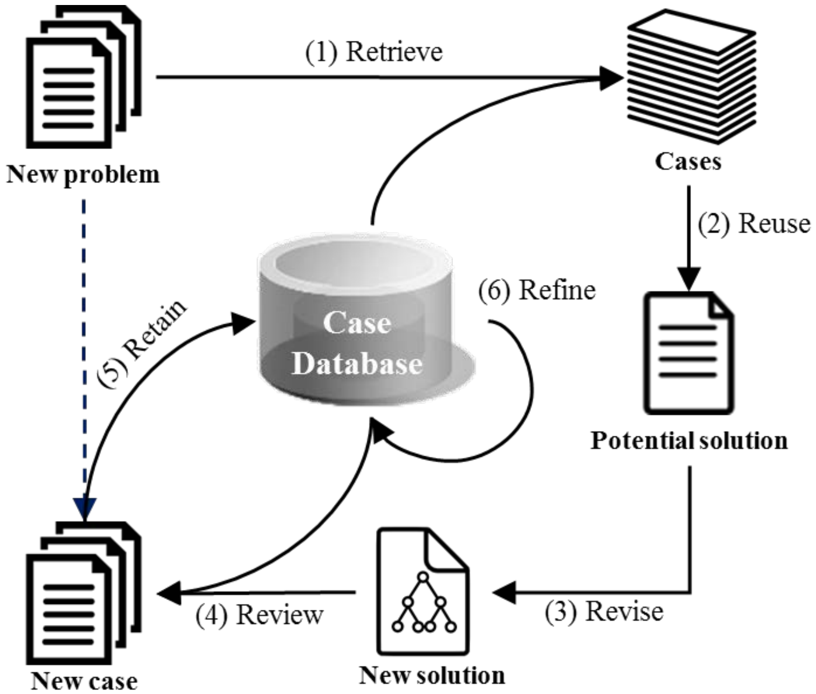

Figure 2-9. Problem solving process of CBR (Watson 2001)

(1) ***Retrieve*** similar instances to the problem description

(2) ***Reuse*** a solution suggested by similar instances

(3) ***Revise*** or adapt solution suitable to the new problem if necessary

(4) ***Review*** the new problem-solution if they are worth retaining as a new instance

(5) ***Retain*** the new solution as determined by step 4

(6) ***Refine*** the case-base index and attribute weights as necessary

With this simple and clear problem-solving capability, the CBR method is effectively applied in construction industry such as decision-making support (Chua et al. 2001; Morcous et al. 2002; Chua and Loh 2006), planning cost and schedule (Yau and Yang 1998; Tah et al. 1998; Ryu et al. 2007), safety hazard identification (Goh and Chua 2010; Kim et al. 2015), and predicting litigation outcomes (Arditi and Tokdemir 1999).

To perform the retrieval of CBR method, K-Nearest Beighbor (K-NN) is widely applied to retrieve pertinent instances by measuring the similarity between a new query and previous examples. The k-NN algorithm is a simple classification method that classifies a new case (i.e., an unknown instance) into a majority group of k-NNs by retrieving its closest instances (Cover and Hart 1967; Mitchell 1997; Tapkın et al. 2013). For retrieving the nearest neighbors, the Euclidean distance is most commonly adopted to retrieve the nearest neighbors by measuring similarity using variables between a new instance and previous examples (Short and Fukunaga 1981). The Euclidean distance is calculated as the square root of the sum of squares of the arithmetical differences between the corresponding coordinates of two objects (Pal and Shiu 2004). Let an arbitrary example x be described by a multidimensional feature vector:

$$[a_1(x), a_2\,(x), \dots\,, a_n(x)] \qquad (Eq. 2-3)$$

where a_r (x) = the value of rth variables of the example. Then, the Euclidean distance between the two cases x_i and x_j is defined as Dis (x_i, x_j):

$$Dis(x_i, x_j) = \sqrt{\sum_{r=1}^{r=n} \left(a_r(x_i) - a_r(x_j)\right)^2} \qquad (Eq.2-4)$$

Furthermore, enhanced k-NN classifiers have been proposed recently. In particular, the Genetic Algorithm (GA) has been generally adopted to optimize the classification results (Kelly and Davis 1991; Lee et al. 2007; Mateos-Garc´ıa et al. 2012).

2.2.3 Genetic Algorithm for Optimization

In accordance with the K-NN algorithm for CBR classifications, a GA, a simultaneous optimization algorithm, is generally adopted to optimize the retrieval results by determining the relative weights of variables (Kelly and Davis 1991; Mateos-García et al. 2010). This research applies the GA to improve the retrieval results from the k-NN by optimizing the distance measurement. The GA is generally regarded as an effective searching and optimization method inspired by natural selection and evolution of genetics (i.e., survival of fittest approach) (Goldberg 1989; Holland 1975; Kim and Kim 2010). For this, the GA adopts a structured exchange of genetic materials called a population to find the optimized solution, which is then represented by a string, called a chromosome, composed of a set of elements called genes (Goldberg 1989).

Based on the concepts of GA, three operations are adopted for GA optimization: (1) reproduction, (2) crossover, and (3) mutation (Senouci and

Eldin 2004). The reproduction operation is a basic engine of natural selection and creates an initial population containing the chromosomes for candidate solutions. For this, fitness of the chromosome (candidate solutions) is evaluated to create next generation of the population. The crossover operation selects a pair of chromosomes from current parent population and splicing two parent chromosomes at a randomly determined point to create offspring chromosomes. In addition, the mutation operation conducts random changes to enforce diversity in a population. Fig. 2-10 shows the GA optimization process and its operations.

In this research, the initial population, which plays the role of parent chromosomes, is randomly generated as candidate solutions (Alghazi et al. 2012). Next, a fitness function is predefined to evaluate the quality of the generated chromosomes (Tavakolan and Ashuri 2012). The chromosomes with better fitness values retain a higher probability of being selected to the next generation. With each successive generation, children, or new chromosomes, are generated by combining parent or old chromosomes by applying a crossover operator to continually improve and transform the specific gene values of an existing chromosome (Alghazi et al. 2013; Lam et al. 2005). The GA continues these processes until the termination condition is reached. As a result, the GA can obtain an optimal or near-optimal solution to a specific problem, which is not the local optima of the gradient descent method but rather the global optima.

Based on these powerful optimization capabilities, many researchers have been applied the GA with various machine-learning methods (Varpa et al. 2014). For instance, Ahn et al. (2006) introduced a GA to optimize the number of neighbors and feature weights, and Lee et al. (2007) developed a new pattern recognition scheme by applying a GA-based attribute-weighting method with k-NN. Furthermore, the GA is an effective method for satisfying needs across the industry such as information retrievals (Kraft et al. 1997), medical learnings (Lopez et al. 1997), and robot selection in construction industry (Navon and McCrea 1997).

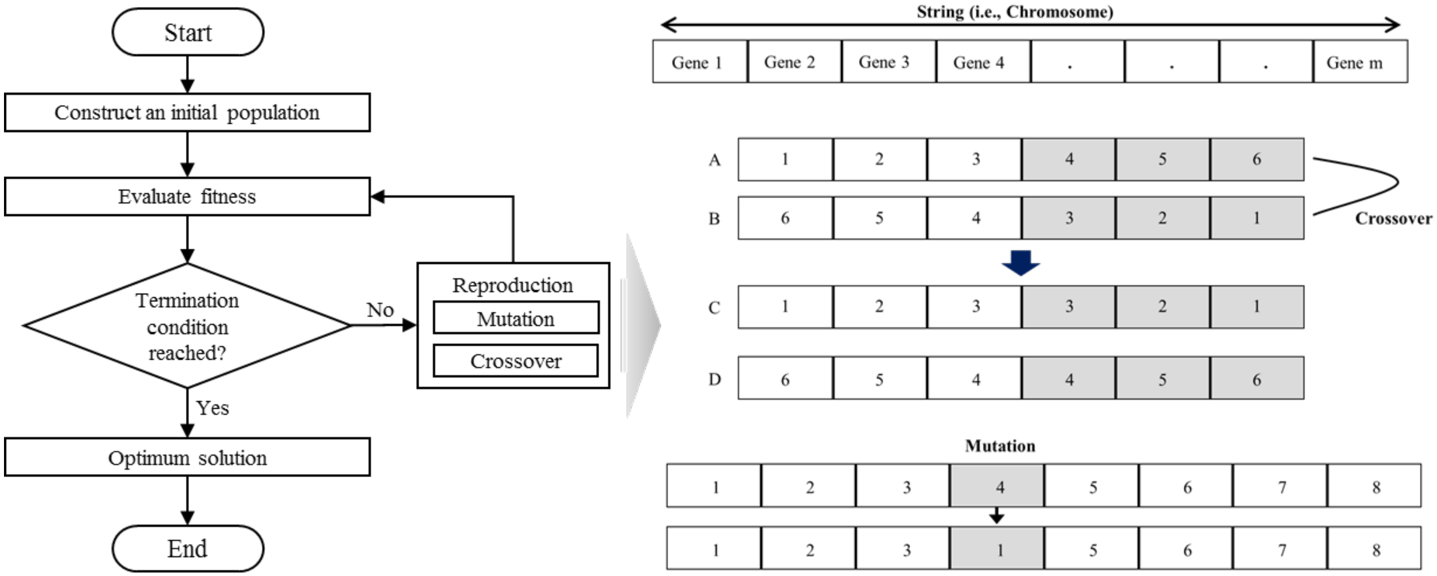

Figure 2-10. GA optimization process

2.3 Summary

This chapter first investigates the various definitions of risks and its related concepts such as uncertainty, crisis, hazard, and opportunity. Based on the analysis results, this research defined the risk as conditions, cases, or chance of something happening that will have a positive or negative effect on a project's performances (e.g., cost and schedule). With this, this research adopts the PMI and CII's risk classification in construction projects to achieve the objective of this research, which classifies the risks into three categories: (1) Knowns, (2) Known-unknowns, and (3) Unknown-unknowns.

For managing the risks, this research analyzes the implementation process of risk management with its principles and framework in international construction projects. According to the analysis results, the generic risk management process is defined as including planning for risk management, risk identification and classification, risk analysis and evaluation, risk response, risk monitoring, risk control, reporting, and review. In addition, this research comprehended the previous literatures for international construction risk management, which have developed using risk management process based approach applicable to predictable risk events.

Although the previous research efforts regarding on risk management of international construction projects have contributed to the body of knowledge, the entire aspects of international project risks have not yet been fully addressed. For instance, the proposed models could only analyze the identifiable risks, and as a result, the risk assessment methods or techniques are only applicable to estimating contingency reserve and planning response strategies and solutions for predictable risk events.

However, the current risk management practices cannot cover or manage the emergent risk events in international construction execution due to its unidentifiable characteristic. In these academic contexts, this research would proposes method for managing the risk events of international construction projects by developing the management reserve estimation method and response strategy decision-making support model.

Next, this research explained the methodologies to develop the case-based learning which is a methodology for achieving research goals. The EFA and reliability test using Cronbach alpha coefficient were first analyzed as a methodology to propose risk management competences for construction projects. With this, this research described the overview of CBR and its problem solving process with the k-NN algorithm. Then, the GA was presented as a simultaneous optimization algorithm for improving retrieval performance of K-NN by assigning relative weights of variables.

By applying the EFA and reliability test, this research would evaluate the construct validity of risk management competences and would propose its theoretical and scientific foundation. For this, the Kaiser-Meyer-Olkin (KMO) and Bartlett's test of sphericity are presented to evaluate the suitability of collected data, and the Principal Component Analysis (PCA) and Orthogonal Varimax rotation are selected as a method for extracting factors and a rotation type for performing EFA. With the application of EFA, the Cronbach alpha coefficient could be calculated to examine the internal consistency of construction project risk management competences.

After explaining the EFA and reliability test, this research described the CBR method. The CBR method has experience-based problem solving process inspired by human reasoning and comprises four or six steps as follows: 1) retrieve, 2) reuse, 3) revise, 4) review, 5) retain, and 6) refine. Using this simple and clear problem-solving capability, the construction industry already applies the CBR to overcome the lack of information or data on the problems. For instance, the previous literatures achieved their objectives related to planning cost and schedule, decision making support, and safety hazard identification. Subsequently, the K-NN is explained as the CBR classification algorithm using Euclidean distance for retrieving pertinent instances which has similar solutions.

With the CBR classification and K-NN algorithm, the GA applications in construction industry is described with its optimization process and operations. The GA operations includes reproduction, crossover, and mutation functions. Based on the GA process and applications, this research could obtain an optimal or near-optimal solution to a specific problem by determining relative weights of variables. The optimal or near-optimal solution is not the local optima of the gradient descent method but rather the global optima.

Chapter 3 . Variable Selection for Case Retrieval Method

The variables are required for achieving the goals of this research by developing the case-based learning using the methodologies described in Chapter 2.2. To extract the variables, this research analyzes the risk sources or factors arising from uncertainties of international construction projects, which influence a negative or positive effect on cost and schedule performance. For instance, the risk sources such as political risk, economic risk, cultural risks, and social risks are investigated as a negative factor increasing the uncertainty in international construction project performances, and risk management competences for construction projects are developed as a positive factor for mitigating the uncertainties. For this, the international construction risks are analyzed through the previous research reviews and expert opinions. This research also develops the risk management competences comprising of skills and individual behavior competences for construction projects. For developing the risk management competences, practical activities of construction project risk management are analyzed to derive skills for managing risks. With this, this research examines the construct validity and internal consistency of project manager's personalities for extracting individual behavior competences for construction risk manager. This research finally selects variables and collects its data sets for applying the CBR classification.

3.1 International Construction Project Uncertainty

The cost and schedule performance of construction projects are closely related to the results of managing the uncertainties of construction projects. In other words, construction project performances can be regarded as the relationship between the uncertainty of international construction projects and mitigation by applying risk management. Fig. 3-1 shows the relationship between the uncertainty and risk management competence.

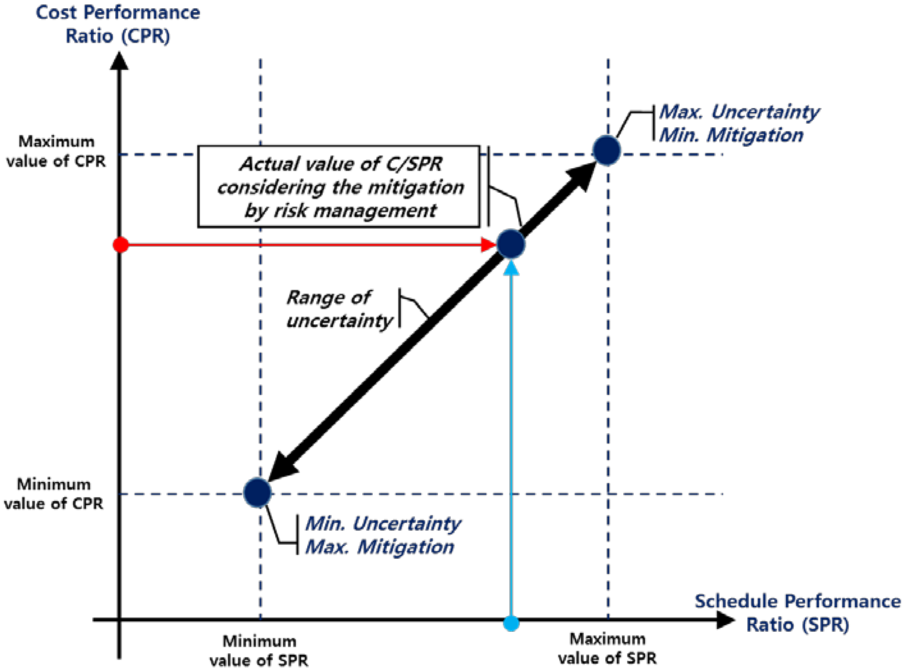

Figure 3-1. A relationship between uncertainty and risk management competence in construction projects

In this context, the variables for retrieving the pertinent instances should be selected by considering the risks from international construction project uncertainties, and the risk management competence is also developed as a positive factor for mitigating the uncertainties. For selecting the variables, this research first analyzes the international construction risks through previous literatures (Bu-Qammaz et al. 2009; El-Sayegh 2008; Han and Diekmann 2001; Zhi 1995).

For instance, Zhi (1995) analyzed the risks of overseas construction projects in accordance with its initial sources: the external risks including national/regional market or the local construction industry and internal risks related to companies involved or determined by the project's own nature. The national or regional risks could be classified into three categories: the political situation, the economic and financial situation, and the social environment. The risks related to the construction industry are divided into four sub-levels: construction market fluctuations, changes in construction law and regulations, differences in construction standards and codes, and differences in construction contract systems. The risk sources related to the company level could be grouped into five categories: risks generated by the employer/owner, risks relating to the architect, risks caused by direct labor and subcontractors, risks caused by materials and equipment suppliers, and risks arising from internal activities of the company. Lastly, the construction project risks contain the risk associated with cost overrun, schedule delay and physical work defects.

Han and Diekmann (2001) also classified the risks of international construction project into five categories: the political risk, the economic risk, the cultural and legal risk, the technological and construction risk, and other risk. The political risk includes seven sub-categories: expropriation, war or riot, government control, repudiation, government subsidy, relationship with government, government act, and regulation. The economic risks are divided into five sub-levels: currency exchange, currency restriction, inflation, burden of financing, and tax discrimination. With this, cultural and legal risks are grouped into six categories: cultural differences, language barrier, different applicable law, different dispute resolution, force majeure, and protection of proprietary information. In addition, technological and construction risks contain difference in geography, labor issue, material availability, subcontractor availability, different standard, different measurement system, and domestic requirement. Lastly, there are other risks including a lack of management skill, lack of experience, warrantee issue, import and export regulation, technology transfer, lack of infrastructure, and public resistance.

In addition, El-Sayegh (2008) developed the risk breakdown structure for United Arab Emirates (UAE) construction industry by classifying the risks into two categories: internal risks and external risks. The internal risks include project-related risks that are under the control of the project management organization, and are divided into five sub-levels: owner, designer, contractor, sub-contractor, and suppliers. With this, the external risks mean that are beyond the control of the project management organization, and are grouped into five categories: political risk, social and cultural risks, economic risks, natural risks, others.

In recent, Bu-Qammaz et al. (2009) developed a hierarchal risk breakdown structure (HRBS) constructed of three levels. The first level represents the identification of risk sources associated with international construction projects. It is defined as the international construction project risk (ICPR). The second level includes the criteria for risk sources classification such as country, inter-country, project team, construction, and contractual risks. Lastly, the third level contains the risk factors involved categories in second level.

Based on these descriptions, this research analyzes the risk factors specific to international construction projects, and then, classifies the international construction project risks into five categories: 1) political risk, 2) economic risk, 3) social and cultural risk, 4) other risk, and 5) construction risk. Table. 3-1 describes the analysis result of international construction project risks.

Table 3-1. International construction project risks

Classification	Risks	Zhi (1995)	Han and Diekmann (2001)	El-Sayegh (2008)	Bu-Qammaz (2009)
Political risk	War threats	✓	✓	✓	✓
	Corruptions & Bribes	✓		✓	✓
	Government stability	✓			
	Expropriation		✓		
	Government control		✓		
	Repudiation		✓		
	Government subsidy		✓		
	Relationship with government		✓		
	Government act & regulation		✓		
	International relationship		✓		✓
	Labor strike		✓	✓	

(Table 3-1. Continued)

Classification	Risks	Zhi (1995)	Han and Diekmann (2001)	El-Sayegh (2008)	Bu-Qammaz (2009)
Economic Risk	GNI	✓			✓ (Instability of Economical Conditions)
	GNI fluctuation	✓			
	Inflation	✓	✓	✓	
	Inflation fluctuation	✓	✓	✓	
	Interest rate	✓			
	Interest rate fluctuation	✓			
	Currency exchange rate fluctuation	✓	✓	✓	
	Tax rate increasing		✓		
	Tax discrimination		✓		
	Burden (Debt) of financing		✓	✓	
	Import and export restriction	✓	✓		

(Table 3-1. Continued)

Classification	Risks	Zhi (1995)	Han and Diekmann (2001)	El-Sayegh (2008)	Bu-Qammaz (2009)
Social and Cultural risk	Language barrier	✓	✓		
	Legal differences	✓	✓	✓	✓
	Constrains on employment and materials availabilities	✓			
	Protection of proprietary information		✓		
	Religious inconsistency	✓			
	Criminal acts	✓		✓	
	Pestilence	✓			
	Substance abuse			✓	

(Table 3-1. Continued)

Classification	Risks	Zhi (1995)	Han and Diekmann (2001)	El-Sayegh (2008)	Bu-Qammaz (2009)
Other risk	Unexpected inclement weather	✓		✓	
	Lack of infrastructure	✓	✓	✓	
	Local Protectionism			✓	
	Poor attitude of host country				✓
	Manpower availability	✓		✓	✓ (Resource availability)
	Material and equipment availability	✓	✓	✓	
Construction risk	Building type			✓	✓
	Construction type			✓	
	Contract type for payment	✓			✓
	Construction complexity			✓	✓
	Construction duration	✓		✓	✓
	Force majeure	✓			
	PM competency	✓	✓	✓	
	Owner’s changes			✓	

3.2 Risk Management Competences for Construction Projects

The risk management competence influences the performance of construction projects as a positive factor for mitigating the uncertainty. For including the risk management competence as one of variables, this research develops the risk management competence model for construction projects, which comprises skills and individual behavior competences. For this, the practical activities of construction project risk management are analyzed based on the risk management principles and guidelines for deriving the skills. Then the derived skills are established through experts' opinions. With this, the individual behavior competences for managing risks are established by examining the construct validity and internal consistency of project manager's personalities. For this, this research applies the EFA and reliability test and finally develops the risk management competences to be more suitable for construction projects.

3.2.1 Skills for Managing Construction Risks

For developing the skills for managing construction project risks, this research first analyzes the practical activities of risk management with consideration of construction project's characteristics, as follows: (1) a life-cycle of construction project and (2) dynamic connection with construction project goals. This research divides the construction project's life-cycle into preconstruction, construction, completion phase, and considers dynamic connections with cost and schedule. Based on these considerations, the previous literature reviews and interviews on experienced professionals were conducted. The interviews are carried out from March 4th, 2015 to April 11th, 2015, and the professionals experiencing construction project risk management comprises 3 practitioners of construction companies, 2 professors of construction engineering, and 2 experts of institute in Korea.

From the literature reviews and experts interviews, practical activities in preconstruction phase are analyzed. The objective of this phase is to win a contract (Han and Diekmann 2001). For this, the enterprise and project management organizations predict the project cost and schedule through the activities, as followings: the board and senior management for decision-making [International Association for Contract and Commercial Management (IACCM) 2003; Yeo and Ren 2009; Zou et al. 2010; Zhao et al. 2013], preliminary identification and analysis of key internal risk (i.e., portfolio risk) (Han et al. 2004; Jia et al. 2013; Kangari and Boyer 1981), preliminary identification and analysis of key external risk (1) country risks (Tanaka 1984; Han 2001), (2) market risks (Hastak and Shaked 2000; Han and Diekmann 2001), (3) project risks (Choi and Mahadevan 2008), considerations of the risk analysis results for cost estimating and scheduling (Laryea and Hughes 2011; Mulholland and Christian 1999), and sharing key risks to related departments (Zhao et al. 2013). The preliminary identification and analysis of the risks is performed through risk management planning, risk identification and classification, and risk analysis and evaluation.

After winning a contract, the enterprise risk management organization sets their project objective and goals (Zhao et al. 2013). Based on the objective and goals, the construction project risk manager should manage the risks for completing their project successfully. The effective risk management activities during construction execution would minimize the likelihood of project cost increase and losses in time. For achieving this purpose, the project and risk manager performs activities, as followings: managing project risks (Akintoye and MacLeod 1997; Raz and Michael 2001; Zeynalian et al. 2013), risk based cost control (Baloi and Price 2003; Dikmen et al. 2007), risk based schedule control (Nasir et al. 2003), and project risk register (Patterson and Neailey 2002; Willams 1994). In particular, the managing project risks are performed based on the risk management processes presented in Chapter 2.1.2.: risk management planning, risk identification and classification, risk analysis and evaluation, risk responses, risk monitoring and control, risk reporting, and risk review.

In addition, based on the registered project data and information, the enterprise risk management organization monitors and reviews their project cost and schedule performances for supporting and controlling the projects. The activities of enterprise risk management organization are as follows:, monitoring and review the project cost and schedule performance and supporting the project management organization (Jia et al. 2013).

Lastly, the risk manager compiles and transfers the collected data and information during project execution when the project is completed. Table. 3-2 summarizes the derived skills for managing construction project risks.

Table 3-2. Skills for construction project risk management

Phases	Competence	Process
Preconstruction phase	The board and senior management for decision making (S1)	
	Preliminary identification & analysis of key internal risk (Portfolio management) (S2)	Risk management planning
		Risk identification & classification
		Risk analysis & evaluation
	Preliminary identification & analysis of key external risk (1) Country risks (S3)	Risk identification & classification
		Risk analysis & evaluation
	Preliminary identification & analysis of key external risk (2) Market risks (S4)	Risk identification & classification
		Risk analysis & evaluation
	Preliminary identification & analysis of key external risk (3) Project risks (S5)	Risk identification & classification
		Risk analysis & evaluation
	Considerations of the risk analysis results for cost estimating (S6)	
	Considerations of the risk analysis results for scheduling (S7)	
	Sharing key risk to related department (S8)	

(Table 3-2. Continued)

Phases	Competence	Process
Construction phase	Objective setting (S9)	
	Monitoring and review the project (S10)	
	Supporting the project (S11)	
	Managing project risks (S12)	Project risk management planning
		Risk identification and classification
		Risk analysis and evaluation
		Risk response
		Risk monitoring and control
		Risk reporting
		Risk review
	Risk based cost control (S13)	
	Risk based schedule control (S14)	
	Project risk register (S15)	
Completion phase	Compiling the data into databases for next project (S16)	
	Transfer of project risk data and information (S17)	

3.2.2 Individual Behavior Competences for Construction Risk Management

By considering a people-oriented characteristic of risk management, the individual behavior competences for construction risk management should be also developed. For instance, the personalities for risk manager enable a risk manager to interact with others effectively for implementing skills (PMI 2007). However, the previous research has only been conducted for the individual behavior competence of project manager without an adequate theoretical validation [Association for Project Management (APM) 2008; Dainty et al. 2005; El-Sabba 2001; Fotwe and MaCaffer 2000; International Project Management Association (IPMA) 2006; Jabar et al. 2013; PMI 2007]. Table 3-3 presents the 11 personalities from the previous research reviews: Leadership, Self-control, Assertiveness, Openness, Results orientation, Efficiency, Negotiation, Problem (Conflict or Crisis) solving, Ethics, Communication, and Teamwork.

Based on the analysis of project manager's personalities, this research derives 11 individual behavior competences and 105 elements of project manager. The EFA is then applied to examine its construct validity, and Cronbach alpha coefficient is measured to evaluate its reliability and internal consistency. For this, questionnaire survey was conducted April 20th, 2015 to May 22th, 2015. It was sent to the 60 practitioners through online and offline. The respondents evaluate importance of derived competences and its elements using a one-to-seven Likert scale, with ‘one’ meaning the worst possible score and ‘seven’ representing the best.

Of the 60 questionnaires distributed, 53 were collected. Based on the questionnaire survey, this research conducts EFA using The Statistical Package for Social Sciences (SPSS version 22.0). The competences and its elements are resolved into their principal components. Prior to the extraction of principal components, the sampling adequacy and multivariate normality should be measured by applying KMO and Bartlett's test. In this research, the result of KMO statistic is 0.832, higher than the acceptable threshold value of 0.5. Therefore, this research regards that the correlation pattern between competences is considered compact and suitable for the EFA (George and Mallery 2006). With this, the results of the Bartlett's test is high enough (value = 856.466) with its associated p-value of 0.000 lower than 0.05, implying that the collected data are considered approximately multivariate normal, and the correlation matrix of the competences is not an identity matrix.

Table 3-3. A comparative summary on individual behavior competence

	Professional organizations			Researches in project management			
	IPMA (2006)	PMI (2007)	APM (2008)	Edum- Fotwe & McCaffer (2000)	El-Sabaa (2001)	Dainty et al. (2005)	Jabar et al. (2013)
Leadership	✓	✓	✓	✓		✓	✓
Self-control	✓				✓	✓	✓
Assertiveness	✓					✓	
Openness	✓				✓	✓	✓
Results orientation	✓	✓				✓	
Efficiency	✓	✓					
Negotiation	✓		✓	✓			
Problem solving	✓	✓	✓	✓	✓		✓
Ethics	✓		✓				✓
Communication		✓	✓	✓	✓		✓
Teamwork			✓			✓	✓

After validating the appropriateness for applying the EFA, this research conducted the EFA with PCA and varimax rotation. The number of principal components are determined as 11 factors intentionally considering the analysis results of previous literature review. According to the analysis result, these 11 competences explain 72.641% of the total variance (i.e., cumulative variance percentage) in the data. This research also removes the elements which has factor-loading value lower than ±0.4 because they are regarded as insignificant for derived factor interpretation (Rencher 2002). Subsequently, 11 factors and 84 elements is determined as the competences and its elements for construction project risk management.

Subsequently, the reliability test is applied to examine internal consistency of the competences and its elements by measuring Cronbach alpha coefficient. This research removes the elements with a Cronbach alpha coefficient value lower than 0.8. Finally, the individual behavior competences for construction risk manager is developed with 11 competences and 76 elements. Table. 3-4 summarizes the rotated factor-loading values and Cronbach alpha coefficients of 11 competences and 76 elements.

Table 3-4. The results of EFA and reliability analysis

Competence	Elements	EFA	Reliability analysis		Note
		Factor loading	Alpha if item deleted	Cronbach alpha	
Leadership	Delegation	.707	.850	.846	The coaching, leadership style, natural authority, tenacity, relationship, morals and commitment element are excluded.
	Feedback	.696	.828		
	Motivation	.672	.808		
	Power (Influencing skills)	.660	.814		
	Recognition	.653	.820		
	Vision	.621	.822		
	Team environment	.598	.844		
	Accountability	.546	.835		
	Collaboration	.522	.828		
	Confidence	.499	.863		
Self-control	Work attitude	.761	.736	.754	The working under stress element are excluded.
	Balance and priorities	.649	.667		
	Time mgt.	.513	.608		

(Table 3-4. Continued)

Competence	Elements	EFA	Reliability analysis		Note
		Factor loading	Alpha if item deleted	Cronbach alpha	
Assertiveness	Persuasion	.788	.889	.896	The authority and personality element are excluded.
	Sociality	.693	.750		
	Personal conviction	.542	.914		
Openness	Accessibility	.722	.850	.840	The broad non RM knowledge and flexibility element are excluded.
	Acknowledgement to the differences	.613	.826		
	Transparency	.602	.650		
Results orientation	Integration of social, technical and environmental aspects	.645	.848	.865	The continuous improvement on results orientation, efficiency element and entrepreneurship are excluded.
	Mgt. of interested parties' expectations	.566	.750		
	Mgt. of risk, changes and configuration	.523	.824		

(Table 3-4. Continued)

Competence	Elements	EFA	Reliability analysis		Note
		Factor loading	Alpha if item deleted	Cronbach alpha	
Efficiency	Benchmarking	.639	.893	0.945	The motivation for efficiency element are excluded.
	Compromises	.587	.893		
	Continuous improvement for efficiency	.543	.947		
	Problem solving for efficiency	.503	.954		
Negotiation	Communication for negotiation	.798	.831	.831	The body language element are excluded.
	Negotiation techniques	.779	.817		
	Problem solving for negotiation	.764	.821		
	Consensus mgt.	.762	.832		
	Identification of negotiation area	.754	812		
	Identification of priorities	.751	.821		
	Decision on desired outcome	.721	.823		
	Decision on minimum acceptable position	.704	.836		

(Table 3-4. Continued)

Competence	Elements	EFA	Reliability analysis		Note
		Factor loading	Alpha if item deleted	Cronbach alpha	
Negotiation (continued)	Collection of available information for negotiation	.673	.815	.831	The body language element are excluded.
	Analysis of available information for negotiation	.665	.821		
	Developments options	.654	.829		
	Negotiation strategy	.652	.814		
	Understanding their motivation, wants and needs	.623	.801		
	Support strategy of project team and stakeholders	.609	.812		
	Negotiation firmly at the content	.574	.845		
	Positive personal relationship	.566	.812		
	Documentation the results of negotiation	.553	.809		
	Sharing the results of negotiation	.502	.842		

(Table 3-4. Continued)

Competence	Elements	EFA	Reliability analysis		Note
		Factor loading	Alpha if item deleted	Cronbach alpha	
Problem (Conflict or Crisis) solving	Problem definition	.695	.852	.848	The building crisis mgt. team and interpersonal skills element are excluded.
	Preparation on potential conflict	.674	.815		
	Identification conflict situation	.656	.834		
	Sharing the conflict with appropriate stakeholders	.623	.804		
	Respect all the views and questions	.612	.846		
	Identification root cause of conflict	.608	.842		
	Seeking paths to resolution	.581	.869		
	Techniques for arbitration	.573	.841		
	Techniques for Mediation	.566	.843		
	Decision making	.513	.830		
	Implementation of solutions	.495	.828		
	Monitoring the ongoing situation	.483	.815		

(Table 3-4. Continued)

Competence	Elements	EFA	Reliability analysis		Note
		Factor loading	Alpha if item deleted	Cronbach alpha	
Ethics	Moral standards	.697	.903	.918	-
	Confidence on ethics	.679	.939		
	Fairness	.648	.891		
	Integrity	.639	.902		
	Transparency for ethics	.601	.885		
	Law-abidingness	.593	.899		
	Respect	.546	.905		
Communica-tion	Identifying communication needs	.687	.890	.901	The preparing communication plans, communication lines and acknowledgement of personal style of communication elements are excluded.
	Formal or informal communication mechanisms	.677	.890		
	Speaking or writing actively	.654	.879		
	Listening actively	.637	.912		
	Understanding actively	.629	.876		
	Response actively	.609	.895		

(Table 3-4. Continued)

Competence	Elements	EFA	Reliability analysis		Note
		Factor loading	Alpha if item deleted	Cronbach alpha	
Communication (continued)	Feedback on the communication	.559	.874	.901	
	Appropriate actions considering the results of communication	.547	.883		
	Information quality	.516	.905		
Teamwork (I11)	Building an effective team	.788	.884	.856	-
	Maintaining an effective team	.746	.891		
	Agreement on ways for working together	.723	.848		
	Mgt the requirement of team	.711	.819		
	Mgt the circumstances of team	.676	.800		
	Mgt the interests of team	.651	.819		
	Taking pride in achievement	.623	.817		
	Communication regularly	.618	.829		
	Asking for support	.574	.831		
	Assistance	.513	.845		

3.3 Variable Selection for Measuring Similarity

This research analyzed the international construction project risks and developed construction risk management competences for selecting the variables. Previous research has already proposed external risks, namely regional or environmental conditions such as war, changes in GDP/GNP, social and cultural differences, and changes in laws or regulations. In addition, international construction projects are also affected by internal risks such as a lack of management skills, building and construction type, contract conditions, tight schedules, and construction complexity.

Based on this analysis, this research conducts interviews on experienced professionals of international construction risk management to draw up a list of project risks and select the variables for model development. These interviews were carried out from July 13th, 2015 to July 24th, 2015. The professionals comprise three professionals of construction companies, professors specializing in construction engineering, and two experts from an institute in Korea. As a result, this research classifies the risks of international construction projects into five categories: (1) political risk, (2) economic risk, (3) social and cultural risk, (4) other risk, and (5) construction risk. For instance, the political risks are divided into five sub-levels: war threat, corruption and bribery, government stability, international relationship, and labor strikes. The risk sources related to economic environment are grouped into nine sub-levels: GNI, GNI fluctuation, inflation rate, inflation rate fluctuation, interest rate, interest rate fluctuation, currency exchange rate fluctuation, burden (debt) of financing, and import and export restriction. The social and cultural risks also include sub-categories such as language barrier, legal differences, criminal acts, and substance abuse. In addition, the risks related to construction contain sub-levels including client type, building type, construction type, contract type for payment, construction complexity, tight schedule, force majeure, project management competence, and owner’s changes. In this research, regarding the project management competence, it is applied with the change of risk management competency. Lastly, there are other risks such as unexpected inclement weather, lack of infrastructure, manpower availability, and material and equipment availability. Fig. 3-2 shows the classification of international construction risks.

From this classification, 30 variables are selected for developing case-based learning. For this, this research excludes the variables of force majeure and owner’s changes due to its difficulties for data collection. Table 3-5 summarizes the configurations of selected variables.

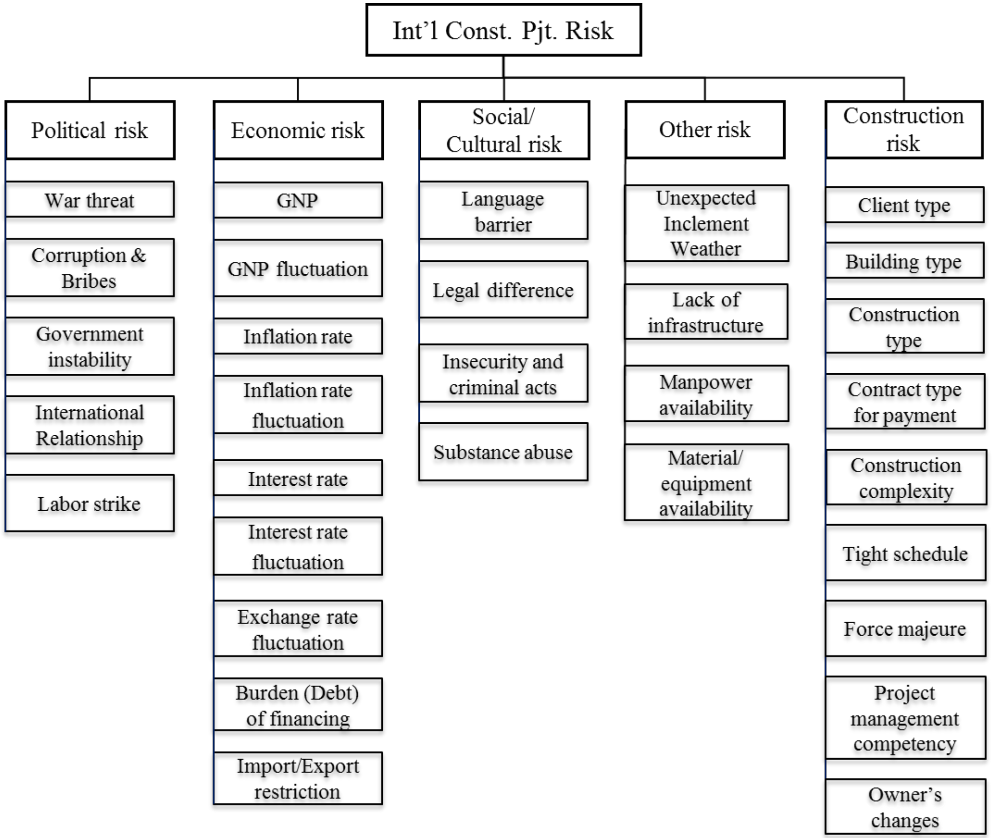

Figure 3-2. Breakdown structure of international construction risks (Revised from various sources)

Table 3-5. Configuration of Variables

	Classification	Variables (Unit)	Type
Political risk	War threat (P1)	Terrorism index – Global rating	Numeric
	Corruption and bribery (P2)	Corruption perceptions index	Numeric
	Government stability (P3)	Political stability	Numeric
	International relationship (P4)	Number of RTAs	Numeric
	Labor strikes (P5)	Global Rights Index – The world's worst countries for workers	Numeric
Economic risk	GNI (E1)	GNI per capita, Atlas method (current US$)	Numeric (Real number)
	GNI fluctuation (E2)	GNI per capita growth (annual %)	Numeric (Real number)
	Inflation (E3)	Inflation, GDP deflator (annual %)	Numeric (Real number)
	Inflation fluctuation (E4)	Inflation of current year – Inflation of last year (annual %)	Numeric (Real number)
	Interest rate (E5)	Lending interest rate (annual %)	Numeric (Real number)

(Table 3-5. Continued)

Classification		Variables (Unit)	Type
Economic risk (Continued)	Interest rate fluctuation (E6)	Interest rate of current year – Interest rate of last year (annual %)	Numeric (Real number)
	Currency exchange rate fluctuation (E7)	$\frac{Exchange\ rate\ of\ current\ year - exchange\ rate\ of\ previous\ y}{Exchange\ rate\ of\ previous\ year}$	Numeric (Real number)
	Burden (debt) of financing (E8)	Government debt to GDP ratio (annual %)	Numeric (Real number)
	Import and export restriction (E9)	Trade freedom	Numeric
Social/ cultural risk	Language barrier (S1)	English or Non-English (1 or 0)	Nominal
	Legal differences (S2)	The Continental law or Anglo-American law or Combined (3 or 1 or 2)	Nominal
	Criminal acts (S3)	Perceptions of criminality	Numeric
	Substance abuse (1) (S4)	Total alcohol consumption per capita (in liters of pure alcohol)	Numeric (Real number)
	Substance abuse (2) (S5)	Annual cigarette consumption per adult	Numeric (Real number)

(Table 3-5. Continued)

Classification		Variables (Unit)	Type
Other risk	Unexpected inclement weather (O1)	Global Climate Risk Index	Numeric
	Lack of infrastructure (O2)	Logistics Performance Index (LPI) – Infrastructure	Numeric
	Manpower availability (O3)	Labor force, total	Numeric (Real number)
	Material & equip. availability (O4)	Logistics Performance Index (LPI)	Numeric
Construction risk	Client type (C1)	Public or Private (1 or 2)	Nominal
	Building type (C2)	Building or Civil or Plant (1 or 2 or 3)	Nominal
	Construction type (C3)	Sub-contractor or construction or Engineering-Procurement-Construction (EPC) (1 or 2 or 3)	Nominal
	Contract type for payment (C4)	Lump sum fixed or Unit price or Cost plus fee (1 or 2 or 3)	Nominal
	Project complexity (C5)	$\frac{Contract\ cost}{Project\ duration}$ (US$ per day)	Numeric (Real number)
	Duration of project (C6)	Project duration (Days)	Numeric (Real number)
	Risk management competence (C7)	Competence level	Numeric

3.4 Data Collection on Selected Variables

This research collects data sets on selected 30 variables to develop the case-based learning by applying methodologies described in chapter 2.2 (Fig 3-3). The data on the twenty three variables related to regional conditions (i.e., political, economic, social and cultural, and other risks) are collected from various sources that provide international indexes. These sources include the Vision of Humanity, Transparency International, Global Economy, World Trade Organization, International Trade Union Confederation, World Bank, Organization for Economic Cooperation and Development (OECD), Trading Economics, World Health Organization, Tobacco Atlas, and German Watch. Next, the data on the six variables related to the internal risks of construction projects (i.e., construction risks) excepting risk management competence are collected from International Contractors Association of Korea (ICAK), leading to a historical data set of 918 international construction projects undertaken by a Korean contractor in 51 countries from 2002 to 2010.

With this, to clarify the data on risk management competence, this research assesses skills and individual behavior competences of construction companies in Korea. A sample size of eight construction companies in Korea is approached, which is positioned in top 50 as an international general contractor according to THE TOP 250 International Contractors published by Engineering News-Record (ENR 2014). The target respondents are the senior management staffs with sufficient experience of construction project risk management (e.g., risk management department head). The interviews were conducted from 24^{th} June 2015 to 7^{th} July 2015 adopting third-party assessment method, which has a merit obtaining answers with a consistent approach. In addition, for assessing the competence level of construction companies, this research defines five levels – from level 1 to 5, which is derived from previous research (Hillson 1997; Hopkinson 2011; IACCM 2003; Jia et al. 2013; PMI 2003; OGC 2006; Yeo and Ren 2009; Zou et al. 2010). The level 1 means a lowest level and level 5 means the highest level. In case of construction companies in Korea, the competence level is mostly between levels 2 and 3, and an average level of skills and individual behavior competences are 2.37 and 2.33.

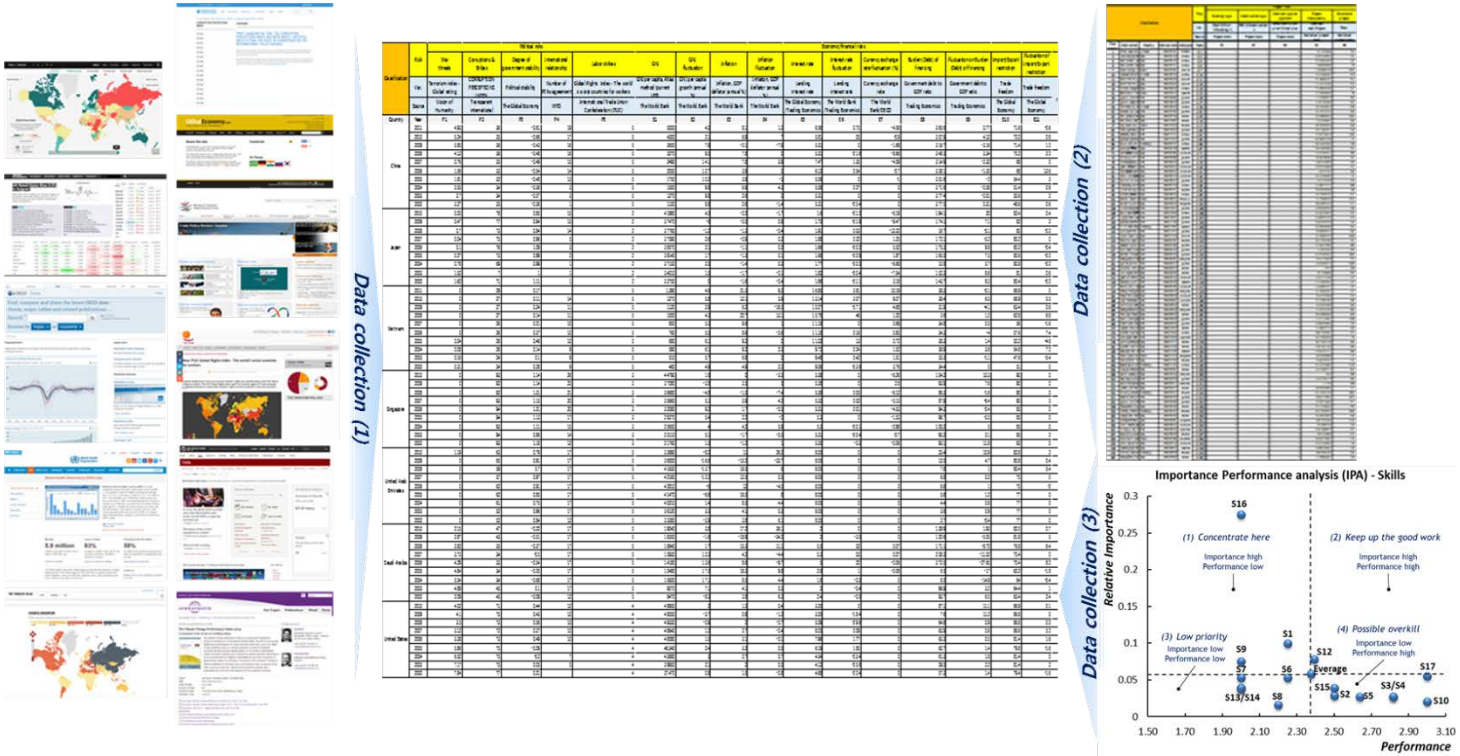

Figure 3-3. Data collection on selected variables

3.5 Summary

This chapter presents the variables for developing the contingency estimation method and response strategy decision-making support model. For this, this research comprehends the relationship between the uncertainty of international construction projects and mitigation by applying risk management. Based on the analysis, international construction risks were analyzed through the previous literatures reviews.

Then the risk management competences for construction projects were developed as one of variables, which comprises skills and individual behavior competences. For developing skills, this research analyzes the practical activities of construction project risk management with considerations of (1) a life-cycle of construction project and (2) dynamic connection with construction project goals. Next, the individual behavior competences are developed by examining construct validity and internal consistency of project manager's personalities by applying EFA and reliability test.

Based on the analysis of international construction risks and developed risk management competences, this research proposed breakdown structure of international construction project risks and classified the risks into five-categories: (1) political risk, (2) economic risk, (3) social and cultural risk, (4) other risk, and (5) construction risk. From the classification, 30 variables could be selected for measuring similarity. This research collects data sets on selected 23 variables related to regional conditions from various sources providing international indexes. The data on the 6 variables related to the internal risks of international construction projects are collected from the historical data set of ICAK in Korea. With this, this research also assessed skills and individual behavior competences of construction companies in Korea. The selected variables and its data collections would be applied for retrieving pertinent instances.

Chapter 4 . Management Reserve Estimation Method

Based on the described methodologies and selected variables, this research proposes the management reserve estimation method for international construction projects. This research first defines the characteristics of management reserve, LDs in Contract, and the CPR and SPR. Then the CPR and SPR are inferred based on the cost and schedule performance of similar construction projects. For this, the K-NN, an instances-based learning algorithm, is applied to retrieve similar projects, and the GA is then adopted to optimize the retrieved instances. Subsequently, the management reserve estimation method is proposed by applying the estimated CPR and SPR. Finally, to evaluate the effectiveness of the developed management reserve estimation method, case study approaches have been conducted using the CPR and SPR of actual construction projects. The first case study validates the estimated CPR and SPR values inferred from similar construction projects. Next, the second case study is applied to actual projects to test the applicability of the developed estimation method. The proposed management reserve estimation method may help construction companies calculate a provision for the unexpected risk events of international construction projects, thereby enabling them to mitigate the likelihood of project cost overruns and schedule delays.

4.1 Backgrounds for Management Reserve Estimation

The construction contractors include a reserve in their project cost: (1) contingency reserve and (2) management reserve. The management reserve is a provision for mitigating cost overruns and schedule delays from unexpected risk events. Considering this purpose of the management reserve, this research first analyzes the characteristics of management reserve by comparing it with contingency reserve. Second, contractually specified damages from schedule delays are explained to clarify the relationship between cost losses and schedule delays. In addition, the CPR and SPR are defined to estimate the management reserve by considering the unique cost and schedule values of construction projects.

4.1.1 Management Reserve for Risk Events

The contingency reserve can only be estimated and reflected in project cost as a provision for dealing with specific risk events (i.e., identified project threats). On the contrary, it is difficult to decide on the appropriate management reserve for unexpected risk events because they cannot be identified until realized as events or outcomes. In addition, historical data may provide only guidance on the catastrophic effects of the risk events, which have a low probability of occurrence (Neil 1989). As a result, the unexpected risk events cause unpredictable losses in cost and schedule performance during project execution. In these contexts, the management reserve should be estimated as a budget set aside in addition to the specific risk provision (i.e., the contingency reserve) to achieve the project objectives in the face of as yet unidentified risk events.

4.1.2 Liquidated Damages in Contract

A contractor's schedule performance is important for achieving its contractual conditions (Crowley et al. 2008). For this reason, many public and private contracts contain LDs clause as one of their contract conditions. LDs are contractually specified damages that represent reasonable compensation charged to the contractor for failure to complete the project on time. For instance, according to the "delay damage" clause in the International Federation of Consulting Engineers' Conditions of Contract for Construction (1999), if the contractor fails to meet the contract time for completion, it must pay delay damage to the employer for this default. The amount of LDs can be calculated by using Eq. (4-1):

$$\begin{aligned} &Total\ amount\ of\ LDs\ paid\ by\ contractor \\ &= Specified\ LDs\ condition\ in\ contract\ (US\ \$/per\ day) \\ &\times Delay\ period\ (days) \qquad\qquad (Eq. 4-1) \end{aligned}$$

In practice, LDs may be capped (e.g., 10% or 20% of the total contract price). However, recent cases have not contained such an upper limit. In other words, the more the contractor delays the time for completion, the more the LDs increase. As a result, the contactor faces a crucial loss. In these circumstances, schedule performance is an important consideration for estimating the management reserve.

4.1.3 Cost and Schedule Performance Ratios

The management reserve is the extra cost for mitigating not only the cost overruns but also the schedule delays caused by unexpected risk events. Meanwhile, a construction project has a unique cost and schedule because of its specific conditions, requirements, and constraints (Huang et al. 2007). Thus, to estimate the management reserve, this research calculates the CPR as the difference between the cost baseline and actual cost at completion divided by the cost baseline. Similarly, the SPR is calculated as the difference between the contract duration and actual duration at completion divided by the contract duration. These ratios are expressed in Eqs. (4-2) and (4-3), as follows:

$$Cost\ Performance\ Ratio\ (CPR) = \frac{Cost\ baseline\ - Actual\ cost\ at\ completion}{Contract\ cost} \qquad (Eq. 4$$

$$Schedule\ Performance\ Ratio\ (SPR) = \frac{Contract\ duration\ - Actual\ duration\ at\ completion}{Contract\ duration} \qquad (Eq. 4 - 3)$$

4.2 Management Reserve Estimation Method Covering Unexpected Risk Events

In line with these definitions, the management reserve of a new project can be planned by using the CPR and SPR. For this, it is required to predict the CPR and SPR of a new project. However, considering the unidentifiable nature of the risk events, the CPR and SPR can only be predicted by using the cost and schedule performance of previous construction projects. One method to predict the CPR and SPR based on pertinent cases is to classify a new instance into the class of its nearest neighbor (NN) instances. This research adopts k-NN, which is a natural expansion of NN, for assigning the majority class of k-NN training cases to a new case. In accordance with k-NN, a GA, namely an effective searching and optimization method inspired by natural selection and the evolution of genetics, is applied to improve the performance of the retrieved cases by assigning weights of selected variables. Using the variables-weighted k-NN algorithm, this research retrieves the optimal pertinent instances for a new project, and the CPR and SPR are inferred by using the CPR and SPR of the retrieved results. Finally, this research calculates the management reserve of a new project. Fig. 4-1 presents the management reserve estimation method scheme.

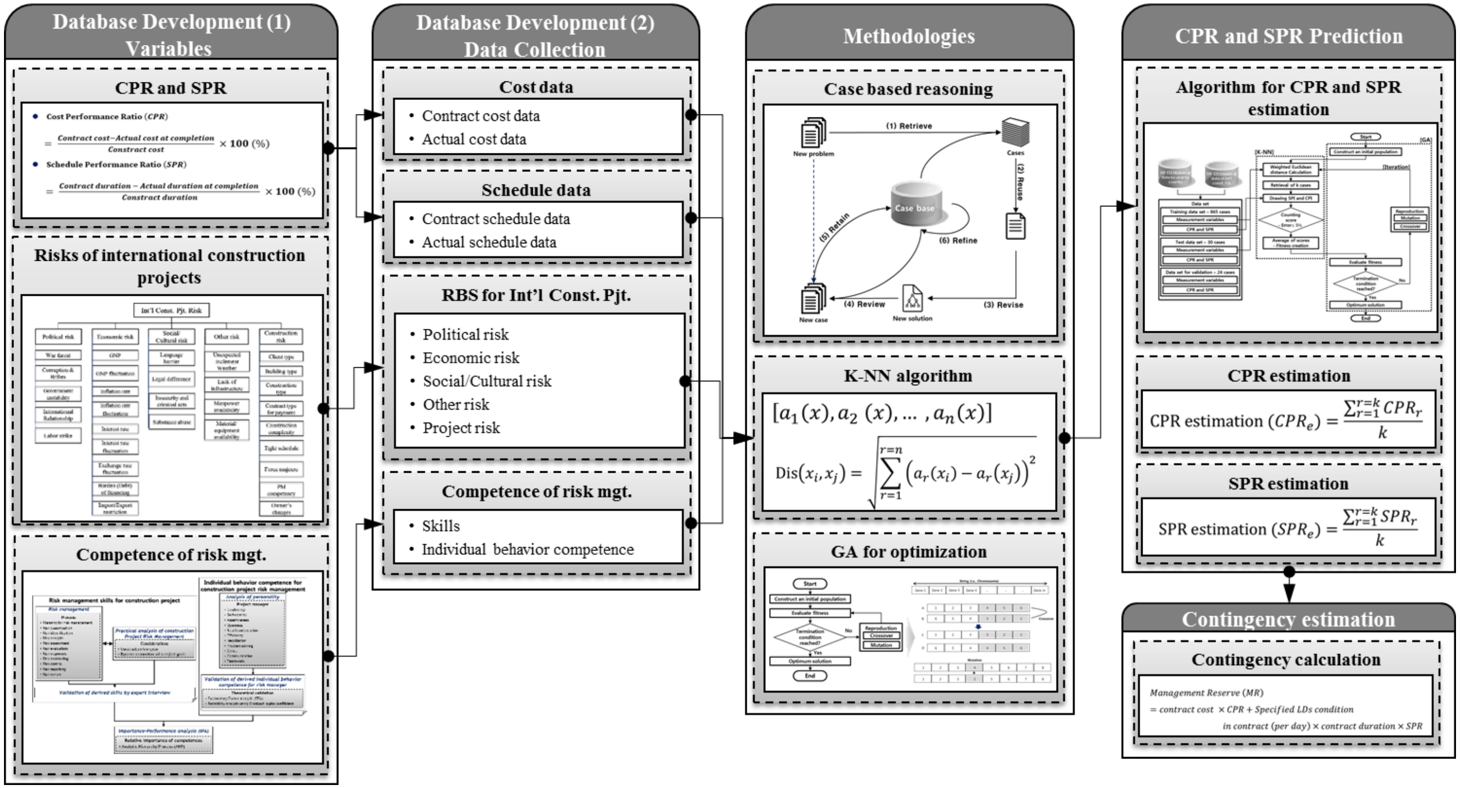

Figure 4-1. Management reserve estimation model scheme

4.2.1 CPR and SPR Prediction using K-NN

Because the derived variables (i.e., attributes) place different degrees of importance on the uncertainty of international construction projects, this divergence should be considered to avoid causing errors in the retrieval results. In addition, the Euclidean distances of k-NN are discrete and have a nonlinear relationship with the predicted CPR and SPR. Thus, this research applies a GA to optimize the retrieval of the nearest neighbors Fig. 4-2 shows the optimized retrieval algorithm using the K-NN and GA.

The first step in the optimization algorithm is to define the fitness function of the GA by comparing the CRP and SPR of the test cases with those of the retrieved instances. To retrieve similar instances, the similarity between the test cases and previous examples is calculated by using the following attributes (i.e., variables)-weighted Euclidean distance, Eq. (4-4):

$$Attributes - weighted\ Euclidean\ Dis(x_i, x_j) = \sqrt{\sum_{r=1}^{r=n} w_r^2 \left(a_r(x_i) - a_r(x_j)\right)^2} \qquad (Eq. 4-4)$$

Where $a_r(x)$ = the value of the rth variables of the case and w_r = the weight of the rth variables of case.

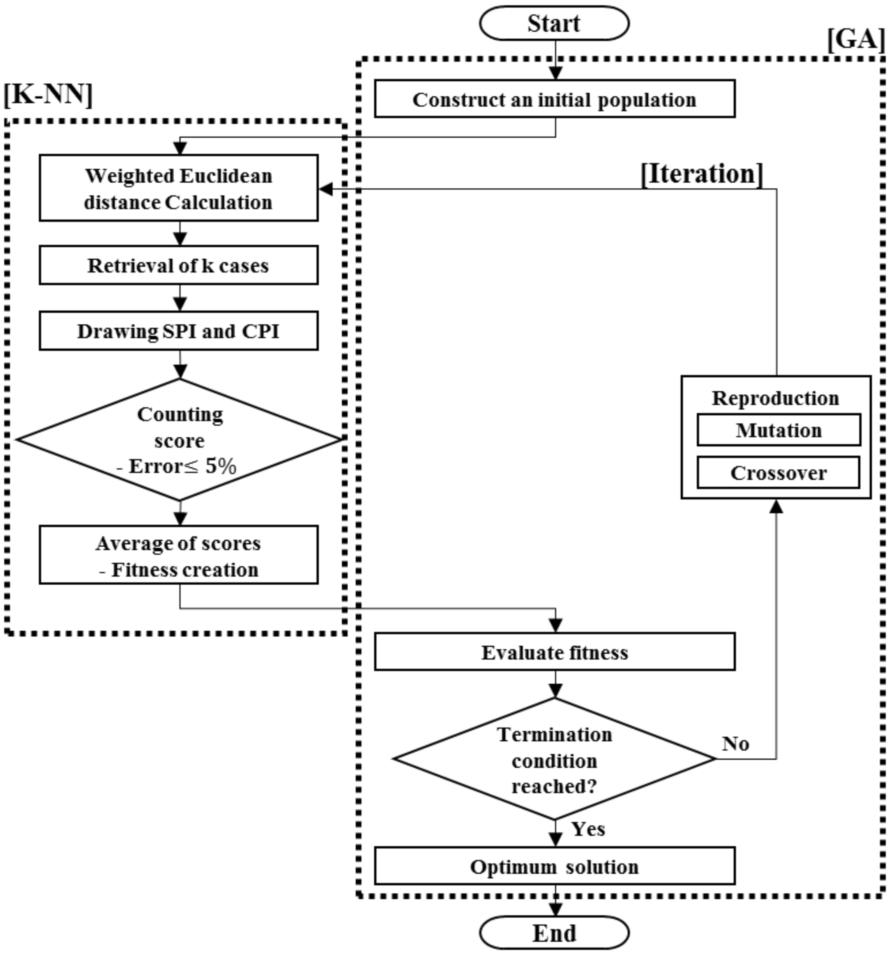

Figure 4-2. Variables weighting algorithm applying GA

Based on the calculation, the k instances that have a short distance are retrieved as the similar instances. Next, the retrieved instances are scored by comparing their CPR and SPR with the CPR and SPR of the test cases using Eq. (4-5):

$$Scoring\ function\ (CPR_r, SPR_r) = \begin{cases} 1, & |CPR_r - CPR_t| < 0.05\ and\ |SPR_r - SPR_t| < 0.05 \\ 0, & |CPR_r - CPR_t| \geq 0.05\ or\ |SPR_r - SPR_t| \geq 0.05 \end{cases} \quad (Eq. 4 - 5)$$

where CPR_r = CPR value of the retrieved cases; SPR_r = SPR value of the retrieved cases; CPR_t = CPR value of the test case; SPR_t = SPR value of the test cases. From the scoring results, the fitness function for optimizing the weight of the variables is developed as a mean value for the scores of the test cases. Eq. (4-6) shows the defined fitness function:

$$Fitness\ function = \frac{\sum_{r=1}^{r=N} S_r}{N} \quad (Eq. 4 - 6)$$

where S_r = score of the rth test case and N = number of test cases. After defining the fitness function, the retrieved instances are optimized. For this, the fitness function should be set to maximize its value because the weight of the variables that have higher fitness indicates higher optimization. Then, the weights of the variables are assigned. By using the assigned weights, the attribute-weighted Euclidean distances are calculated by applyling Eq. (4-4) to measure similarity, and the retrieved instances are optimized through iteration to maximize the fitness value. Based on the CPR and SPR of the retrieved instances, the CPR and SPR of a new instance can be estimated by calculating the mean value of the CPR and SPR of the retrieved cases, Eqs. (4-7) and (4-8):

$$CPR\ estimation\ (CPR_e) = \frac{\sum_{r=1}^{r=k} CPR_r}{k} \qquad (Eq.\ 4-7)$$

$$SPR\ estimation\ (SPR_e) = \frac{\sum_{r=1}^{r=k} SPR_r}{k} \qquad (Eq. 4-8)$$

4.2.2 Management Reserve Calculation using CPR and SPR

By using the estimated CPR_e and SPR_e, this research finally proposes a management reserve calculation. As the management reserve is a provision for cost overruns and schedule delays from unexpected risk events, its calculation must consider the predicted cost performance and the schedule performance of a new project. Based on the estimated CPR_e and SPR_e, the expected cost performance of a new project can be calculated by using contract cost, while expected schedule performance can be calculated by considering the specified LDs in the contract as well as the contract duration of the new project. Thus, the management reserve is calculated as the sum of expected cost performance and schedule performance. When the CPR of the historical data set does not include the loss from schedule delay, the management reserve is calculated as follows:

$$Contingency\ estimation\ for\ unplanned\ changes$$
$$= contract\ cost\ \times CPR_e$$
$$+ Specified\ LDs\ condition\ in\ contract\ (per\ day)$$
$$\times contract\ duration \times SPR_e \qquad (Eq. 4-9)$$

4.3 Case Study for Validation

This research conducts two case studies to validate the CPR_e and SPR_e values, and test an applicability of the proposed management reserve estimation method. For this, data on case projects are first collected. Based on these data sets, case study 1 first develops the weight of the variables to estimate the CPR_e and SPR_e. Next, the accuracy of the estimated CPR_e and SPR_e is assessed by comparing those ratios with their actual CPR and SPR values. Case study 2 applies the proposed management reserve estimation method to actual construction projects and compares the estimated management reserve by applying the method proposed in this research with the traditional percentage method.

4.3.1 Accuracy of CPR and SPR Prediction

To conduct these case studies, this research first collects data set on previous international construction projects. The historical data set are collected from ICAK in Korea, which is 915 international construction projects undertaken by Korean contractors in 51 countries from 2002 to 2010. This research randomly classifies historical cases into three groups: (1) a training data set (i.e., instances data set) that contains 865 instances; (2) a test data set for weighting the variables that contains 30 instances; and (3) a validation data set that contains 23 instances.

By using the collected data set, case study 1 is conducted to validate the effectiveness of the weight applied to the variables by the GA. For this, the CPR_e and SPR_e values are compared with their actual values to evaluate the estimation accuracy. The actual values of CPR and SPR are calculated by using Eqs. (4-2) and (4-3). This research applies a contract cost as the baseline cost to calculate the CPR because, according to the expert interviews, construction contractors in Korea rarely include the MR in their project costing, with the contract cost estimated systematically and reasonably. With this, it is hard to collect data on the baseline of construction projects. As a result, this research assumes that the contract cost of construction companies in Korea is similar to the amount of cost baseline. Then, the actual values of CPR can be calculated by using the contract cost. Subsequently, 20 validation data sets from 2005 to 2010 are employed randomly among the international construction projects examined.

This research first measures the attribute-weighted Euclidean distances between the 865 training data sets and 30 test data sets to optimize the weight of the variables. The weight values are optimized in the different number of k retrieved cases (i.e., k= 5, 6, 7, 8, 9, 10, and 15) to examine an appropriate k value that has a higher fitness value. Here, k (i.e., the number of retrieved cases) influences the reliability of the retrieval results. To optimize the weights and derive an appropriate k, this research uses "EVOLVER 5.5," a GA tool, setting the condition of 0 to 1 for the attribute weight (i.e., adjusting cell) range, 0.2 for the crossover rate, and 0.9 for the mutation rate. According to the results of the fitness value in Table 4-1, this research finally adopts 5-NN. The optimized weights for 5-NN are shown in Table 4-2.

Table 4-1. Fitness values of GA optimization

Number of k retrieved cases	K=5	K=6	K=7	K=8	K=9	K=10	K=15
Fitness value (Reliability=$\frac{\text{Fitness value}}{\text{Number of k}} \times 100$)	4.06 (81.2%)	4.42 (73.7%)	5.23 (74.7%)	5.23 (65.4%)	5.74 (63.8%)	6.26 (62.6%)	8.8 (58.7%)

Table 4-2. Weight values of variables by applying GA

Variables	Weights by GA
	K=5
War threat (P1)	0.640144956619666
Corruption and bribery (P2)	0.439239576387032
Government stability (P3)	0.697842106375395
International relationship (P4)	0
Labor strikes (P5)	0.926817325155667
GNI (E1)	0.606918906356507
GNI fluctuation (E2)	0.901580620879758
Inflation (E3)	1
Inflation fluctuation (E4)	0.945684354942803
Interest rate (E5)	0.0884802793776587
Interest rate fluctuation (E6)	0.82010590056171
Currency exchange rate fluctuation (E7)	0.867627068405232
Burden (debt) of financing (E8)	0
Import and export restriction (E9)	0.0533977312410017
Language barrier (S1)	1
Legal differences (S2)	0.658285303696517
Criminal acts (S3)	0.436779671652017
Substance abuse (1) Alcohol (S4)	1
Substance abuse (2) Tobacco (S5)	0.171711703909315

(Table 4-2. Continued)

Variables	Weights by GA
	K=5
Unexpected inclement weather (O1)	0.795004658502494
Lack of infrastructure (O2)	1
Manpower availability (O3)	0.0000362134339170326
Material and equipment availability (O4)	0.316009598536766
Client type (C1)	1
Building type (C2)	0.163225708168562
Construction type (C3)	0.640697474563997
Contract type for payment (C4)	0.892061578716131
Project complexity (C5)	0.809397783353799
Duration of project (C6)	0.405339057211066
Risk management competence (C7)	0.817423948266072

Then, the similar instances of the 20 test data sets are retrieved by applying 5-NN and their variable weights, and the CPR_e and SPR_e are estimated by using Eqs. (4-7) and (4-8). Consequently, the accuracy of the CPR_e and SPR_e can be evaluated by calculating their error rate as follows:

$$Error\ rate\ of\ the\ CPR\ estimation\ (\%) = |CPR_e - CPR_a| \quad (Eq. 4$$

$$Error\ rate\ of\ the\ SPR\ estimation\ (\%) = |SPR_e - SPR_a| \quad (Eq. 4$$

Where CPR_e = estimated CPR value; SPR_e = estimated SPR value; CPR_a = actual value of the validation data set; SPR_a = actual value of the validation data set. Table 4-3 summarizes the error rates of the CPR_e and SPR_e. According to the validation results, the mean error rate of the CPR_e is 2.83% with a 1.77% standard deviation and the mean error rate of the SPR_e is 3.46% with a 2.26% standard deviation. The maximum error rate of the CPR_e is 6.36% (Test case 5), whereas the minimum error rate is 0.40% (Test case 17). Likewise, the maximum error rate of the SPR_e is 7.02% (Test case 3), whereas the minimum error rate is 0.20% (Test case 17). In addition, the reliability of the CPR_e and SPR_e within a 5% error rate is 85% and 75%. These results show that the error rates of the CPR_e and SPR_e are in the range of 5% with approximately 80% reliability.

The accuracy and reliability of the CPR_e and SPR_e could be improved by including more variables such as owner's changes. In addition, the proposed attribute-weighted K-NN method must be implemented by considering the long-term nature of construction projects. One possible solution here is to develop a time series model to predict the variable values with high uncertainty and high variance.

Table 4-3. Error ratio for validation

Data set for validation	Actual values (%)		Estimated values (%)		Error rate (%)	
	CPR_a	SPR_a	CPR_e	SPR_e	CPR_e	SPR_e
Test case 1	8.26	-4.82	11.1	-1.33	2.84	3.49
Test case 2	0.4	-1.5	1.89	-0.22	1.49	1.28
Test case 3	11.71	-16.9	8.37	-23.92	3.34	7.02
Test case 4	4.49	-6.43	1.5	-2.14%	2.99	6.409
Test case 5	15.72	-4.18	9.36	-1.39	6.36	2.79
Test case 6	8.06	22.3	3.85	15.66	4.21	6.64
Test case 7	10	-10.27	6.37	-6.42	3.63	3.85
Test case 8	-5.12	-5.91	-1.71	-1.97	3.41	3.94
Test case 9	5.98	-4.2	3.66	-1.4	2.32	2.8
Test case 10	-1.97	-8.94	2.51	-3.98	4.48	4.96
Test case 11	13.4	-9.98	7.8	-3.33	5.6	6.65
Test case 12	1.77	1.41	0.99	0.47	0.78	0.94
Test case 13	10	-2.82	8.33	-0.94	1.67	1.88
Test case 14	12.37	-4.66	6.79	-1.55	5.58	3.11
Test case 15	4.78	-4.11	3.61	-1.37	1.17	2.74
Test case 16	6.99	-1.92	6.33	-0.64	0.66	1.28
Test case 17	4.6	0.2	4.2	0	0.4	0.2
Test case 18	3	-7.83	4.03	-8.12	1.03	0.29
Test case 19	1.91	-11.44	0.27	-4.76	1.64	6.68
Test case 20	7	-3.4	10.07	-1.13	3.07	2.27
Reliability of the estimation with a 5% error rate					85%	75%
Mean error rate of the CPR_e and SPR_e					2.83	3.46
Standard deviation of error rate of the CPR_e and SPR_e					1.77	2.26

4.3.2 Applications for Actual Projects

After the validation of the CPR_e and SPR_e, this research tests the applicability of the proposed management reserve estimation method by selecting three actual construction projects (projects A, B, and C). These projects were procured by a lump sum fixed price contract, and the contract type is a joint venture. The contract costs are approximately US$82,888,000–311,958,000, and a management reserve account was not reflected in the contract costs. In addition, the contract duration is 670 days, 939 days, and 913 days for projects A, B, and C, respectively. Moreover, since the LDs clause was not included in the contract, the cost performance of actual projects did not cover the loss from LDs. Thus, this research assumes that LDs were 0.1% of the contract costs to explore the effectiveness of the proposed contingency estimation method.

The cost performance of project A is -$3,299,000 (i.e., -4.0 CPR_a) with 44 delay days (i.e., -6.6 SPR_a). Hence, according to the assumption of LDs (i.e., 0.1% per day), the loss from schedule delays is -$3,647,072. As a result, the total loss of project A is -$6,946,072, which is the sum of cost performance and losses from schedule delays. Likewise, the cost performance of project B is -$19,879,000 (i.e., -6.4 CPR_a) with 191 delay days (i.e., -20.3 SPR_a), causing a cost loss of -$59,583,978. As a result, the total loss of project B can be determined as -$79,462,978. The cost performance of project C is -$7,296,000 (i.e., -29.3 CPR_a) with 274 delay days (i.e., -30.0 SPR_a), causing a cost loss of -$6,831,094. As a result, the total loss of project C is -$14,127,094. Table 4-4 summarizes the analysis of projects A, B, and C.

Next, the management reserve of each project are estimated by using the data on the case projects shown in Table 4-5. The CPR_e and SPR_e are predicted by applying the suggested attribute-weighted 5-NN. As a result, the management reserve of project A is calculated as $5,909,914 using the -5.23 of the CPR_e and -2.74 of the SPR_e. In addition, the management reserve of project B is determined as $79,549,290 from the -4.78 of the CPR_e and -16.79 of the SPR_e. The management reserve of project C is calculated as $14,173,273 from the -32.35 of the CPR_e and -26.81 of the SPR_e. Table 4-6 summarizes the estimated management reserve of actual projects.

Based on these results, the proposed management reserve estimation is evaluated by comparing it with the traditional percentage estimation method. The management reserve under the traditional percentage method is about 5% of cost baseline estimate depending on a joint venture's experience of international construction projects (Kumas and Ergonul 2007).

As summarized in Table 4-6, the traditional percentage contingency of project A is $4,144,400. This only mitigates 59.67% of the total loss (i.e., 40.33% of the error rate). On the contrary, the proposed management reserve in this research can mitigate 85.08% of the total loss (i.e., 14.92% of the error rate). The difference between the estimations is 25.41% (i.e., a decrease from 40.33% to 14.92%). In the case of project B, the traditional percentage management reserve is $15,597,900, mitigating 19.52% of the total loss (i.e., 80.48% of the error rate). While the proposed management reserve mitigates 99.89% of the total loss (i.e., 0.11% of the error rate), it also reduces the error rate from 80.48% to 0.11% (i.e., an 80.37 % difference). The management reserve of project C is $1,246,550 for the traditional management reserve, which only mitigates 8.82% of the total loss (i.e., 91.18 % of the error rate). On the contrary, the proposed management reserve mitigates 99.67% of the total loss and decreases the error rate from 91.18% to 0.33% (i.e., by 90.85%).

These test results indicate that the proposed management reserve estimation method yields a more accurate management reserve than the traditional percentage estimation approach. In particular, the proposed method using the inferred CPR_e and SPR_e is more effective for projects that have an expected larger loss and LDs clause, which reveals its potential applicability to construction projects.

Table 4-4. Descriptions of case projects

Classification	Project A	Project B	Project C
Contract cost ($)	82,888,000	311,958,000	24,931,000
Contract duration (day)	670	939	913
Loss from CPR_a ($)	-3,299,000	-19,879,000	-7,296,000
Delay period (day)	44	191	274
CPR_a (%)	-4.0	-6.4	-29.3
SPR_a (%)	-6.6	-20.3	-30.0
Loss from LDs (0.1%/day) ($) $= \text{contract cost} \times 0.001 \times \text{delay periods}$	-3,647,072	-59,583,978	-6,831,094
Total Loss considering LDs ($) $= \text{Loss from } CPR_a + \text{ Loss form LDs}$	-6,946,072	-79,462,978	-14,127,094
Actual management reserve($)	0	0	0

Table 4-5. Data profile of the case projects for the applicability tests

Classification	Project A	Project B	Project C
War threat (P1)	0	4.56	3.27
Corruption and bribery (P2)	5.7	1.6	3.5
Government stability (P3)	0.97	-1.72	-0.36
International relationship (P4)	17	15	1
Labor strikes (P5)	5	5	5
GNI (E1)	42160	610	1100
GNI fluctuation (E2)	-10.1	29.5	8.8
Inflation (E3)	12.5	-0.2	0.6
Inflation fluctuation (E4)	0.5	-11.3	-1.4
Interest rate (E5)	8.05	19.18	5.31
Interest rate fluctuation (E6)	0	-1.53	-0.54
Currency exchange rate fluctuation (E7)	0	2.84	0
Burden (debt) of financing (E8)	6.8	63.9	37.75
Import and export restriction (E9)	75	45	48.6
Language barrier (S1)	0	1	0
Legal differences (S2)	1	1	3

(Table 4-5. Continued)

Classification	Project A	Project B	Project C
Criminal acts (S3)	2	5	4
Substance abuse (1) Alcohol (S4)	4.3	12.3	4.9
Substance abuse (2) Tobacco (S5)	715.01	172.68	2249.79
Unexpected inclement weather (O1)	76.5	53	27.5
Lack of infrastructure (O2)	3.8	2.23	3.2
Manpower availability (O3)	3,735,627	42,105,536	738,923,140
Material and equipment availability (O4)	3.73	2.4	3.32
Client type (C1)	2	2	2
Building type (C2)	1	3	3
Construction type (C3)	1	2	1
Contract type for payment (C4)	3	3	3
Project complexity (C5)	123.71	343.24	27.31
Duration of project (C6)	670	939	939
Risk management competence (C7)	2.62	2.40	2.14

Table 4-6. Test results using the accuracy of the management reserve estimation

Classification	Project A	Project B	Project C
CPR_e (%)	-5.23	-4.78	-32.35
SPR_e (%)	-2.74	-21.79	-26.81
Estimated loss from CPR_e (\$) $= \text{contract cost} \times CPR_e$	4,335,042	14,911,592	8,065,178
Estimated delay (day)	19	205	245
Estimated loss from SPR_e (\$) $= \text{contract cost} \times 0.001 \times \text{delay periods}$	1,574,872	63,951,390	6,108,095
Management reserve by traditional percentage estimation (5% of project cost) (\$)	4,144,400	15,597,900	1,246,550
Proposed management reserve (\$) $= \text{estimated loss from } \mathrm{CPR_e} +$ $\text{estimated loss form } \mathrm{SPR_e}$	5,909,914	79,549,290	14,173,273

(Table 4-6. Continued)

Classification	Project A	Project B	Project C
Total loss applying 5% management reserve ($) $= \text{contingency by point estimation} - \text{total loss}$	-2,801,672	-63,951,390	-12,880,544
Total loss applying proposed management reserve ($) $= \text{proposed contingency - total loss}$	-1,036,158	86,312	46,179
Error rate of 5% (traditional percentage) management reserve $= \frac{\lvert\text{Total loss applying 5\% contingency}\rvert}{Total\ loss} \times 100$	40.33%	80.48%	91.18%
Error rate of the proposed management reserve $= \frac{\lvert\text{Total loss applying proposed contingency}\rvert}{Total\ loss} \times 100$	14.92%	0.11%	0.33%
Difference in the error rate = Error rate of management reserve using 5% percentage – error rate of proposed management reserve	25.41%	80.37%	90.85%

4.4 Summary

This research proposes a management reserve estimation method using the predicted CPR_e and SPR_e to deal with the unexpected risk events of international construction projects. For this, the k-NN classification and GA methodology are applied to develop the proposed management reserve estimation method by applying attribute-weighted 5-NN. In addition, two case studies are conducted to validate the CPR_e and SPR_e as well as the applicability of the proposed method. The case studies showed that the proposed method can predict the CPR_e and SPR_e within a 5% error rate, thus estimating the management reserve more accurately than the traditional percentage method.

In this regard, the estimated management reserve enables construction companies to cope with emergent risk events during construction execution phase and can thus be used to plan project costs accurately. In addition, for estimating the management reserve, this research could estimate the schedule performance of a new project with its cost performance, and makes the construction contractors plan their contract costs and schedules strategically by considering a trade-off relation between them. The construction companies could minimize the likelihood of project cost increase and losses in time of international construction projects.

In terms of future research directions, the accuracy of the CPR_e and

SPR_e could be improved by including important variables such as the owner's data change. Further, time series models of variables with high significance and variance could improve the performance of the proposed method by enabling a comparison with other projects. Lastly, this research is based on data from a limited number of cases, and additional tests must be conducted to further validate the model and generalize the effects of the proposed methods.

Chapter 5 . Response Strategy Decision-making Support Model

By using the management reserve, the construction contractors should respond to the unexpected risk events immediately when the risk events are realized during construction execution. For this, appropriate response strategy and solution is required. In this context, this research proposes a response strategy decision-making support model by suggesting response strategies and solutions applied in previous construction projects. This research first reviews the literatures about managing risk events and comprehends the limitations of current risk event management. Next, applicable response strategies are explains to dealing with the risk events. This research then provides an appropriate response strategy and solution by retrieving similar risk event cases. For this, CBR is used as a methodology for problem solving when applied with the K-NN for retrieving pertinent cases by measuring similarity. In addition, for improving the effectiveness of K-NN retrieval, this research also applies the AHP for determining the weights of variables. Subsequently, to clarify the suggested model, case studies are conducted to evaluate the retrieval performance.

5.1 Backgrounds for Response Strategy Decision Support

In initiating or planning stage, the construction contractors could not plan response strategies for unexpected risk events due to its unpredictable characteristic. When the risk events are realized during project execution, it cause unexpected negative effects on their project performances (i.e., cost and schedule) markedly because of difficulties to respond immediately to the risk events. As a result, the risk events would bring about crisis that critically threatens the project performances (Gillanders 2003). In these contexts, this research suggests response strategies and solutions applied in similar risk events for supporting contractors' appropriate and immediate response to a new risk event. To explain the rationale for response strategy decision support, this research first reviews the literatures for managing or recovering risk events and then describes applicable strategies for recovering risk events.

5.1.1 Overview of Risk Event Management

To mitigate the negative effects on project performances from the risk events, previous research has been proposed mainly focusing on (1) development of crisis management framework (Anthopoulos et al. 2013; Bejestani 2014; Ha¨llgren and Wilson 2008; Sahin et al. 2015; Zamani and Salahshour 2015) and (2) effective communication for managing the risk events or crisis recently (Loosemore 1998; Vondruška 2014; Zhong and Low 2009 and 2012). For instance, Sahin et al. (2015) have been developed innovative construction crisis management approaches and process that includes catching and evaluating crisis signals or developing proactive methods for defending them. Zhong and Low (2009) made a contribution to crisis response communication in construction projects from a complexity perspective. In addition, Anthopoulos et al. (2013) proposed structure a generic model comprising principles and processes, which could recover a construction project after a disaster effect.

On the contrary, few investigations have been conducted for supporting an effective counterplan for the risk events. As a result, despite its role and importance, the response strategy and solution for realized risk events are still determined by only using the intuition and experience of construction contractor. As an effort to address these challenging issues, this research proposes the response strategy decision-making support model for supporting construction contractor’s immediate decision-making by suggesting appropriate response strategies and solutions.

5.1.2 Response Strategy for Risk Events

This research supports the contractors’ decision-making for responding to a new risk event by suggesting response strategies and solutions applied in previous risk events. For coping with the risk events during construction execution, many response strategies for risk events are already suggested. The response strategies can be defined as an action taken to avoid the risk events, to reduce a probability of occurrence, or to mitigate impacts (i.e., risk consequences) from the risk events (Nasirzadeh et al. 2013).

The risk response strategies are commonly classified into four categories: (1) Avoidance that explains the rejection or change of an alternative for removing the risk events, (2) Transference or sharing that means a switch of risk event responsibility between contracting participants in project, (3) Mitigation that denotes reduction of the occurring probability or the expected impacts of risk events, and (4) Acceptance or retention that is applied when the risk events cannot be eliminated or identify any other suitable response strategy (ISO 2004; Nasirzadeh et al. 2013; PMI 2008; Standards Australia 2004). These response strategies are not mutually exclusive or appropriate in all circumstances, and can be applied as a combination of multiple approaches (ISO 2009; Standards Australia 2004). Based on the response strategies, the contractors should select most appropriate response strategy and plan a solution for recovering risk events that minimize the loss in project cost including the schedule delay.

5.2 Response Strategy Decision-Making Support Model recovering Unexpected Risk Event

Based on the methodologies and backgrounds, this research proposes a response strategy decision-making support model for recovering the unexpected risk events in international construction projects. To develop the model, this research first classifies the risk events commonly generated during international construction execution. This research then provides appropriate response strategies and solutions for supporting the contractor's decision-making. One method to suggest the appropriate response strategies and solutions is to retrieve similar risk event cases and uses its response strategies and solutions. For this, the K-NN algorithm is applied with AHP, a multi-attribute decision analysis method, for determining weights of selected variables. As a result, this research improves the effectiveness of retrieval results by applying attribute-weighted K-NN. Subsequently, by using the proposed model, the construction contractors would plan an appropriate response strategy and solution in time when the risk events are realized in international construction execution. Fig. 5-1 presents the proposed model scheme.

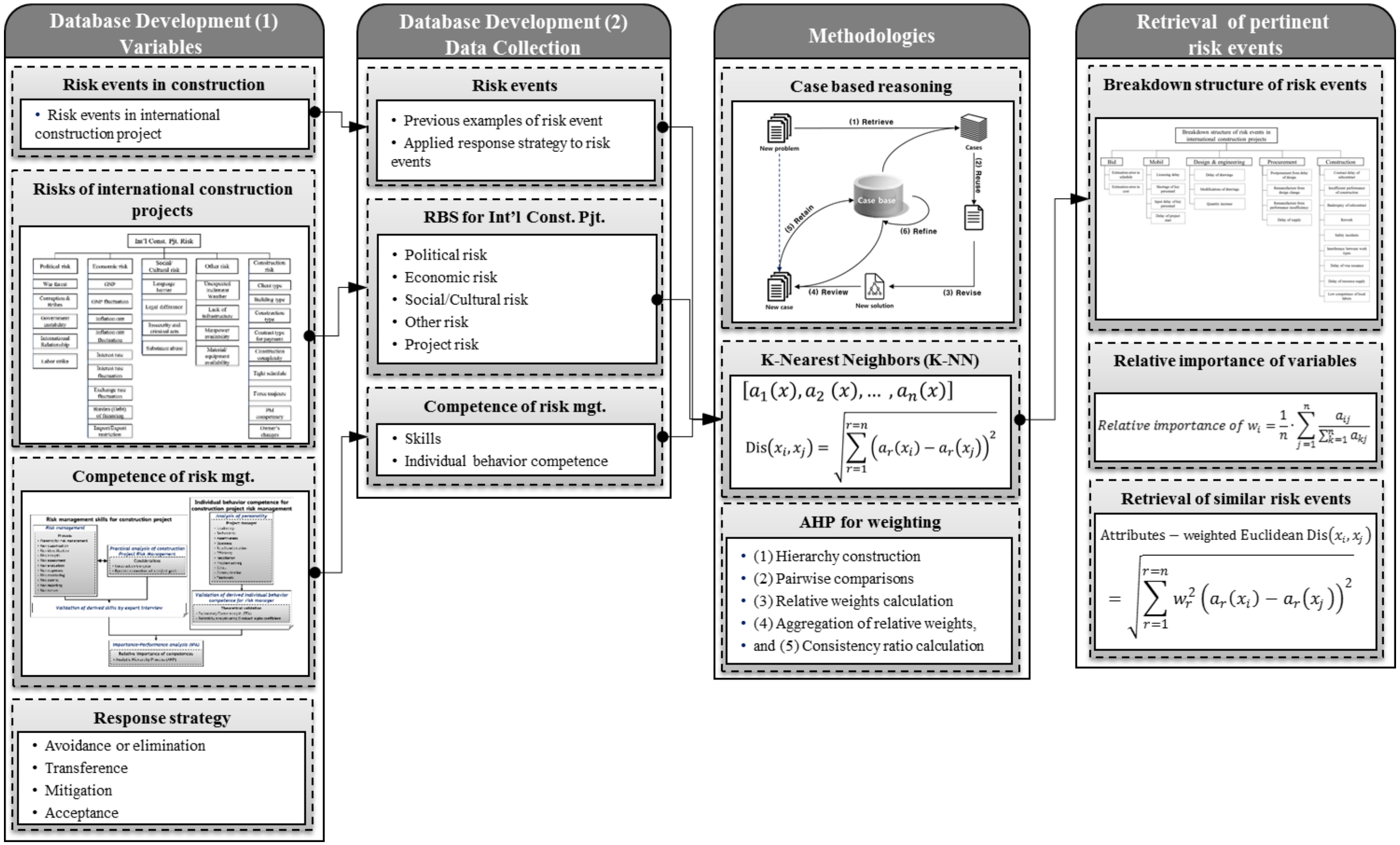

Figure 5-1. Response strategy decision-making support model scheme

5.2.1 Risk Event in international construction projects

For retrieving similar risk events and using its applied counterplan, this research first develop database comprising risk events and its applied response strategies and solutions. For this, the instances of risk event in international construction projects are required. This research investigates the previous research on the risk events (Eybpoosh et al. 2011; Fang et al. 2004; Ocal et al. 2006). Next, interviews on practitioners of construction companies in Korea are conducted to develop the breakdown structure of risk events for international construction projects. The interviews are carried out from 4th December 2015 to 11th January 2016, and the target respondents are senior management staffs with sufficient experience of international construction project management. As a result, this research could classify the risk events into five categories by considering the construction life-cycle; (1) Bid, (2) Mobilization, (3) Design and engineering, (4) Procurement, and (5) Construction. Fig. 5-2 shows the breakdown structure of risk events in international construction projects.

From this classification, 22 sub-categories are developed. For instance, the risk events in bid phase are divided into two sub-levels such as estimation error in cost and schedule. In mobilization phase, the risk events are grouped into four sub-categories as follows: licensing delay, shortage of key personnel, input delay of key personnel, and delay of project start. With this, the risk events related to design and engineering are classified into three sub-levels such as delay of drawings, modifications of drawings, and quantity increase. The type of risk events in procurement phase includes postponement from delay of design, remanufacturing from design change, remanufacturing from performance insufficiency, and delay of supply. Finally, there are nine types of risk events in construction phase such as contract delay of subcontract, insufficient performance of construction, bankruptcy of subcontract, rework, interference between work types, delay of visa issuance, delay of resource supply, and low competence of local labors. By using the breakdown structure, this research can classify a new risk event of international construction project for retrieving similar risk event cases.

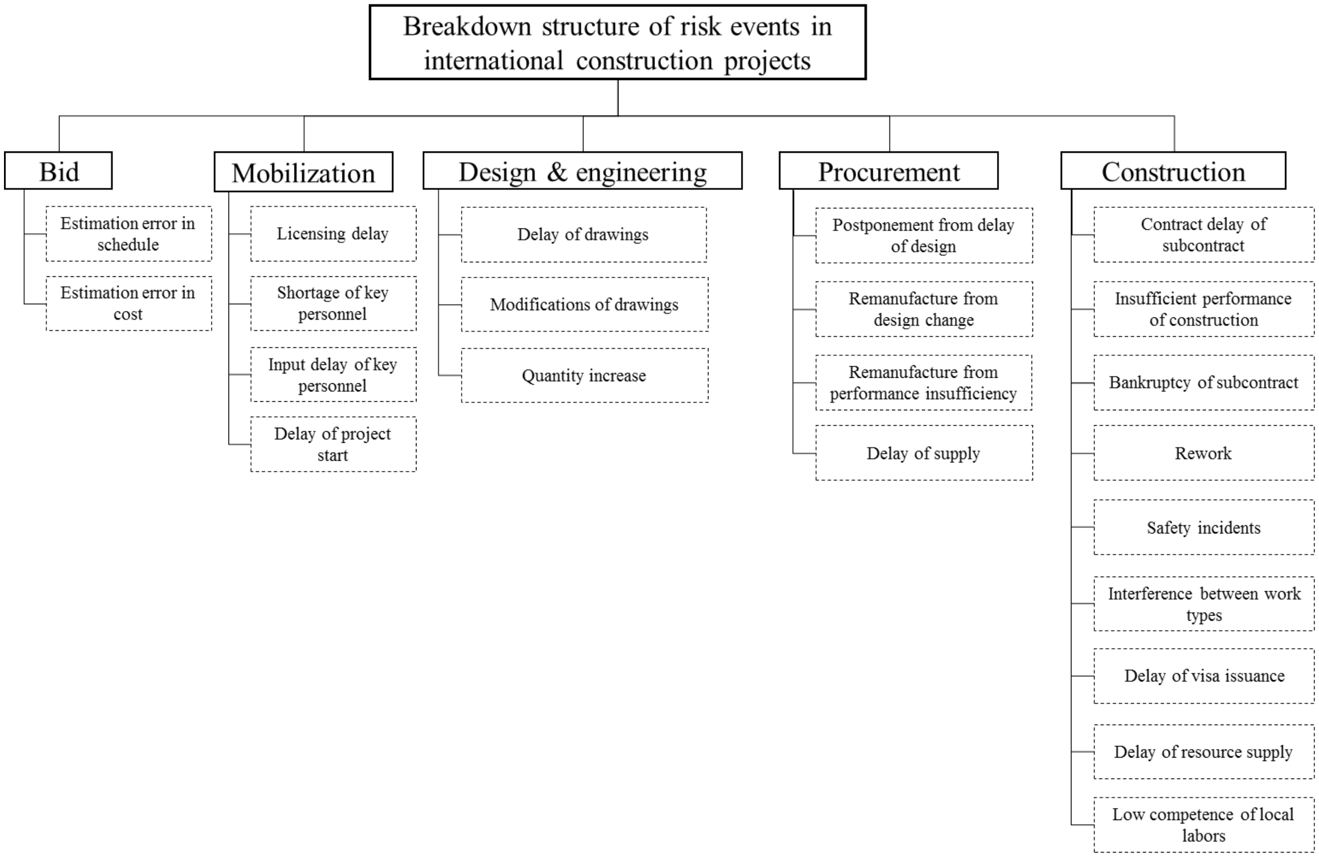

Figure 5-2. Breakdown structure of risk events in international construction projects

5.2.2 Weights of Variables

For improving retrieval performance of K-NN algorithm, this research determines weights of selected variables (Kolodner 1992). For this, the AHP developed by Saaty (1980) is applied, which comprises two-stages: (1) decomposing the complexity and (2) synthesizing the relations (Saaty 1980). For achieving the stages, five processes are also conducted: (1) hierarchy construction for decomposing the complexity, (2) pairwise comparisons considering interrelationships between variables, (3) relative weights calculation based on the results of pairwise comparisons, (4) aggregation of relative importance, and (5) consistency ratio calculation of pairwise comparisons (Satty 1980; Shapira and Goldenburg 2005).

Considering these processes, questionnaire survey is conducted for calculating the weights of variables by comparing the extracted variables in pairs. The pairwise comparisons are performed using one-to-nine scale, and the questionnaire was sent to 20 experts, each of whom has experience of international construction risk management. Of the 20 questionnaires distributed, 17 were collected. Using the collected data, the weights of selected variables are calculated by using Eq. (5-1), as follows:

$$Relative\ importance\ of\ w_i = \frac{1}{n} \cdot \sum_{j=1}^{n} \frac{a_{ij}}{\sum_{k=1}^{n} a_{kj}} \qquad (Eq. 5-1)$$

where w_i=the relative importance of the variables in row i; a_{ij}= variables located in row i and column j. In addition, a Consistency Ratio (CR) should be measured to control the consistency of pairwise comparisons and less than or equal to 0.10 (Shapira and Goldenberg 2005). This research calculates the weights of variables only using questionnaires with a CR below 0.10. Table 5-1 shows the weights of variable with the survey results.

Table 5-1 Weights of variables using AHP

Classification	Variables	Relative weights
Political Risk	War threat	0.048496143
	Corruption and bribery	0.007010333
	Government stability	0.028963241
	International relationship	0.019264012
	Labor strikes	0.014670483
Economic risk	GNI	0.005692343
	GNI fluctuation	0.005692343
	Inflation	0.011335631
	Inflation fluctuation	0.011335631
	Interest rate	0.019755058
	Interest rate fluctuation	0.019755058
	Currency exchange rate fluctuation	0.038146897
	Burden (debt) of financing	0.008964198
	Import and export restriction	0.007783
Other risk	Unexpected inclement weather	0.019177179
	Lack of infrastructure	0.008600674
	Manpower availability	0.007787097
	Material and equipment availability	0.019001835

(Table 5-1. Continued)

Classification	Variables	Relative weights
Social and cultural risk	Language barrier	0.067988811
	Legal differences	0.01448217
	Criminal acts	0.033496926
	Substance abuse (1)	0.012492253
	Substance abuse (2)	0.017201349
Construction risk	Client type	0.027846155
	Building type	0.031959822
	Construction type	0.036790836
	Contract type for payment	0.035512652
	Construction complexity	0.116006953
	Tight schedule	0.107023145
	Risk management competence	0.216769604
Survey	Number of distributed surveys	20
	Number of collected surveys	17
	Number of collected surveys with a CR below 0.1	14

5.2.3 Similar Risk Event Retrieval

By using the extracted variables and its weights, this research can retrieve the pertinent instances of a new risk event. To retrieve similar risk events, this research first selects risk event type related to a new case using the breakdown structure of risk events in international construction projects, and then the similarity between a new case and previous examples is calculated by applying following attribute-weighted Euclidean distance Eq.

(5-2):

$$Attributes - weighted\ Euclidean\ Dis(x_i, x_j) = \sqrt{\sum_{r=1}^{r=n} w_r^2 \left(a_r(x_i) - a_r(x_j)\right)^2} \qquad (Eq. 5-2)$$

Where $a_r(x)$ = the value of the rth variable of the case, and w_r = the weight of the rth variable of the case. Based on the similarity calculation, the previous examples that have a short distance can be retrieved as the similar risk events. As a result, the construction contractors can examine the response strategies and solutions of retrieved pertinent cases. From this procedure, this research finally supports the contractor's decision-making for an appropriate response strategy and solution.

5.3 Applicability Test using Safety Incident Cases

This research conducts case study to validate the proposed model and test its applicability. For performing case study, data sets on the variables and examples of risk events with applied response strategies and solutions are required. Thus this research first collects data sets on safety incidents as one of risk event type with work type occurred the risk event and its applied response strategy and solution for recovery from Korea Occupational Safety and Health Agency (KOSHA).

By using the collected data set, this research conducts a partial evaluation of the proposed model's retrieval performance. For evaluating the retrieval performance of search engine, precision and recall are applied, which are the two most frequent and basic indexes for measuring effectiveness of information retrieval (Manning et al. 2008). Fig. 5-3 shows the concepts of precision and recall, and its descriptions are as follows: (1) Precision means ratio of retrieved items that are relevant items and (2) recall indicates the ratio of relevant items that are retrieved items (Kim et al. 2013). As a result, the precision and recall can be calculated by using the Eqs. (5-3) and (5-4). Using the precision and recall indexes, this research can measure the retrieval performance of the proposed model's search engine.

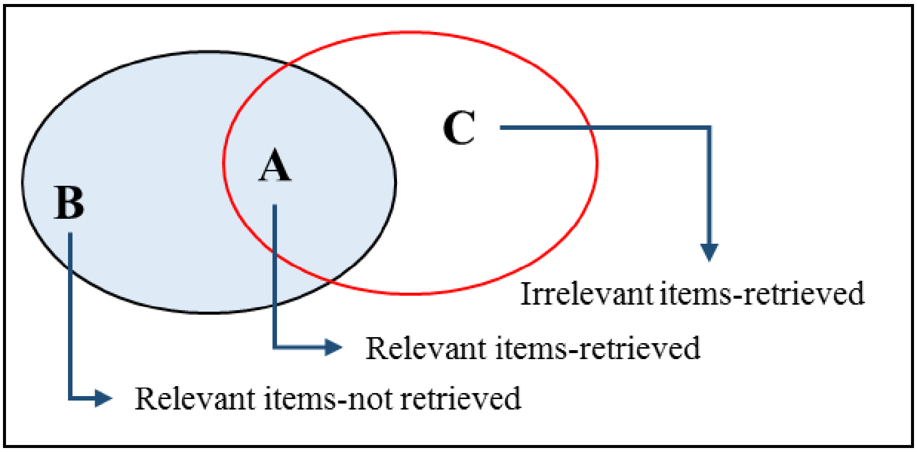

Figure 5-3. The concepts of precision and recall

$$Precision\ (P) = \frac{relevant\ items\ retrieved\ (A)}{retrieved\ items\ (A+C)}$$

$$= P\left(\frac{relevant}{retrieved}\right) \qquad (Eq. 5-3)$$

$$Recall\ (R) = \frac{relevant\ items\ retrieved\ (A)}{relevant\ items\ (A+B)}$$

$$= R\left(\frac{retrieved}{relevant}\right) \qquad (Eq. 5-4)$$

The retrieval performance of proposed model also can be evaluated by comparison with the precision and recall values of KOSHA's safety accident retrieval system which is commonly used for searching past accident cases in Korea (Kim et al. 2013). The KOSHA's past accident case retrieval system were developed based on a structured accident case database including domestic and international fatal accident cases about entire field of the industry. By using the KOSHA's system, a user (i.e., safety manager) could search past fatal accident cases.

For instance, the structured accident case database contains 3817 domestic and 19 international fatal accident cases related to construction execution which consists of a title and descriptions about accident circumstances including figures (Fig. 5-4). Based on the structured database, a user inputs queries such as primary keywords into a search box. Then the KOSHA's system searches the structured database and provides a list of past safety accident cases related to the input queries. The search engine includes application of Boolean operators AND, OR, NOT for supporting more detailed search. However, the KOSHA's system only provide exactly matched overall instances with the input keywords, not providing a degree of relation such as similarity between a new case and previous instances. For instance, the structured database of KOSHA's system does not provide a ranking of retrieved relevant results despite its sufficient past accident cases. As a result, users can not select and apply most appropriate response strategy and solution for recovery when the safety risk event occur.

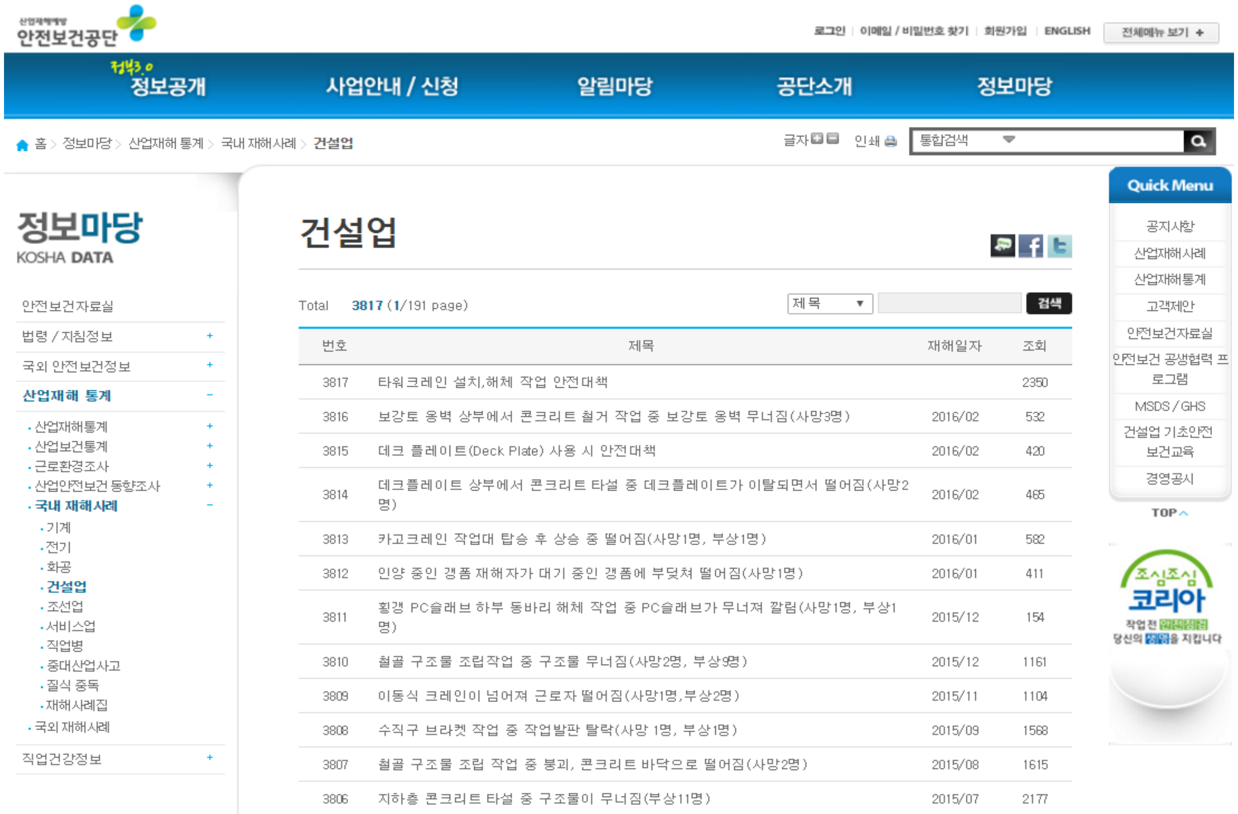

Figure 5-4. KOSHA's system for past accident case retrieval (http://www.kosha.or.kr/board.do?menuId=544)

The proposed model in this research provides the safety risk events in order of similarity between a new safety risk event and past accident instances. For evaluating the retrieval performance of suggested model, 149 past accident instances are randomly extracted from construction accidents category in KOSHA's system. In addition, three safety accident cases are selected as test instances for measuring the precision and recall of proposed model, which mainly occur during construction execution (Reese and Edison 2006): (1) "fall caused while performing formwork", (2) "collision with equipment such as excavator while conducting foundation work", and (3) "electrocution or electric shock from high-tension power line while conducting cable installation".

Next, this research calculates similarity between each test case (i.e., three safety accident cases) and previous instances (i.e., 149 past accident cases) by applying the suggested Eq. (5-2) and retrieves similar safety accidents of each test case. For improving the retrieval performance of suggested model, this research includes the safety accident type and work type as variables with its data sets. The safety accidents are classified into twelve categories: (1) fall from elevation and ground level, (2) electrocution, (3) stuck by equipment or (falling) materials, (4) caught in/between equipment or material, (5) cave-in, (6) explosion, (7) fire, (8) explosion and fire, (9) asphyxiation, (10) drowning, (11) natural causes, (12) others (Hinze et al. 1998). With this, this research also divides the work type into 32 categories: (1) danger equipment, (2) temporary electricity, (3) shifting inconvenience, (4) blasting, (5) refilling, (6) temporary road, (7) grouting, (8) foundation, (9) tower crane, (10) working environment, (11) (gang) form work, (12) excavation, (13) E/V, (14) retaining wall bearing, (15) landscaping, (16) metal, (17) concrete, (18) window and door, (19) tile, (20) safety scaffolding, (21) painting, (22) watertight, (23) steel-frame, (24) earth, (25) manhole, (26) reinforced, (27) panel, (28) plastering, (29) Electric installation, (30) Electric installation, and (31) Machinery (Lee et al. 2014). Considering these classification, the data on the safety accident cases are shown in Table 5-2. Using the data set, this research could conduct case studies for validating the retrieval performance of proposed decision support model.

Table 5-2. Data profile of the safety accident cases

Classification	Test case 1	Test case 2	Test case 3
War threat (P1)	0.06	1.3	.96
Corruption and bribery (P2)	5.6	5	5.1
Government stability (P3)	0.4	0.45	0.53
International relationship (P4)	17	1	17
Labor strikes (P5)	5	5	5
GNI (E1)	22850	17800	22460
GNI fluctuation (E2)	2.4	3.1	5
Inflation (E3)	3	1	2.4
Inflation fluctuation (E4)	0.6	-2	2.5
Interest rate (E5)	7.17	5.59	6.55
Interest rate fluctuation (E6)	0.62	-0.31	0.56
Currency exchange rate fluctuation (E7)	172.79	-121.2	-25.53
Burden (debt) of financing (E8)	28.162	26.959	28.651
Import and export restriction (E9)	66.4	73.6	69.2
Language barrier (S1)	0	0	0
Legal differences (S2)	3	3	3

(Table 5-2. Continued)

Classification	Test case 1	Test case 2	Test case 3
Criminal acts (S3)	2	2	2
Substance abuse (1) Alcohol (S4)	3.7	3.7	3.7
Substance abuse (2) Tobacco (S5)	2072.57	2072.57	2072.57
Unexpected inclement weather (O1)	76.83	46	98.83
Lack of infrastructure (O2)	3.62	3.44	3.44
Manpower availability (O3)	24606210	24115234	24499326
Material and equipment availability (O4)	3.64	3.52	3.52
Client type (C1)	2	1	1
Building type (C2)	1	2	3
Construction type (C3)	1	1	1
Contract type for payment (C4)	3	3	3
Project complexity (C5)	54.601973684	23.390243902	27.856353591
Duration of project (C6)	152	123	181
Risk management competence (C7)	2.23	2.54	2.04
Work type (C8)	11	15	29
Safety accident type (C9)	1	3	2

Based on the retrieval results, the precision and recall are calculated using the Eqs. (5-3) and (5-4). This research compares the precision and recall values of proposed model with that of KOSHA's system. Table 5-3 presents the calculation results of proposed model and KOSHA's system.

The average precision values of suggested model is calculated as 0.43 with a 0.17 standard deviation and the average recall values of suggested model is 0.56 with a 0.11 standard deviation, which is higher than that of KOSHA's system (i.e., 0.21 average precision value with a 0.06 standard deviation and 0.43 average recall value with a 0.08 standard deviation). For instance, in case of "fall caused while performing formwork" (i.e., test case 1), the precision value is 0.28 and the recall value is 0.45, which is higher than that of the KOSHA's system (i.e., the precision value = 0.18 and the recall value = 0.37). In addition, in case of "collision with equipment such as excavator while conducting foundation work" (i.e., test case 2), the precision value is 0.37 and the recall value is 0.57, which is higher than the KOSHA's 0.18 precision value and 0.4 recall value. The "electrocution or electric shock from high-tension power line while conducting cable installation" case (i.e., test case 3) shows that 0.61 precision value and 0.67 recall value of proposed model is higher than 0.26 precision value and 0.51 recall value of KOSHA's system.

These evaluation results indicate that the proposed model has higher retrieval performance than the KOSHA's system, and the proposed model has a potential benefit for providing more abundant and related similar cases. Besides, the contractors retrieve pertinent instances of a new safety risk events with the ranking of retrieved relevant results. Based on the retrieval results, the construction contractor would select an appropriate response strategy and solution to come up with an effective counterplan for recovering risk events.

Table 5-3. Evaluation of retrieval performance using precision and recall

<table>
<tr><th rowspan="2">Classification</th><th colspan="2">Case (1)</th><th colspan="2">Case (2)</th><th colspan="2">Case (3)</th></tr>
<tr><th>Precision</th><th>Recall</th><th>Precision</th><th>Recall</th><th>Precision</th><th>Recall</th></tr>
<tr><td>KOSHA's system</td><td>0.18</td><td>0.37</td><td>0.18</td><td>0.40</td><td>0.28</td><td>0.51</td></tr>
<tr><td>Proposed model</td><td>0.28</td><td>0.45</td><td>0.37</td><td>0.57</td><td>0.61</td><td>0.67</td></tr>
<tr><td rowspan="4">KOSHA's system</td><td colspan="2" rowspan="2">Precision</td><td colspan="2">Average</td><td colspan="2">0.21</td></tr>
<tr><td colspan="2">Standard deviation</td><td colspan="2">0.06</td></tr>
<tr><td colspan="2" rowspan="2">Recall</td><td colspan="2">Average</td><td colspan="2">0.43</td></tr>
<tr><td colspan="2">Standard deviation</td><td colspan="2">0.08</td></tr>
<tr><td rowspan="4">Proposed model</td><td colspan="2" rowspan="2">Precision</td><td colspan="2">Average</td><td colspan="2">0.42</td></tr>
<tr><td colspan="2">Standard deviation</td><td colspan="2">0.17</td></tr>
<tr><td colspan="2" rowspan="2">Recall</td><td colspan="2">Average</td><td colspan="2">0.56</td></tr>
<tr><td colspan="2">Standard deviation</td><td colspan="2">0.11</td></tr>
</table>

5.4 Summary

This research proposes a response strategy decision-making support model to deal with the risk events occurring in construction execution. For this, the previous literatures and applicable response strategies are first explained. Then the k-NN for retrieving pertinent cases with the AHP for weighting variables are applied for efficient attribute-weighted classification. Subsequently, to evaluate the applicability of the proposed model, case study using precision and recall were conducted. The case study shows that the proposed model could provide an effective retrieval performance. As a result, the response strategy model would support the contractor’s decision-making using the response strategies of retrieved similar cases in order of similarity.

In this regard, the suggested model enables construction contractors to cope with emergent risk events during construction execution. Furthermore, construction companies use the model for coming up with an effective counterplan immediately when the unexpected risk events are realized. Finally, the construction contractors could minimize the likelihood of project cost increase and losses in time of international construction projects. In terms of future research directions, a most appropriate response strategy could be retrieved by including data on cost and schedule performance of past response strategy applications. By using the data, construction contractors can evaluate the applied response strategies and select an optimized solution that minimizes expected losses in project cost and schedule.

Chapter 6 . Conclusions

This research proposed a method for managing unexpected risk events in international construction projects by using case-based learning method. Considering the objective of this dissertation, this research first discusses the overview of research backgrounds and motivation, problem statements, research objective and scope, and research significance. Then preliminary studies about international construction project risk management and methodologies for developing case-based learning are described. In line with the preliminary study and research methodologies, the variables are selected to retrieve similar cases for a new instance. As a result, a management reserve estimation method is proposed to provide a provision for unplanned changes and a response strategy decision-support model is described to respond to the emergent risk events.

In this chapter, this research finally summarizes the findings and results of proposed method and model. The practical, methodological and technical, and academic contributions to the body of knowledge in the field of current risk management of international construction projects are also discussed. Subsequently, limitations and recommendations are provided for the further practical applications of this research's outcomes to international construction projects.

6.1 Research Results

The international construction projects are generally regarded as high risk business because of the differences in external environments between domestic and overseas markets. The risks of construction projects cause risk events through their interrelationship, and as a result, the risk events influence negative effects on cost and schedule performances of construction projects. To mitigate the losses in project cost and schedule from risk events, the construction companies have been applied the risk management process with its principles and framework. For instance, the contractors assess the identified risks, and then they propose treatments such as a contingency reserve covering potentially required changes, removing or avoiding the risk events, and planning response strategies and solutions. However, the risk management process based approach cannot cover the overall risk events occurring construction execution because of an interrelationship complexity between risks, a limitation of risk identification, and difficulties in predicting risk value. As a result, few investigations have proposed to manage unexpected risk events due to its unpredictable characteristic. In these contexts, this challenging issue has raised a need for a more robust and systematic approach for managing the risk events of international construction projects.

As an effort to address these challenging issue, this research proposed a method for managing the risk events of international construction projects by using case-based learning. Considering the risk event's unpredictable characteristic, the case-based learning could propose an optimized solution for problem solving by using similar previous instances for a new case. Based on the method, to achieve the objective of this dissertation, the management reserve estimation method was proposed to provide a provision in their project costing, and the response strategy decision-support model is suggested to deal with emergent risk events during construction execution. For this, this dissertation first conducted preliminary research about risk management for international construction projects and methodologies for developing the case-based learning. Then the variables related to uncertainty of international construction project were selected with the development of risk management competences for construction projects. Next, the K-NN algorithm was applied for retrieving pertinent cases with applications of GA and AHP for optimizing the retrieval results. Subsequently, this research have been performed case studies to validate the management reserve estimation method and the response strategy decision support model. The case studies showed that the management reserve estimation method could predict the management reserve more accurately than the traditional percentage method. In addition, the response strategy decision support model could support the contractor's decision-making using the response strategies of retrieved similar cases in order of similarity.

6.2 Research Contributions

By using the proposed method and model, construction contractors can manage the unexpected risk events occurring international construction execution. The estimated management reserve is used as a contingency for unplanned changes. With this, the proposed decision support model could provide pertinent response strategies and solutions of similar risk events when the risk events are realized. Therefore, using the proposed method and model, the contractors could minimize their losses in project cost time. The results and contributions of this dissertation are summarized in details as follows:

(1) Risk event management for international construction projects

- The current risk management practices is conducted generally based on risk management process including risk identification, risk assessment, and risk treatment. However, the approach cannot manage the unexpected risk events during construction execution. In these contexts, this research proposed a method for managing risk events of international construction projects by using an inductive reasoning based approach.
- The proposed method complements this limitation of current risk management practices. In addition, this research makes practical contributions to the body of knowledge in the field of the risk management of international construction projects.

(2) Case-based learning for risk events management

- This research proposed the case-based learning as a method for managing unexpected risk events of construction projects. For this, the variables for applying case-based learning are selected, and methodologies such as CBR, K-NN, GA are described. In line with the variables and methodologies, this research finally developed case-based learning algorithm.
- The proposed case-based learning would provide a method for managing risk events with consideration of its unpredictable characteristic in planning phase. In addition, this research also contribute to CBR applications by proposing data based learning.

(3) Breakdown structure of international construction project risks

- This research proposed the breakdown structure of international construction project risks. For this, the international construction project risks are classified into five categories: 1) political risk, 2) economic risk, 3) social and cultural risk, 4) other risk, and 5) construction risk. Based on this classification, 30 variables related to uncertainty in international construction project were selected with its configurations.
- With this, risk management competences for construction projects are also established, which is one of the variables comprising skills and individual behavior competences. The proposed competences enables the construction contractors to

diagnose their current competence level of project risk management and can retrieve pertinent cases more accurately.

(4) Management reserve estimation method

- This research proposed the management reserve estimation method to include a provision for unplanned changes of international construction projects. The results of case studies for validation showed that the proposed method can estimate the management reserve more accurately than the traditional percentage method. The estimated contingency for unplanned changes enables construction contractors to cope with emergent risk events during construction execution. In addition, by using the method, the construction contractors plan their contract costs and schedules strategically and estimate their project cost accurately.

(5) Response strategy decision-making support model

- This research proposed the decision-making support model for responding to the unexpected risk events when they are realized. The case study for validating the proposed model showed that the model included similar risk events in order of similarity with its applied response strategies and solutions. The proposed model enables construction contractors to make proper decisions on a new risk event.

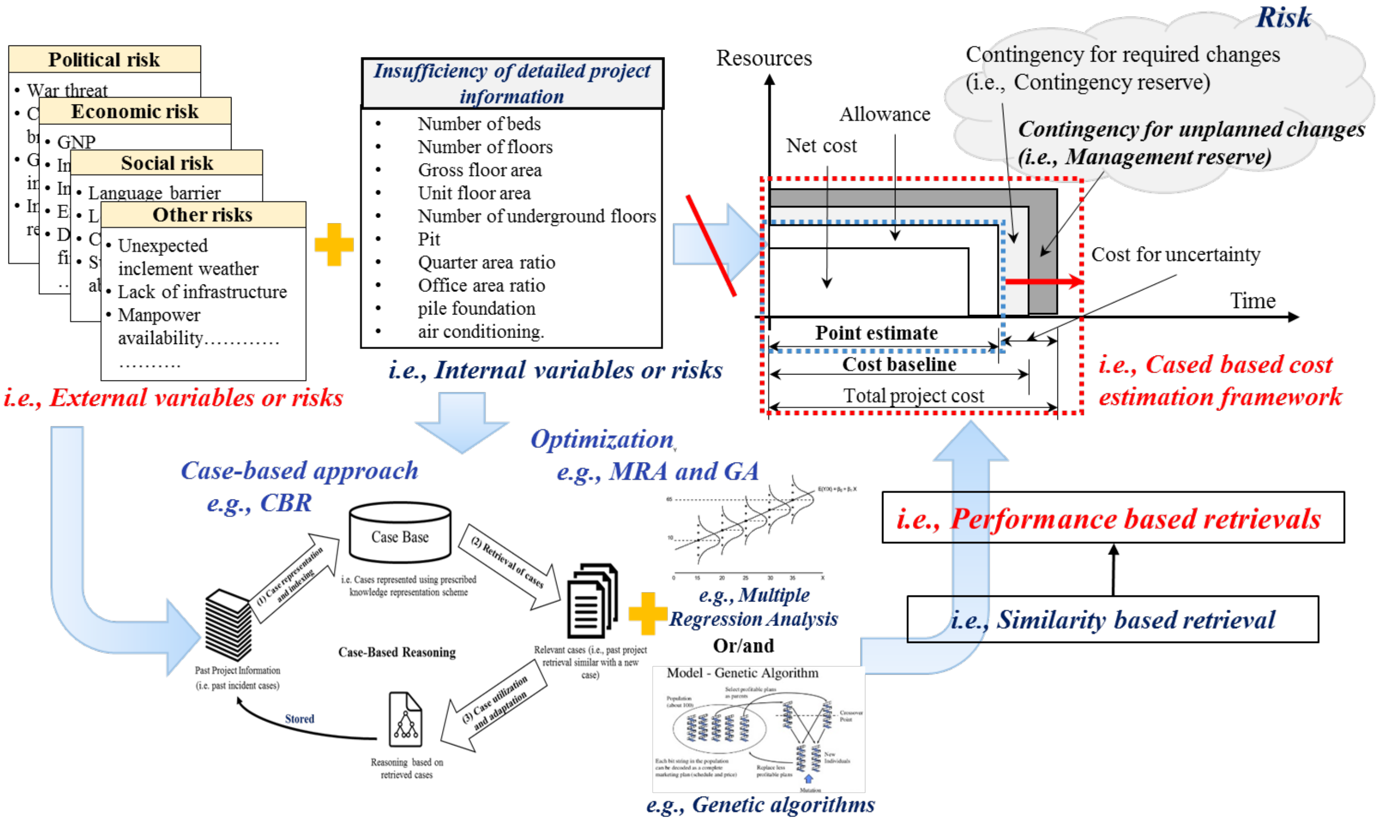

Figure 6-1. Contribution of management reserve estimation method

6.3 Limitations and Recommendations

Despite the contributions of this research, further developments and validations are required to generalize the proposed method and improve the applicability of the research's outcomes. Regarding this, this research summarizes the limitations of the proposed method and suggests recommendations for improving usability of the proposed method. The limitations of this dissertation are as follows:

(1) Risk management competences for construction projects

- The derived skills and individual behavior competences for construction project risk management may not be exhaustive with the passage of time. Also, the applicability of the developed competences should be cautious when the competences are applied in construction companies with other nationalities because some of analysis results are from the results of survey on experienced experts in Korea.

(2) Management reserve estimation method

- To develop the management reserve estimation, the CPR_e and SPR_e are estimated using attribute-weighted 5-NN. Regarding this, the accuracy of attribute-weighted 5-NN could be improved by considering the long-term nature of construction projects.
- In addition, to infer CPR_e and SPR_e, this research only applied

the CPR and SPR of retrieved pertinent cases. Thus the error rates between actual values and estimated values are generated.

(3) Response strategy decision-making support model

- Although the decision support model provided the response strategies and solutions, the attribute-weighted classification was developed based on the experts' opinions for weighting variables.

With the limitations of this dissertation, additional research is required to further validate the suggested outcomes and generalize them by overcoming their limitations. This research suggests the future research as follows:

(1) Continuous improvement of risk management competences

- The risk management competences should be improved according to the passage of time and developed by considering the characteristics of construction project such as a concept of life-cycle and dynamic connection with project goals. With this, when relative importance of the developed competences are determined, the construction contractors could assess their competence level more accurately.

(2) Risk value prediction using time series model

- This research estimated the CPR_e and SPR_e only using the variable values at the time of construction project initiation, not considering the long-term nature of construction projects. One possible solution here is to develop a time series model to predict the attribute values with high uncertainty and high variance.

(3) Data set on cost and schedule performance of risk events

- When the data on cost and schedule loss from risk events are collected, a most appropriate response strategy could be retrieved. By using the data, the construction contractors can evaluate response strategies and then select an optimized response strategy minimizing the expected losses in project cost and schedule.
- In addition, the construction contractors can monitor and predict the actual performances at completion by connecting the results of managing risk events with the estimated cost and duration. For instance, the management reserve is monitored by considering costs for recovering the unpredictable risk events. Based on this monitoring, the construction companies could make a provision required for expected losses at their project completion.

(4) Correction factor for improving accuracy of management reserve estimation

- When the data sets on cost and schedule performance of international construction projects are collected continuously, the factor for revising the estimated cost and schedule performance values can be developed using differences between attributes-weighted Euclidean Distances and error rates of the estimated project performances.

(5) Applicability and usability improvement of proposed method

- The management reserve estimation method and response strategy decision-support model are developed by using selected 30 variables. The many variables could decrease an applicability and usability of proposed method and model. One possible way to improve the applicability and usability is to reduction of variables by applying EFA or removing variable with low weights. In addition, the database development with automated data collection would also improve the applicability and usability.
- After improving the applicability and usability, the proposed method and model can be developed as a system. With this, the construction contractors should collect data on cost and schedule performance of international construction projects continuously for updating or improving system.

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Appendices

Appendix A: Terminology

Terminology	Description
Analytic Hierarchy Process	A new approach to dealing with complex problems by assisting in the making of decisions (Shapira and Goldenberg 2005)
Case-Based Reasoning	A method for solving problems by using or adapting solution from pertinent cases (Watson 1999).
Competence	A cluster of related knowledge, attitudes, and skills that affects a superior job performance (Boyatzis 1982; Parry 1996).
Contingency reserve	A provision for managing expected risk events (PMI 2008)
Crisis	Potential or possible risk factor's actual affection causing damage to the project (Wideman 1992).
Exploratory Factor Analysis	A multivariate analytical technique to extract a smaller number of underlying variables or factors from the observed variables (Alroomi et al. 2011; Karami 2014)
Genetic Algorithm	a simultaneous optimization algorithm developed based on the principle of the survival of the fittest and natural selection (Holland 1975)
Hazard	Source of potential harm such as casualties or damage (Edward 1995; ISO 2009)
K-Nearest Neighbor	a simple classification method that classifies a new case into a majority group of k-nearest neighbors by retrieving its closest instances (Cover and Hart 1967;

	Mitchell 1997; Tapkın et al. 2013)

Terminology	**Description**
Knowns	A risk that have been identified in planning stage and assessed with a probability of occurrence (Berg and Tideholm 2012; Neil and Diekmann 1989).
Known -unknowns	A risk that that have been also identified in planning phase but for which a probability of occurrence cannot be assigned (Berg and Tideholm 2012; Neil and Diekmann 1989).
Liquidated Damages	Contractually specified damages that represent reasonable compensation charged to the contractor for failure to complete the project on time (Crowley et al. 2008).
Management Reserve	A provision for managing unexpected risk events (PMI 2008)
Opportunity	Conditions or situations which are favorable to the project such as a positive set of circumstances, a positive set of events, a risk that will have a positive impact on objectives, or a possibility for positive changes (PMI 2008).
Precision	Ratio of retrieved items that are relevant items (Manning 2008).
Principal Components	A simple method to reduce the number of variables by creating linear combinations that retain as much of the

Analysis	original measures' variance as possible (Conway & Huffcutt, 2003)

Terminology	**Description**
Recall	Ratio of relevant items that are retrieved items (Manning 2008).
Reserve	A provision in the project management plan to mitigate cost and/or schedule risk (PMI 2008)
Risk	Chance of something happening that will have a positive or negative effect on a project's objectives and rationally know probability distribution with information regarding loss (Edward 1995; ISO 2009; Lindley 1972; PMI 2008; Rothcorf 1975; Schumpeter 1934; Smith 1998; Standards Australia 2004; Wideman 1992).
Risk evaluation	A process of comparing the results of risk analysis with risk criteria to determine whether the risk and/or its magnitude is acceptable or tolerable (ISO 2009).
Reliability test	A test to examine internal consistency of variables by calculating Cronbach alpha coefficient (Cramer 1994)
Risk event	Occurrence or change of a particular set of circumstances from risk sources.
Risk identification	A process for finding, recognizing and describing risks, and involving the identification of risk sources, events, their causes and their potential consequences

	(ISO 2009).
Risk management	Coordinated activities to direct and control an organization with regard to risk (ISO 2009).

Terminology	Description
Risk management competence	A cluster of related knowledge, attitudes, and skills that affects a risk management
Risk path	A process of risk sources, risk event, and risk consequences (Dikmen et al. 2008)
Risk treatment (i.e., Risk response)	An action taken to avoid the risk events, to reduce a probability of occurrence, or to mitigate impacts from the risk events (Nasirzadeh et al. 2013).
Uncertainty	Circumstances which is the state or partial state of deficiency of information related to knowledge such as consequence and likelihood of an event and do not quantify probability or possibility (Schumpeter 1934; Lindley 1972; Smith 1998; ISO 2009).
Unknown -unknowns	A risk that have not been identified in advance and therefore the probability cannot be known (Berg and Tideholm 2012; Neil and Diekmann 1989).

Appendix B: Glossary of Acronyms

Acronyms	Fullname
AHP	Analytic Hierarchy Process
CBR	Case-Based Reasoning
CII	Construction Industry Institute
CPR	Cost Performance Ratio
CR	Consistency Ratio
EFA	Exploratory Factor Analysis
ENR	Engineering News-Record
GA	Genetic Algorithm
GATT	General Agreement on Tariffs and Trade
HRBS	Hierarchal Risk Breakdown Structure
ICAK	International Contractors Association of Korea
ICJVs	International Construction Joint Ventures
ICPR	International Construction Project Risk
ICRAM-1	International Construction Risk Assessment Model
IPRA	International Project Risk Assessment
ISO	International Organization for Standardization
KMO	Kaiser-Meyer-Olkin
K-NN	K-Nearest Neighbor
KOSHA	Korea Occupational Safety and Health Agency
LDs	Liquidated Damages

Acronyms	**Fullname**
PAF	Principal Axis Factoring
PCA	Principal Components Analysis
RMAA	Repair, Maintenance, Minor Alteration, and Addition
PMI	Project Management Institute
SPR	Schedule Performance Ratio
SPSS	Statistical Package for Social Sciences
UAE	United Arab Emirates

Appendix C: Risk Management Competences for Construction Projects

B-I Skills for Managing Construction Project Risks

(1) Preconstruction Phase

Phases	Classification and criteria	
Preconstruction phase	**Skill (1)**	**The board and senior management for decision making**
	Elements	• The board, committee, and senior management actively take part in project risk management. • A project risk management policy, commitment, and plan are approved by the board and senior management. • All the risk-related decision making and management practices are fully consistent with the project risk management policy, commitment, and plan.
	Skill (2)	**Preliminary identification & analysis of key internal risk (Portfolio management**

Process (2-1)	Risk management planning
Elements	• Risk coordination and balance of each project are considered for new project. • Risk management is combined with project management, program management, and portfolio management
Process (2-2)	Risk identification & classification
Elements	• The internal risk identification procedures are established • A systematic identification method is used to identify major internal risks • The interdependence of the risks is considered.
Process (2-3)	Risk analysis & evaluation
Elements	• The likelihood of occurrence and magnitude of impacts of a risk is assessed to determine the ranking and management priority. • Qualitative risk analysis tools or methods are used to assess identified risks. • Quantitative risk analysis tools or methods are used to assess identified risks. • The results of risk analysis are used to aid decision making for risk responses. • The results of risk analysis are used as a basis for resource allocation and distribution to projects
Skill (3)	**Preliminary identification & analysis of key external risk (1) Country risks**

Process (3-1)	Risk identification & classification
Elements	• Potential risks are identified each time for new projects • The risk identification procedures are established • A systematic identification method is used to identify major risks • The interdependence of risks is considered. • Information on risks identified are grouped, and classified. • Information on risks identified are communicated to all project participants
Process (3-2)	Risk analysis & evaluation
Elements	• The likelihood of occurrence and magnitude of impacts of a risk is assessed to determine the ranking and management priority. • Qualitative risk analysis tools or methods are used to assess identified risks. • Quantitative risk analysis tools or methods are used to assess identified risks. • The results of risk analysis are used to aid decision making for risk responses. • The results of risk analysis are used as a basis for resource allocation and distribution to projects
Skill (4)	**Preliminary identification & analysis of key external risk (2) Market risks**
Process (4-1)	Risk identification & classification

Elements	• Potential risks are identified each time for new projects • The risk identification procedures are established • A systematic identification method is used to identify major risks • The interdependence of risks is considered. • Information on risks identified are grouped, and classified. • Information on risks identified are communicated to all project participants
Process (4-2)	Risk analysis & evaluation
Elements	• The likelihood of occurrence and magnitude of impacts of a risk is assessed to determine the ranking and management priority. • Qualitative risk analysis tools or methods are used to assess identified risks. • Quantitative risk analysis tools or methods are used to assess identified risks. • The results of risk analysis are used to aid decision making for risk responses. • The results of risk analysis are used as a basis for resource allocation and distribution to projects
Skill (5)	**Preliminary identification & analysis of key external risk (3) Project risks**
Process (5-1)	Risk identification & classification
Elements	• Potential risks are identified each time for new projects

	• The risk identification procedures are established • A systematic identification method is used to identify major risks • The interdependence of risks is considered. • Information on risks identified are grouped, and classified. • Information on risks identified are communicated to all project participants
Process (5-2)	Risk analysis & evaluation
Elements	• The likelihood of occurrence and magnitude of impacts of a risk is assessed to determine the ranking and management priority. • Qualitative risk analysis tools or methods are used to assess identified risks. • Quantitative risk analysis tools or methods are used to assess identified risks. • The results of risk analysis are used to aid decision making for risk responses. • The results of risk analysis are used as a basis for resource allocation and distribution to projects
Skill (6)	**Considerations of the risk analysis results for cost estimating**
Elements	• The project cost is estimated using the historical data related with the risk. • The cost contingency is estimated considering the risk. • The project cost is estimated considering the escalation.

	• The project cost is estimated considering the risk hedging.
Skill (7)	**Considerations of the risk analysis results for scheduling**
Elements	• The project schedule is estimated using the historical data related with the risk. • The schedule contingency is estimated considering risk. • The project schedule is estimated considering the risk hedging.
Skill (8)	**Sharing key risk to related department**
Elements	• Clear communication lines are established to ensure exchange of critical information and decisions. • A project risk management policy, commitment, and plan are consistently distributed and communicated and shared across all project participants. • External risk information is consistently distributed and communicated and shared across all project participants. • Internal risk information is consistently distributed and communicated and shared across all project participants. • Strategies for managing project risk are consistently distributed and communicated and shared across all project participants.

(2) Construction Phase

Phases	Classification and criteria	
Construction phase	**Skill (9)**	**Objective setting**
	Elements	• The enterprise risk management organizations set the project goal. • Objectives of the project are consistently distributed and communicated and shared across all project participants. • Formalized performance measures are established for assessing project goal. • Deviations from plans or expectations are assessed.
	Skill (10)	**Monitoring and review the project**
	Elements	• The enterprise risk management organization performs monitoring the project risks, which are registered from risk manager. • The enterprise risk management organization reviews the project risks, which are registered from risk manager.
	Skill (11)	**Supporting the project**
	Elements	• The enterprise risk management organization supports the risks response of project management organization.
	Skill (12)	**Managing project risks**

Process (12-1)	Project risk management planning
Elements	• The project manager utilize historical risk information for project risk management planning. • The staff of project management set the goal congruence and attitude alignment. • Appropriate risk management techniques, tools and implementation process defined for project management
Process (12-2)	Risk identification and classification
Elements	• The risk identification procedures are established • A systematic identification method is used to identify major risks • The risk manager identify residual or secondary risk generated in project • The interdependence of risks is considered • The identified risks are grouped and classified. to all project participants • The identified risk information is consistently distributed and communicated and shared across all project participants. • Actual risks found in construction phase are compared with initially identified risks.
Process (12-3)	Risk analysis and evaluation

	Elements	• The likelihood of occurrence and magnitude of impacts of a risk is assessed to identify the rank and management priority. • Qualitative risk analysis tools or methods are used to assess identified risks. • Quantitative risk analysis tools or methods are used to assess identified risks. • The results of risk analysis are used to aid decision making for risk responses. • The results of risk analysis is used as a basis for resource allocation and distribution to projects
	Process (12-4)	Risk response
	Elements	• The decision making for risk responses are performed based on the result of risk analysis and evaluation. • Risk response actions are performed using the formalized methods or strategies (elimination, transfer, avoiding, reduction, turndown, treat, tolerate, and detour). • The results of risk response are recorded
	Process (12-5)	Risk monitoring and control
	Elements	• The risk manager performs monitoring the project risks consistently. • The PM organization conducts the monitoring meeting regularly for tracking, and analyzing variation of risk

		• The risk manager conduct the action item management of the risks.
	Process (12-6)	Risk reporting
	Elements	• The results of risk management are reported to the project manager in a periodic or immediate manner
	Process (12-7)	Risk review
	Elements	• The project manager reviews the results of risk management in a periodic or immediate manner
	Skill (13)	**Risk based cost control**
	Elements	• The analysis result of project risk is converted to cost. • Project cost at completing phase is estimated periodically considering the analysis results of project risk. • Project cost at completing phase, which is applied the analysis results of project risk, is monitored consistently.
	Skill (14)	**Risk based schedule control**
	Elements	• The analysis result of project risk is converted to schedule. • Project schedule at completing phase is estimated periodically considering the

		analysis results of project risk. • Project schedule at completing phase, which is applied the analysis results of project risk, is monitored consistently.
	Skill (15)	**Project risk register**
	Elements	• The risk manager conduct the risk registration. • The risk information, which is resisted, are ensured relevant and reliable.

(3) Completion Phase

Phases	Classification and criteria	
Completion phase	**Skill (16)**	**Compiling the data into databases for next project**
	Elements	• The risk data and information of project are compiled into databases for next project.
	Skill (17)	**Transfer of project risk data and information**
	Elements	• The risk manager manage the risk data and information of project for transferring the data to enterprise RM organization.

B-II Standard for Assessing Risk Management Competences

Levels	Meanings	Descriptions
Level 1	Naïve or ad-hoc	• Is lowest level. • Is unaware of need for project risk management. • Has no formal or structured approach to project risk management process for dealing with project risk. • Has no experience in managing risk. • Is no attempt to learn from past project and prepare for future project. • Does not provide a stable environment of project risk management. • Depends entirely on capable and forceful risk manager or seasoned and effective risk team. • Adopts a reactive and mechanistic mindset and react after a problems
Level 2	Novice or Repeatable	• Recognize the requirement for project risk management and is aware of the potential benefits and managing risk. • Has basic project risk management process which is established on a project-by-project basis. • May not be consistently achieved project risk management in always and has not effectively implemented project risk management process.

Levels	Meanings	Descriptions
Level 2 (Continued)	Novice or Repeatable	• Is not gaining the full benefits of construction project risk management. • Makes realistic project commitments based on the results observed on previous projects.
Level 3	Defined or Formalized	• Has a generic project risk management process which are formalized, implemented, and documented. • Performs routine and consistent project risk management process across all projects. • Has individual projects flexible within the project risk management process to suit the particular project.
Level 4	Managed	• Has a risk-aware culture with a proactive approach to risk management in all aspects of the project. • Manage risk as opportunities as well as potential negative impacts • Obtain and retain specific measurable processes quantitatively on its project risk management performance which are established in identification, assessment and response.
Level 5	Optimizing	• Has the means to identify weakness and strength for improving project risk management process proactively. • Focus on continuous improvement of project risk management process to achieve higher level of performance.

Appendix D: Data Collection on Selected Variables

[Data on Variable for Attribute-weighted K-NN]

This research have used a significantly large data set for retrieving pertinent cases. The data on 23 variables related to regional conditions in 51 countries from 2002 to 2010 was collected from various sources, including the Vision of Humanity, Transparency International, Global Economy, World Trade Organization, International Trade Union Confederation, World Bank, OECD, Trading Economics, World Health Organization, Tobacco Atlas, and German Watch. The primary data of 20 countries are presented in this dissertation

Note: (P1) War threat, (P2) Corruption and bribery, (P3) Government stability, (P4) International relationship, (P5) Labor strikes, (E1) GNI, (E2) GNI fluctuation, (E3) Inflation, (E4) Inflation fluctuation, (E5) Interest rate, (E6) Interest rate fluctuation, (E7) Currency exchange rate fluctuation, (E8) Burden (debt) of financing, (E9) Import and export restriction, (S1) Language barrier, (S2) Legal differences, (S3) Criminal acts, (S4) Substance abuse (1), (S5) Substance abuse (2), (O1) Unexpected inclement weather, (O2) Lack of infrastructure, (O3) Manpower availability, (O4) Material & equip.

availability

[Korea]

Year	P1	P2	P3	P4	P5	E1	E2	E3	E4	E5	E6	E7	E8	E9	S1	S2	S3	S4	S5	O1	O2	O3	O4
2010	0.01	5.4	0.29	18	5	21320	6.4	3.2	-0.3	5.51	-0.14	-120.87	30.825	70.8	0	3	2	3.7	2072.57	83.17	3.62	24,955,811	3.64
2009	0.03	5.5	0.38	17	5	21090	0	3.5	0.5	5.65	-1.52	174.88	31.38	70.2	0	3	2	3.7	2072.57	81.83	3.62	24,608,118	3.64
2008	0.06	5.6	0.4	17	5	22850	2.4	3	0.6	7.17	0.62	172.79	28.162	66.4	0	3	2	3.7	2072.57	76.83	3.62	24,606,210	3.64
2007	0.41	5.1	0.53	17	5	22460	5	2.4	2.5	6.55	0.56	-25.53	28.651	69.2	0	3	2	3.7	2072.57	93.83	3.44	24,499,326	3.52
2006	0.96	5.1	0.38	7	5	19980	5.1	-0.1	-1.1	5.99	0.4	-69.33	29.727	65	0	3	2	3.7	2072.57	31.25	3.44	24,288,702	3.52
2005	1.3	5	0.45	1	5	17800	3.1	1	-2	5.59	-0.31	-121.2	26.959	73.6	0	3	2	3.7	2072.57	46	3.44	24,115,234	3.52
2004	1.99	4.5	0.4	1	5	15650	4.7	3	-0.4	5.9	-0.34	-46.29	23.251	66.6	0	3	2	3.7	2072.57	46	3.44	23,909,321	3.52
2003	2.62	4.3	0.21	0	5	13360	2.4	3.4	0.3	6.24	-0.53	-59.48	20.449	73.2	0	3	2	3.7	2072.57	34	3.44	23,435,054	3.52
2002	0.15	4.5	0.17	0	5	12470	7.1	3.1	-0.6	6.77	-0.94	-39.9	17.551	67.6	0	3	2	3.7	2072.57	34	3.44	23,433,976	3.52

[China]

Year	P1	P2	P3	P4	P5	E1	E2	E3	E4	E5	E6	E7	E8	E9	S1	S2	S3	S4	S5	O1	O2	O3	O4
2010	5.24	3.5	-0.66	17	5	4300	2.1	6.9	7	5.81	0.5	-0.9	35.79	72.2	0	3	4	6.7	2249.79	23.5	3.54	774,172,295	3.49
2009	5.85	3.6	-0.43	16	5	3650	7.9	-0.1	-7.9	5.31	0	-1.69	31.67	71.4	0	3	4	6.7	2249.79	36,33	3.54	773,686,144	3.49
2008	4.12	3.6	-0.48	16	5	3070	9.5	7.8	0	5.31	-2.16	-8.66	34.83	70.2	0	3	4	6.7	2249.79	15.5	3.54	770,992,463	3.49
2007	0.76	3.5	-0.49	15	5	2490	14.1	7.8	3.9	7.47	1.35	-4.59	31.49	68	0	3	4	6.7	2249.79	26.67	3.2	768,074,459	3.32
2006	1.56	3.3	-0.54	14	5	2050	12.7	3.9	0	6.12	0.54	-2.7	33.81	68	0	3	4	4.9	2249.79	12.25	3.2	763,693,185	3.32
2005	1.81	3.2	-0.48	13	5	1750	10.2	3.9	-3	5.58	0	-1	35.16	54.4	0	3	4	4.9	2249.79	16.75	3.2	758,612,921	3.32
2004	2.55	3.4	-0.36	3	5	1500	9.8	6.9	4.3	5.58	0.27	0	37.16	51.4	0	3	4	4.9	2249.79	16.75	3.2	752,711,357	3.32
2003	2.7	3.4	-0.57	3	5	1270	9.8	2.6	2	5.31	0	0	37.74	50.6	0	3	4	4.9	2249.79	27.5	3.2	746,320,096	3.32
2002	3.27	3.5	-0.36	1	5	1100	8.8	0.6	-1.4	5.31	-0.54	0	37.75	48.6	0	3	4	4.9	2249.79	27.5	3.2	738,923,140	3.32

[Japan]

Year	P1	P2	P3	P4	P5	E1	E2	E3	E4	E5	E6	E7	E8	E9	S1	S2	S3	S4	S5	O1	O2	O3	O4
2010	0.23	7.8	0.85	15	2	41980	4.5	-2.2	-1.7	1.6	-0.12	-6.19	194.1	82.4	0	3	2	7.2	1713	77.67	4.19	66,743,482	3.97
2009	0.47	7.7	0.94	15	2	37470	-6	-0.5	0.8	1.72	-0.19	-9.47	174.1	82	0	3	2	7.2	1713	48,00	4.19	66,550,717	3.97
2008	0.7	7.3	0.84	14	2	37760	-1.2	-1.3	-0.4	1.91	0.03	-12.22	167	80	0	3	2	7.2	1713	71.08	4.19	66,818,190	3.97
2007	0.04	7.5	0.96	5	2	37590	2.6	-0.9	0.2	1.88	0.22	1.25	172.1	80.2	0	3	2	7.2	1713	65.17	4.11	66,928,772	4.02
2006	0.1	7.6	1.09	3	2	38570	2.1	-1.1	0.2	1.66	-0.02	5.52	175.3	80.2	0	3	2	8	1713	34.25	4.11	66,656,767	4.02
2005	0.27	7.3	0.99	2	2	39140	1.7	-1.3	0.1	1.68	-0.09	1.87	165.5	80.6	0	3	2	8	1713	18.25	4.11	66,632,176	4.02
2004	0.78	6.9	0.99	1	2	37150	2.5	-1.4	0.3	1.77	-0.05	-6.68	158	80.8	0	3	2	8	1713	18.25	4.11	66,634,318	4.02
2003	1.52	7	1	1	2	34010	1.5	-1.7	-0.1	1.82	-0.04	-7.54	152.3	81	0	3	2	8	1713	63.5	4.11	66,938,884	4.02
2002	1.62	7.1	1.11	1	2	33750	0	-1.6	-0.4	1.86	-0.11	3.18	143.7	80.4	0	3	2	8	1713	63.5	4.11	67,107,893	4.02

[Viet nam]

Year	P1	P2	P3	P4	P5	E1	E2	E3	E4	E5	E6	E7	E8	E9	S1	S2	S3	S4	S5	O1	O2	O3	O4
2010	0	2.7	0.11	14	5	1270	5.8	12.1	5.9	13.14	3.07	9.07	38.4	68.9	0	3	2	6.6	1215.3	29	2.56	51,013,859	2.96
2009	0	2.7	0.24	11	5	1120	2.9	6.2	-16.5	10.07	-5.71	4.68	31.9	63.4	0	3	2	6.6	1215.3	10,83	2.56	50,072,336	2.96
2008	0	2.7	0.14	11	5	1000	4.3	22.7	13.1	15.78	4.6	1.22	36	62.8	0	3	2	6.6	1215.3	9.58	2.56	49,116,555	2.96
2007	0	2.6	0.21	10	5	850	5.3	9.6	1	11.18	0	0.69	34.8	56	0	3	2	6.6	1215.3	16.25	2.5	48,166,101	2.89
2006	0	2.6	0.37	10	5	760	5.5	8.6	-0.6	11.18	0.16	0.85	34.3	57.6	0	3	2	3.8	1215.3	9	2.5	47,240,116	2.89
2005	0.04	2.6	0.46	10	5	680	6.1	9.2	0	11.02	1.3	0.72	38.3	50.2	0	3	2	3.8	1215.3	28.5	2.5	46,296,076	2.89
2004	0.08	2.6	0.14	9	5	590	6.1	9.2	2.3	9.72	0.24	1.52	36.9	54.8	0	3	2	3.8	1215.3	28.5	2.5	45,329,210	2.89
2003	0.16	2.4	0.1	9	5	510	5.7	6.9	2	9.48	0.42	1.51	33.3	47.6	0	3	2	3.8	1215.3	21.25	2.5	44,295,277	2.89
2002	0.31	2.4	0.28	9	5	460	4.9	4.9	2.2	9.06	-0.36	3.76	34.4	51	0	3	2	3.8	1215.3	21.25	2.5	43,287,625	2.89

[Singapore]

Year	P1	P2	P3	P4	P5	E1	E2	E3	E4	E5	E6	E7	E8	E9	S1	S2	S3	S4	S5	O1	O2	O3	O4
2010	0	9.3	1.14	26	3	44790	18	0	-3.5	5.38	0	-6.26	104.2	90	1	1	3	2	651.63	87.67	4.22	2,819,903	4.09
2009	0	9.2	1.14	23	3	37080	-3.8	3.5	5	5.38	0	2.8	93.9	90	1	1	3	2	651.63	92,83	4.22	2,737,054	4.09
2008	0	9.2	1.31	21	3	36680	-4.8	-1.5	-7.4	5.38	0.05	-6.12	86.3	90	1	1	3	2	651.63	125.5	4.22	2,644,490	4.09
2007	0	9.3	1.15	20	3	35660	5.1	5.9	4.2	5.33	0.02	-5.15	87.9	90	1	1	3	2	651.63	125.5	4.27	2,482,294	4.19
2006	0	9.4	1.21	20	3	32080	9.2	1.7	-0.5	5.31	0.01	-4.53	94.3	85	1	1	3	1	651.63	76.5	4.27	2,360,073	4.19
2005	0	9.4	1.13	17	3	28370	5.4	2.2	-2	5.3	0	-1.53	96.7	85	1	1	3	1	651.63	91	4.27	2,238,348	4.19
2004	0	9.3	1.11	15	3	25650	4	4.2	5.9	5.3	-0.01	-2.98	100.2	85	1	1	3	1	651.63	91	4.27	2,140,754	4.19
2003	0	9.4	0.86	14	3	23110	5.1	-1.7	-0.5	5.31	-0.04	-2.7	95.2	85	1	1	3	1	651.63	151.5	4.27	2,101,249	4.19
2002	0	9.3	1.18	12	3	21760	1.5	-1.2	1	5.35	-0.3	-0.06	93.1	83	1	1	3	1	651.63	151.5	4.27	2,119,100	4.19

[Indonesia]

Year	P1	P2	P3	P4	P5	E1	E2	E3	E4	E5	E6	E7	E8	E9	S1	S2	S3	S4	S5	O1	O2	O3	O4
2010	3.55	2.8	-0.85	14	4	2540	5.7	15.3	7	13.25	-1.25	-12.51	26.48	77.9	0	3	3	0.6	1322.3	49	2.54	114,503,985	2.76
2009	4.26	2.8	-0.76	11	4	2160	3.2	8.3	-9.8	14.5	0.9	7.12	30.25	76.4	0	3	3	0.6	1322.3	41.33	2.54	112,927,742	2.76
2008	3.73	2.6	-1.09	11	4	1950	5.3	18.1	6.8	13.6	-0.26	6.1	32.33	73	0	3	3	0.6	1322.3	45	2.54	110,968,624	2.76
2007	4.23	2.3	-1.2	10	4	1610	5.1	11.3	-2.8	13.86	-2.12	-0.2	35.84	74	0	3	3	0.6	1322.3	21.08	2.83	109,421,521	3.01
2006	5.14	2.4	-1.4	10	4	1390	4.6	14.1	-0.2	15.98	1.93	-5.62	42.61	74.6	0	3	3	0.6	1322.3	5.75	2.83	107,904,549	3.01
2005	5.84	2.2	-1.48	10	4	1230	3.9	14.3	5.7	14.05	-0.07	8.57	51.32	77.2	0	3	3	0.6	1322.3	5.75	2.83	106,377,062	3.01
2004	6.02	2	-1.87	9	4	1090	2.7	8.6	3.1	14.12	-2.81	4.22	55.64	74.2	0	3	3	0.6	1322.3	46.75	2.83	104,371,427	3.01
2003	6.25	1.9	-2.12	9	4	910	13.2	5.5	-0.4	16.93	-2.01	-7.88	62.33	74.6	0	3	3	0.6	1322.3	46.75	2.83	102,515,240	3.01
2002	6.73	1.9	-1.62	9	4	730	1.8	5.9	-8.4	18.94	0.39	-9.26	73.7	72.6	0	3	3	0.6	1322.3	46.75	2.83	100,611,493	3.01

[Thailand]

Year	P1	P2	P3	P4	P5	E1	E2	E3	E4	E5	E6	E7	E8	E9	S1	S2	S3	S4	S5	O1	O2	O3	O4
2010	7.12	3.5	-1.43	18	4	4320	7.2	3.7	1.8	5.93	-0.03	-7.58	45.8	75.9	0	3	3	7.1	895.24	25.17	3.16	38,781,149	3.29
2009	7.17	3.4	-1.42	15	4	3860	-2.9	1.9	-2	5.96	-1.08	2.92	38.1	75.6	0	3	3	7.1	895.24	44	3.16	38,651,150	3.29
2008	6.95	3.5	-1.28	15	4	3750	2.5	3.9	0.4	7.04	-0.01	-3.49	38.7	75.2	0	3	3	7.1	895.24	40.92	3.16	38,607,132	3.29
2007	6.96	3.3	-1.15	13	4	3280	5	3.5	-1.7	7.05	-0.3	-8.88	41.3	74.2	0	3	3	7.1	895.24	67.92	3.16	38,276,044	3.31
2006	6.5	3.6	-1.14	13	4	2890	5.3	5.2	0.7	7.35	1.56	-5.81	47.3	68.4	0	3	3	6.8	895.24	21.25	3.16	37,452,868	3.31
2005	5.92	3.8	-0.85	13	4	2600	3.6	4.5	1.4	5.79	0.29	-0.01	49.5	67.6	0	3	3	6.8	895.24	21.25	3.16	37,370,933	3.31
2004	4.91	3.6	-0.69	10	4	2370	5	3.1	1.8	5.5	-0.44	-3.04	50.7	65.6	0	3	3	6.8	895.24	58.75	3.16	36,847,367	3.31
2003	3.89	3.3	-0.15	10	4	2060	5.3	1.3	0.5	5.94	-0.94	-3.43	55.1	64.8	0	3	3	6.8	895.24	58.75	3.16	34,147,843	3.31
2002	4.25	3.2	0.44	10	4	1900	3.3	0.8	-1.3	6.88	-0.37	-3.31	57.5	77.8	0	3	3	6.8	895.24	58.75	3.16	35,716,480	3.31

[Philippines]

Year	P1	P2	P3	P4	P5	E1	E2	E3	E4	E5	E6	E7	E8	E9	S1	S2	S3	S4	S5	O1	O2	O3	O4
2010	6.86	2.4	-1.63	15	5	2740	6.2	4.2	1.4	7.67	-0.9	-5.39	54.8	77.8	1	2	4	5.4	1291.08	26.5	2.57	39,126,595	3.14
2009	6.82	2.4	-1.71	12	5	2480	4.5	2.8	-4.7	8.57	-0.18	7.57	54.7	78.6	1	2	4	5.4	1291.08	9.5	2.57	37,896,522	3.14
2008	6.72	2.3	-1.77	12	5	2240	3.5	7.5	4.4	8.75	0.06	-3.95	51.4	78.8	1	2	4	5.4	1291.08	10.5	2.57	36,883,231	3.14
2007	6.13	2.5	-1.63	10	5	1900	4.3	3.1	-1.8	8.69	-1.09	-10.07	55.4	79.8	1	2	4	5.4	1291.08	53.17	2.26	35,784,409	2.69
2006	5.94	2.5	-1.65	10	5	1660	3.1	4.9	-0.9	9.78	-0.4	-6.85	62.8	79.8	1	2	4	6.4	1291.08	4	2.26	35,315,304	2.69
2005	6.1	2.5	-1.22	10	5	1530	5	5.8	0.3	10.18	0.1	-1.7	69.7	79.4	1	2	4	6.4	1291.08	4	2.26	34,994,459	2.69
2004	6.63	2.6	-1.68	9	5	1400	5	5.5	2.3	10.08	0.61	3.39	71.4	77	1	2	4	6.4	1291.08	16.75	2.26	35,124,577	2.69
2003	6.74	2.5	-1.58	9	5	1270	6.3	3.2	-1	9.47	0.33	5.04	66.5	77.4	1	2	4	6.4	1291.08	16.75	2.26	34,592,776	2.69
2002	6.3	2.6	-0.91	9	5	1190	2	4.2	-0.8	9.14	-3.26	1.2	62.8	71.6	1	2	4	6.4	1291.08	16.75	2.26	33,497,187	2.69

[India]

Year	P1	P2	P3	P4	P5	E1	E2	E3	E4	E5	E6	E7	E8	E9	S1	S2	S3	S4	S5	O1	O2	O3	O4
2010	8.22	3.3	-1.23	22	5	1290	8.3	9	2.9	8.33	-3.86	-5.54	72.5	67.9	1	1	4	4.3	110.93	39.5	2.91	466,390,538	3.15
2009	8.19	3.4	-1.33	10	5	1170	7.1	6.1	-2.6	12.19	-1.12	11.26	74.72	51	1	1	4	4.3	110.93	23.83	2.91	466,896,011	3.15
2008	8.09	3.4	-1.1	5	5	1050	2.3	8.7	2.9	13.31	0.29	5.22	75.44	51	1	1	4	4.3	110.93	16.58	2.91	466,233,702	3.15
2007	7.91	3.5	-1.15	5	5	960	8.7	5.8	-0.6	13.02	1.83	-8.74	78.49	51.2	1	1	4	4.3	110.93	29.5	2.9	466,033,315	3.07
2006	7.92	3.3	-1.06	4	5	820	7.6	6.4	2.2	11.19	0.44	2.74	81.76	24	1	1	4	3.6	110.93	11.5	2.9	465,456,462	3.07
2005	7.56	2.9	-0.99	3	5	740	7.7	4.2	-1.5	10.75	-0.17	-2.68	84.06	38	1	1	4	3.6	110.93	11.5	2.9	464,498,005	3.07
2004	7.56	2.8	-1.22	2	5	630	6.3	5.7	1.8	10.92	-0.54	-2.72	84.3	23.6	1	1	4	3.6	110.93	20.75	2.9	451,934,600	3.07
2003	7.7	2.8	-1.53	2	5	530	6.1	3.9	0.2	11.46	-0.46	-4.17	82.2	23	1	1	4	3.6	110.93	20.75	2.9	440,212,534	3.07
2002	7.73	2.7	-1.24	1	5	470	2.4	3.7	0.5	11.92	-0.16	3.02	77.85	21.8	1	1	4	3.6	110.93	20.75	2.9	428,601,673	3.07

[United Arab Emirates]

Year	P1	P2	P3	P4	P5	E1	E2	E3	E4	E5	E6	E7	E8	E9	S1	S2	S3	S4	S5	O1	O2	O3	O4
2010	1.19	6.3	0.79	17	5	33690	-8.2	11	26.2	8.05	0	0	23.4	82.8	0	1	2	4.3	715.01	81.17	3.81	5,686,382	3.63
2009	0	6.5	0.91	17	5	36000	-16.6	-15.2	-33.7	8.05	0	0	12.5	80.8	0	1	2	4.3	715.01	69,83	3.81	5,136,379	3.63
2008	0	5.9	0.7	17	5	41630	-13.7	18.5	6	8.05	0	0	7.8	80.4	0	1	2	4.3	715.01	141.58	3.81	4,461,176	3.63
2007	0	5.7	0.97	17	5	42160	-12.2	12.5	0.5	8.05	0	0	6.8	75	0	1	2	4.3	715.01	76.5	3.8	3,735,627	3.73
2006	0	6.2	0.91	17	5	42810	-6	12	-4.5	8.05	0	0	6.6	75	0	1	2	2.5	715.01	76.5	3.8	3,066,204	3.73
2005	0	6.2	0.85	17	5	41470	-6.6	16.5	8	8.05	0	0	5.6	77	0	1	2	2.5	715.01	86.5	3.8	2,541,209	3.73
2004	0	6.1	0.75	17	5	40210	1.4	8.5	4.4	8.05	0	0	4.4	77	0	1	2	2.5	715.01	86.5	3.8	2,182,248	3.73
2003	0	5.2	0.96	17	5	36120	3.3	4.1	0.3	8.05	0	0	3.6	77	0	1	2	2.5	715.01	151.5	3.8	1,968,908	3.73
2002	0	5.2	0.84	12	5	33380	-3.9	3.8	6.1	8.05	0	0	2.7	77	0	1	2	2.5	715.01	151.5	3.8	1,861,504	3.73

[Saudi Arabia]

Year	P1	P2	P3	P4	P5	E1	E2	E3	E4	E5	E6	E7	E8	E9	S1	S2	S3	S4	S5	O1	O2	O3	O4
2010	2.15	4.7	-0.22	17	5	19040	3.8	17.2	36.1	2	0	0	13.99	82.5	0	1	3	0.2	1395.14	59.17	3.27	9,725,111	3.22
2009	2.87	4.3	-0.51	17	5	18350	-1.6	-18.9	-34.2	2	-3.5	0	12.06	81.8	0	1	4	0.2	1395.14	12,50	3.27	9,400,411	3.22
2008	2.82	3.5	-0.37	17	5	18640	17	15.3	11.1	5.5	0.2	0.07	17.11	76.8	0	1	4	0.2	1395.14	73.5	3.27	9,174,577	3.22
2007	3.73	3.4	-0.5	17	5	15930	12.3	4.2	-4.4	5.3	0.3	0.07	25.83	70.4	0	1	4	0.2	1395.14	77.25	2.95	8,920,244	3.02
2006	4.29	3.3	-0.54	17	5	14180	13.6	8.6	-9.7	5	2.2	-0.06	37.35	70.4	0	1	4	0.3	1395.14	77.25	2.95	8,601,112	3.02
2005	4.84	3.4	-0.25	17	5	12480	17.5	18.3	9.8	2.8	1	-0.08	65	62.2	0	1	4	0.3	1395.14	84.75	2.95	8,208,531	3.02
2004	5.54	3.4	-0.68	17	5	10620	17.1	8.5	4.4	1.8	-0.2	0	82	64	0	1	4	0.3	1395.14	84.75	2.95	7,753,305	3.02
2003	4.89	4.5	0.1	17	5	9070	7.1	4.1	0.3	2	-0.4	0	96.9	64.4	0	1	4	0.3	1395.14	122.25	2.95	7,235,405	3.02
2002	2.09	4.5	-0.09	12	5	8470	-8.3	3.8	6.3	2.4	-0.5	0	93.7	63.4	0	1	4	0.3	1395.14	122.25	2.95	6,721,316	3.02

[Malaysia]

Year	P1	P2	P3	P4	P5	E1	E2	E3	E4	E5	E6	E7	E8	E9	S1	S2	S3	S4	S5	O1	O2	O3	O4
2010	0.35	4.4	0.12	17	5	8150	4.1	4.1	10.1	5	-0.08	-8.61	52.81	78.7	0	1	2	1.3	583.67	96.67	3.5	12,084,841	3.44
2009	0.82	4.5	-0.07	13	5	7590	-2.1	-6	-16.4	5.08	-1	5.66	41.24	78.2	0	1	2	1.3	583.67	83.17	3.5	11,834,730	3.44
2008	1.12	5.1	0.08	13	5	7500	1.9	10.4	5.5	6.08	-0.33	-2.96	41.22	76.2	0	1	2	1.3	583.67	57.75	3.5	11,605,640	3.44
2007	0	5.1	0.17	11	5	6600	5.2	4.9	0.9	6.41	-0.08	-6.29	41.54	76.8	0	1	2	1.3	583.67	75	3.33	11,394,970	3.48
2006	0	5	0.26	11	5	5810	5.2	4	-4.9	6.49	0.54	-3.14	42.71	76.6	0	1	2	0.8	583.67	25	3.33	11,180,638	3.48
2005	0.02	5.1	0.55	10	5	5240	4.1	8.9	2.9	5.95	-0.1	-0.34	45.7	75.8	0	1	2	0.8	583.67	25	3.33	10,961,174	3.48
2004	0.13	5	0.31	9	5	4700	4.9	6	2.7	6.05	-0.25	0	45.1	73.4	0	1	2	0.8	583.67	61.5	3.33	10,736,943	3.48
2003	0.26	5.2	0.46	9	5	4130	4.8	3.3	0.2	6.3	-0.23	0	43.1	73	0	1	2	0.8	583.67	61.5	3.33	10,509,126	3.48
2002	0.52	4.9	0.46	9	5	3760	4	3.1	4.7	6.53	-0.6	0	41.4	66.6	0	1	2	0.8	583.67	61.5	3.33	10,278,039	3.48

[United States]

Year	P1	P2	P3	P4	P5	E1	E2	E3	E4	E5	E6	E7	E8	E9	S1	S2	S3	S4	S5	O1	O2	O3	O4
2010	4.02	7.1	0.44	12	4	48950	2	1.2	0.4	3.25	0	0	95.2	86.9	1	1	2	9.2	1082.87	37.5	4.15	157,464,257	3.86
2009	4.1	7.5	0.43	12	4	48050	-3.7	0.8	-1.2	3.25	-1.84	0	87.1	86.8	1	1	2	9.2	1082.87	30,00	4.15	157,889,958	3.86
2008	3.5	7.3	0.56	10	4	49330	-0.9	2	-0.7	5.09	-2.96	0	76	86.8	1	1	2	9.2	1082.87	13.92	4.15	157,724,796	3.86
2007	3.12	7.2	0.37	10	4	48640	1.2	2.7	-0.4	8.05	0.09	0	64.8	86.6	1	1	2	9.2	1082.87	30.08	4.07	155,976,570	3.84
2006	3.38	7.3	0.49	10	4	48080	1.5	3.1	-0.1	7.96	1.77	0	63.9	81.4	1	1	2	9.5	1082.87	16.25	4.07	154,694,540	3.84
2005	5.63	7.6	-0.09	8	4	46340	2.4	3.2	0.5	6.19	1.85	0	63.3	79.8	1	1	2	9.5	1082.87	16.25	4.07	152,846,134	3.84
2004	6.52	7.5	-0.2	7	4	43680	3	2.7	0.7	4.34	-0.34	0	62.7	81.4	1	1	2	9.5	1082.87	18.25	4.07	150,729,170	3.84
2003	7.17	7.5	0.05	5	4	39950	2.1	2	0.5	4.12	-0.56	0	61.3	81.4	1	1	2	9.5	1082.87	39.25	4.07	149,705,300	3.84
2002	7.39	7.7	0.21	5	4	37,470	0.8	1.5	-0.8	4.68	-2.24	0	59.5	79.4	1	1	2	9.5	1082.87	39.25	4.07	149,157,182	3.84

[Libya]

Year	P1	P2	P3	P4	P5	E1	E2	E3	E4	E5	E6	E7	E8	E9	S1	S2	S3	S4	S5	O1	O2	O3	O4
2010	0.06	2.2	-0.03	19	6	12710	4.1	14.2	39.5	6	0	1.06	8.8	85	0	1	5	0.1	1332.77	106.17	2.18	2,271,617	2.33
2009	0.12	2.5	0.81	19	6	12430	-2.2	-25.3	-47.1	6	0	2.45	6.3	90	0	1	5	0.1	1332.77	106.17	2.18	2,243,920	2.33
2008	0.23	2.6	0.81	19	6	12580	0.9	21.8	10.8	6	0	-3.1	8.2	39.6	0	1	5	0.1	1332.77	106.17	2.18	2,205,476	2.33
2007	0.16	2.5	0.73	19	6	10750	4.4	11	1.5	6	-0.33	-3.88	10.1	39.6	0	1	5	0.1	1332.77	106.17	2.18	2,158,251	2.33
2006	0	2.7	0.35	19	6	8900	4.6	9.5	-19.1	6.33	0.2	0.4	11.7	34.6	0	1	5	0.1	1332.77	144.25	2.18	2,105,392	2.33
2005	0	2.5	0.44	19	6	7110	10	28.6	6	6.13	0.05	0.26	16.7	53.2	0	1	5	0.1	1332.77	144.25	2.18	2,057,009	2.33
2004	0	2.5	0.34	19	6	5330	2.7	22.6	8.2	6.08	-0.92	0.93	21.2	42.4	0	1	5	0.1	1332.77	144.25	2.18	2,005,735	2.33
2003	0	2.1	0.08	19	6	5350	11.2	14.4	-12.8	7	0	1.75	21.2	42.4	0	1	5	0.1	1332.77	144.25	2.18	1,954,742	2.33
2002	0	2.1	-0.16	19	6	5360	-2.6	27.2	20	7	0	110.01	21.2	49	0	1	5	0.1	1332.77	144.25	2.18	1,903,379	2.33

[Nigeria]

Year	P1	P2	P3	P4	P5	E1	E2	E3	E4	E5	E6	E7	E8	E9	S1	S2	S3	S4	S5	O1	O2	O3	O4
2010	6.48	2.4	-2.19	15	5	1460	8.5	103.8	108.1	17.58	-0.78	0.94	15.2	67.2	1	1	5	10.1	172.68	58.67	2.43	49,706,564	2.59
2009	6.58	2.5	-1.95	15	5	1160	3	-4.3	-15.1	18.36	2.88	25.61	11.6	61.8	1	1	5	10.1	172.68	70.33	2.43	48,361,547	2.59
2008	5.87	2.7	-1.86	15	5	1160	2.9	10.8	6	15.48	-1.46	-5.77	12.8	63.4	1	1	5	10.1	172.68	80	2.43	47,063,053	2.59
2007	6	2.2	-2.01	15	5	970	0	4.8	-12.5	16.94	0.04	-2.21	11.8	61.6	1	1	5	10.1	172.68	65.5	2.23	45,724,201	2.4
2006	6.12	2.2	-2.04	15	5	840	16.3	17.3	-4.7	16.9	-1.05	-2	28.6	51.2	1	1	5	12.3	172.68	65.75	2.23	44,509,061	2.4
2005	4.39	1.9	-1.65	15	5	660	-0.3	22	22.2	17.95	-1.23	-1.21	52.7	53.4	1	1	5	12.3	172.68	65.75	2.23	43,250,247	2.4
2004	4.56	1.6	-1.72	15	5	610	29.5	-0.2	-11.3	19.18	-1.53	2.84	63.9	45	1	1	5	12.3	172.68	53	2.23	42,105,536	2.4
2003	4.5	1.4	-1.65	15	5	410	6.9	11.1	-28.8	20.71	-4.06	7.17	68.8	45	1	1	5	12.3	172.68	53	2.23	41,290,885	2.4
2002	3.88	1.6	-1.7	15	5	350	0.2	39.9	40.2	24.77	1.33	8.4	88	45	1	1	5	12.3	172.68	53	2.23	40,558,453	2.4

[Kuwait]

Year	P1	P2	P3	P4	P5	E1	E2	E3	E4	E5	E6	E7	E8	E9	S1	S2	S3	S4	S5	O1	O2	O3	O4
2010	0	4.5	0.44	14	4	42480	10.2	11.2	28.4	4.91	-1.25	-0.41	11.05	82.5	0	1	2	0.1	1517.26	105.33	3.33	1,512,542	3.28
2009	0.1	4.1	0.34	14	4	45500	10.2	-17.2	-35.9	6.16	-1.45	7.05	9.57	81	0	1	2	0.1	1517.26	94.33	3.33	1,436,885	3.28
2008	0.2	4.3	0.46	14	4	50830	10.2	18.7	14.4	7.61	-0.93	-5.41	11.83	81	0	1	2	0.1	1517.26	74.75	3.33	1,354,894	3.28
2007	0.47	4.3	0.56	14	4	46630	10.2	4.3	-11.9	8.54	-0.04	-2.05	10.57	77.2	0	1	2	0.1	1517.26	74.75	2.83	1,283,963	2.99
2006	1.12	4.8	0.36	14	4	40660	10.2	16.2	-6.2	8.58	1.08	-0.62	14.14	77.2	0	1	2	0.1	1517.26	74.75	2.83	1,217,897	2.99
2005	1.84	4.7	0.2	14	4	34110	10.2	22.4	11.6	7.5	1.86	-0.92	18.62	77.8	0	1	2	0.1	1517.26	74.75	2.83	1,159,849	2.99
2004	0.84	4.6	0.31	14	4	28240	10.2	10.8	5.9	5.64	0.22	-1.11	24.62	77	0	1	2	0.1	1517.26	74.75	2.83	1,113,784	2.99
2003	1.55	5.3	0.24	14	4	23080	13	4.9	-0.3	5.42	-1.06	-1.94	32.33	80.5	0	1	2	0.1	1517.26	74.75	2.83	1,074,039	2.99
2002	0.35	5.3	-0.26	6	4	19770	-5.1	5.2	13.4	6.48	-1.4	-0.9	36.43	76.8	0	1	2	0.1	1517.26	74.75	2.83	1,035,735	2.99

[Taiwan]

Year	P1	P2	P3	P4	P5	E1	E2	E3	E4	E5	E6	E7	E8	E9	S1	S2	S3	S4	S5	O1	O2	O3	O4
2010	0.06	5.8	0.84	4	3	4300	2.1	6.9	7	5.81	0.5	-0.9	33.1	85.8	0	3	2	6.7	2249.79	52.17	3.62	774,172,295	3.71
2009	0.12	5.6	0.53	4	3	3650	7.9	-0.1	-7.9	5.31	0	-1.69	29.9	85.2	0	3	2	6.7	2249.79	6.67	3.62	773,686,144	3.71
2008	0.23	5.7	0.8	4	3	3070	9.5	7.8	0	5.31	-2.16	-8.66	28.8	86.7	0	3	2	6.7	2249.79	6.67	3.62	770,992,463	3.71
2007	0	5.7	0.52	2	3	2490	14.1	7.8	3.9	7.47	1.35	-4.59	29.6	81.6	0	3	2	6.7	2249.79	69.42	3.62	768,074,459	3.64
2006	0	5.9	0.62	2	3	2050	12.7	3.9	0	6.12	0.54	-2.7	30.2	81.8	0	3	2	4.9	2249.79	52	3.62	763,693,185	3.64
2005	0	5.9	0.62	1	3	1750	10.2	3.9	-3	5.58	0	-1	29.6	78.4	0	3	2	4.9	2249.79	52	3.62	758,612,921	3.64
2004	0	5.6	0.56	1	3	1500	9.8	6.9	4.3	5.58	0.27	0	29.2	78	0	3	2	4.9	2249.79	22	3.62	752,711,357	3.64
2003	0	5.7	0.6	0	3	1270	9.8	2.6	2	5.31	0	0	27.4	77.2	0	3	2	4.9	2249.79	22	3.62	746,320,096	3.64
2002	0	5.6	0.6	0	3	1100	8.8	0.6	-1.4	5.31	-0.54	0	27.8	80	0	3	2	4.9	2249.79	22	3.62	738,923,140	3.64

[Russia]

Year	P1	P2	P3	P4	P5	E1	E2	E3	E4	E5	E6	E7	E8	E9	S1	S2	S3	S4	S5	O1	O2	O3	O4
2010	7.01	2.1	-0.91	17	2	9980	4.3	14.2	12.2	10.82	-4.49	-4.32	11	68.4	0	3	4	15.1	2690.33	11	2.38	76,567,196	2.61
2009	6.48	2.2	-0.95	17	2	9230	-4.7	2	-16	15.31	3.08	27.71	7.9	60.8	0	3	4	15.1	2690.33	62	2.38	76,911,924	2.61
2008	6.28	2.1	-0.76	17	2	9590	10.6	18	4.2	12.23	2.2	-2.85	8.5	44.2	0	3	4	15.1	2690.33	73.67	2.38	77,074,406	2.61
2007	6.23	2.3	-0.86	17	2	7560	7.5	13.8	-1.4	10.03	-0.4	-5.92	9	62.6	0	3	4	15.1	2690.33	87.58	2.23	76,715,688	2.37
2006	6.66	2.5	-0.91	17	2	5800	8.7	15.2	-4.1	10.43	-0.25	-3.87	14.2	62.6	0	3	4	16.1	2690.33	24.75	2.23	75,612,193	2.37
2005	7.23	2.4	-1.25	16	2	4450	6.3	19.3	-1	10.68	-0.76	-1.84	22.3	63.2	0	3	4	16.1	2690.33	24.75	2.23	75,357,641	2.37
2004	7.6	2.8	-1.46	16	2	3410	8.5	20.3	6.5	11.44	-1.54	-6.12	30.4	63.2	0	3	4	16.1	2690.33	37.75	2.23	74,773,525	2.37
2003	7.24	2.7	-1.2	16	2	2580	6.6	13.8	-1.7	12.98	-2.72	-2.09	40.3	57.4	0	3	4	16.1	2690.33	37.75	2.23	73,971,402	2.37
2002	7.2	2.7	-0.77	16	2	2100	4.7	15.5	-1	15.7	-2.21	7.47	47.6	57.4	0	3	4	16.1	2690.33	37.75	2.23	72,523,648	2.37

[Sri Lanka]

Year	P1	P2	P3	P4	P5	E1	E2	E3	E4	E5	E6	E7	E8	E9	S1	S2	S3	S4	S5	O1	O2	O3	O4
2010	6.48	3.2	-0.92	12	3	2260	6.9	7.3	1.4	10.22	-5.45	-1.64	86.4	62.2	1	1	3	3.7	322.44	56.67	1.88	8,505,489	2.29
2009	7.16	3.1	-1.35	12	3	1970	3.7	5.9	-10.4	15.67	-3.22	6.1	81.4	71	1	1	3	3.7	322.44	83.5	1.88	8,559,010	2.29
2008	7.4	3.2	-1.8	12	3	1770	3.6	16.3	2.3	18.89	1.81	-2.07	85	69.6	1	1	3	3.7	322.44	30.83	1.88	8,516,285	2.29
2007	7.3	3.2	-1.74	12	3	1540	6.1	14	2.7	17.08	4.23	6.46	87.8	71.6	1	1	3	3.7	322.44	54.75	2.13	8,453,327	2.4
2006	7.48	3.1	-1.43	12	3	1350	6.4	11.3	0.9	12.85	2.09	3.4	90.6	71.4	1	1	3	2.2	322.44	49.5	2.13	8,604,475	2.4
2005	5.92	3.2	-1.19	12	3	1210	4.9	10.4	1.6	10.76	1.29	-0.69	102.3	76.6	1	1	3	2.2	322.44	49.5	2.13	8,057,275	2.4
2004	5.12	3.5	-1.06	11	3	1070	4	8.8	3.7	9.47	-0.87	4.84	102.3	70.6	1	1	3	2.2	322.44	75.75	2.13	7,909,059	2.4
2003	5.37	3.4	-0.88	6	3	950	5.1	5.1	-6.7	10.34	-2.83	0.9	102	70.2	1	1	3	2.2	322.44	75.75	2.13	7,920,593	2.4
2002	5.9	3.7	-0.85	6	3	860	3.5	11.8	-1.9	13.17	-6.22	7.02	103.2	72	1	1	3	2.2	322.44	75.75	2.13	7,842,389	2.4

[Bangladesh]

Year	P1	P2	P3	P4	P5	E1	E2	E3	E4	E5	E6	E7	E8	E9	S1	S2	S3	S4	S5	O1	O2	O3	O4
2010	4.14	2.4	-1.4	9	5	780	4.6	7.1	0.3	13	-1.6	0.88	25.3	58	0	1	3	0.2	664.98	60.83	2.49	73,014,258	2.74
2009	4.17	2.4	-1.54	9	5	710	4.2	6.8	-1.1	14.6	-1.78	0.64	26.5	40.2	0	1	3	0.2	664.98	18.33	2.49	71,661,990	2.74
2008	4.33	2.1	-1.48	9	5	650	6	7.9	1.4	16.38	0.38	-0.4	29.1	40.2	0	1	3	0.2	664.98	50.42	2.49	70,372,739	2.74
2007	4.59	2	-1.5	9	5	590	6.7	6.5	0.6	16	0.67	-0.08	30.5	40.2	0	1	3	0.2	664.98	3	2.29	69,111,445	2.47
2006	5.25	2	-1.48	9	5	560	6.6	5.9	1.3	15.33	1.33	7.16	29.1	48.2	0	1	3	0.2	664.98	29.5	2.29	67,828,612	2.47
2005	5.63	1.7	-1.84	9	5	540	5.2	4.6	0	14	-0.75	8.09	33.9	34	0	1	3	0.2	664.98	29.5	2.29	66,488,284	2.47
2004	5.2	1.5	-1.38	9	5	490	4.1	4.6	-1.2	14.75	-1.25	2.34	34.3	38	0	1	3	0.2	664.98	9.75	2.29	65,081,482	2.47
2003	4.92	1.3	-1.14	5	5	450	3.1	5.8	1.9	16	0	0.45	34.3	38	0	1	3	0.2	664.98	9.75	2.29	63,618,367	2.47
2002	5.54	1.2	-1.08	5	5	420	3.1	3.9	0.6	16	0.17	3.73	31.4	50.6	0	1	3	0.2	664.98	9.75	2.29	62,105,927	2.47

[Mexico]

Year	P1	P2	P3	P4	P5	E1	E2	E3	E4	E5	E6	E7	E8	E9	S1	S2	S3	S4	S5	O1	O2	O3	O4
2010	2.51	3.1	-0.74	21	4	8780	5.1	4.5	1	5.29	-1.78	-6.49	29.7	82	0	3	4	7.2	329.26	27.67	2.95	50,387,831	3.05
2009	2.68	3.3	-0.7	21	4	8500	-5.7	3.5	-2.5	7.07	-1.64	21.42	21.1	80.2	0	3	4	7.2	329.26	56.67	2.95	48,606,636	3.05
2008	3.4	3.6	-0.8	21	4	9350	0.6	6	1.1	8.71	1.15	1.84	17.1	79	0	3	4	7.2	329.26	39.58	2.95	48,549,880	3.05
2007	4	3.5	-0.73	21	4	8820	1.7	4.9	-1.4	7.56	0.05	0.27	18.2	77.6	0	3	4	7.2	329.26	31.08	2.68	47,400,119	2.87
2006	1.35	3.3	-0.64	21	4	8230	3.3	6.3	0.9	7.51	-2.18	0.01	19.8	57.4	0	3	4	8.5	329.26	43	2.68	46,367,100	2.87
2005	1.01	3.5	-0.44	21	4	7650	1.3	5.4	-2.9	9.69	2.25	-3.44	21.1	75.2	0	3	4	8.5	329.26	43	2.68	44,845,642	2.87
2004	1.77	3.6	-0.22	20	4	7310	3.4	8.3	2.3	7.44	0.42	4.61	22.7	81.6	0	3	4	8.5	329.26	51.5	2.68	44,117,855	2.87
2003	2.02	3.6	-0.14	20	4	6790	0.1	6	0.4	7.02	-1.19	11.73	21.6	81	0	3	4	8.5	329.26	51.5	2.68	42,330,230	2.87
2002	2.02	3.6	-0.1	20	4	6510	-1	5.6	0.2	8.21	-4.59	3.36	19.9	81.2	0	3	4	8.5	329.26	51.5	2.68	42,012,501	2.87

Appendix E: Sample Data on International Construction Projects

[Sample Data on Test Cases of SPR and CPR Validation]

This research have used a significantly large data set for retrieving pertinent cases. The data on 7 variables related to internal risks of construction projects was collected from ICAK, leading to a historical data set of international construction projects undertaken by a Korean contractor in 51 countries from 2002 to 2010. This research shows the data set of test cases for validating CPR and SPR prediction.

Note: (C1) Client type, (C2) Building type, (C3) Construction type, (C4) Contract type for payment, (C5) Project complexity, (C6) Duration of project, (C7) Risk management competence

No.	C1	C2	C3	C4	C5	C6	C7
Test Case 1	2	1	1	3	30.354	311	1.98
Test Case 2	1	2	1	2	25.64	731	2.03
Test Case 3	2	3	1	3	404.50	912	2.37
Test Case 4	2	1	1	3	30.56	731	1.62
Test Case 5	2	1	2	3	101.17	1033	2.03
Test Case 6	1	3	2	3	660.57	1095	1.62
Test Case 7	1	3	2	3	1541.13	1096	2.37
Test Case 8	2	3	2	3	213.33	731	2.37
Test Case 9	2	3	2	3	621.17	851	1.98
Test Case 10	1	1	1	3	7.71	1090	1.62

No.	C1	C2	C3	C4	C5	C6	C7
Test Case 11	2	3	2	3	400.43	1065	2.03
Test Case 12	1	3	2	3	795.45	1014	2.03
Test Case 13	2	1	1	3	113.62	988	1.62
Test Case 14	1	2	1	3	8.95	1096	2.37
Test Case 15	1	2	1	3	24.60	1218	1.98
Test Case 16	1	2	1	2	25.76	1095	2.03
Test Case 17	2	1	2	3	83.86	1005	1.62
Test Case 18	2	1	1	3	54.78	660	1.98
Test Case 19	2	1	2	3	66.99	1034	2.37
Test Case 20	2	2	1	3	7.82	1049	2.03
Test Case 19	2	1	2	3	66.99	1034	1.98
Test Case 20	2	2	1	3	7.82	1049	2.37

國 文 抄 錄

事例基盤學習을 活用한 海外建設事業 危險事件 管理方案

해외건설사업은 정치, 경제, 사회, 문화 등의 사업 외부적 환경에서 국내건설사업과 차이를 나타내며, 이러한 이유로 해외건설사업은 일반적으로 높은 리스크(Risk)를 보유하고 있는 사업으로 인식된다. 건설사업에서 발생하는 리스크는 사업초기 발견여부 및 발생확률에 대한 인지여부에 따라 Knowns, Known-unknowns, Unknown-unknowns로 분류한다. 이러한 리스크는 상호연계작용을 통해 리스크 사건 (Risk event) 으로 발현되며, 건설사업의 공사비 및 공사기간 성과에 악영향을 미친다. 이에 건설기업들은 리스크 관리(Risk Management) 프로세스 및 가이드라인(Guideline)을 도입함으로써 리스크 사건에 대비하고, 공사비 및 공사기간에 대한 손실발생 가능성을 저감시키고자 노력한다. 예를 들어, 건설사업 계약자는 사업초기 발견가능한 리스크를 예측하고 이를 평가함으로써 리스크 사건을 제거하거나 이에 대비하기 위한 예비비(Contingency)를 산정하며, 리스크 사건(Risk Event)을 처리하기 위한 계획을 수립한다.

그러나, 기존의 프로세스 및 평가기반의 리스크 관리방안은 사업초기 운영 중 발생하는 모든 리스크 사건을 고려할 수 없다는 한계점이 존재한다. 이는 리스크 상호작용의 복잡성, 사업초기 예측할

수 없는 리스크의 존재, 리스크 값 예측의 어려움으로 인해 발생하며, 사업 운영 중 예상하지 못한 리스크 사건을 발생시킨다. 즉, 사업초기 산정한 예비비 및 리스크 사건 대응계획(Response strategy)은 예측가능한 리스크 사건에 한정하여 적용가능하다. 예를 들어, 건설사업 계약자는 리스크 사건에 대비하기 위한 예비비를 결정론적인 점추정 방식(Deterministic Point Estimation)을 이용해 산정하고 있으며, 사업 수행 중 발생하는 리스크 사건은 사업관리자 및 리스크 관리자의 경험을 기반으로 대응하고 있다. 이러한 사업 리스크 관리 방식은 최종적으로 공사비 및 공사기간에 대한 손실발생 가능성을 완전히 제거하지 못하며, 이는 사업의 성과에 실질적 손실로 구현될 수 있다.

본 연구는 이러한 현행 리스크 관리방식의 한계점을 인지하고 이를 보완하기 위해, 사례기반학습에 의거한 해외건설사업 리스크 사건 관리방안을 제안한다. 구체적으로, 건설사업 계획단계에서 예측하지 못한 리스크 사건에 대비하기 위한 예비비(Management reserve)를 산정할 수 있는 방안 및 운영단계에서 리스크 사건 발생 시 이에 대응하기 위한 의사결정을 지원할 수 있는 모델을 제안한다. 이를 위해 본 연구는 과거 사례로부터 가장 유사한 사례를 추출하여 리스크 사건을 관리하기 위해 사례기반추론 (Case-Based Reasoning, 이하 CBR) 방법론을 적용하였다. 또한, 최적화 방법론인 유전자 알고리즘 (Genetic Algorithm, 이하 GA)과 계층적 분석방법론 (Analytic Hierarchy Process, 이하 AHP)을 통해 유사사례 추출의 정확도를 증진시켰다. 그리고 이러한 방법론을 적용하여 유사사례를 추

출하기 위해 해외건설사업의 불확실성으로부터 발생하는 리스크 인자(Risk Source)의 분류체계를 제안하고 변수를 도출하였다. 최종적으로 사례연구를 수행함으로써 본 연구에서 제안한 예비비 산정 방안 및 리스크 사건 대응 의사결정지원 모델의 유효성 및 적용성을 검증하였다.

본 연구에서 제안하는 해외건설공사 리스크 사건 관리방안은 예측하기 어려운 리스크 사건에 대비하기 위한 예비비를 산정함으로써 공사비 예측의 정확성을 증진시키고, 리스크 사건 발생 시 선택 가능한 대응방안을 제시함으로써 건설계약자의 의사결정을 지원한다. 계획단계의 예비비 산정방안은 신규사업의 공사비 및 공사기간 성과를 예측하여 산정되며, 이는 사업 입찰 및 계약 시 발주자와의 협상 근거로 활용하여 계약금액 및 공사기간에 대한 전략적 수주를 가능하게 한다. 또한, 정확한 공사비 산정을 통해 계획 대비 성과에 대해 일관성 있는 수행결과를 확보할 수 있을 것이다. 운영단계의 리스크 사건 대응 의사결정지원 모델은 리스크 사건 발생 시 유사 사례의 정보를 제공함으로써 건설계약자가 신속하고 적절한 대응전략 및 해결방안을 도출할 수 있도록 의사결정을 지원할 것이다. 최종적으로, 본 연구에서 제시한 리스크 사건 관리방안은 해외건설사업 수행 시 손실이 발생할 가능성을 감소시킬 것이다.

주요어: 해외건설공사; 리스크 사건 관리; 예비비 산정; 대응전략; 사례기반학습; 최적화

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