

# **Development of Multi-party Risk and Uncertainty Management Process for an Infrastructure Project**

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Graduate School of Engineering

Kochi University of Technology

A dissertation submitted to  
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in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

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by

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# Abstract

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Many infrastructure projects in Southeast Asian countries still have not secured good project goal achievement. Such failure could be realized in terms of severe project delay. One major reason is because of common external and internal risks and uncertainties that are inherent in all stages of project i.e., from planning, bidding, contracting to construction stage.

To cope with these risks, several risk management process (RMP) have been introduced by many researchers. Generally, conventional RMP consists of three main processes i.e., risk identification, risk structuring and analysis, and risk response. However, there are still limitations associated with conventional RMP.

Conventional RMPs is designed for the events that have high probability and high impact by prioritizing risk based on expected impact. This results in redundant risk events and tendency in overlooking a risk event with very low frequency of occurrence but extremely high impact. In many cases, we may not have sufficient necessary experience to properly deal with this type of uncertainty because of insufficiency, inaccuracy, and inapplicability of historical data, and bounded rationality of human in subjective assessment. Inattention on catastrophic event (which is ‘uncertainty’ event) is the first fundamental limitation.

The second fundamental limitation is realized in interpreting the output of conventional RMPs. Since output of conventional RMPs, which is normally presented as map of tradeoff between dimensionless expected impact and risk, does not represent how much project is delayed, it is considered difficult to interpret the output and use in communication.

Third, since the conventional RMPs do not put attention on involvement of multiple parties, the risks and uncertainties caused by involved parties may not be solved

efficiently. Conflict or problems among multiple parties often arise due to difference in their perceptions towards risks and uncertainties. With this limitation, the problem solving processes including problem awareness, problem identification, and problem solving cannot be completely executed by RMP.

The objective of this research is to overcome these fundamental limitations of conventional RMPs.

### **Chapter 1: Introduction**

This chapter provides general introduction and problem statement of infrastructure projects, brief description of limitations associated with conventional RMPs, objectives of research, and description of organization of dissertation.

### **Chapter 2: Reviews of Risk Management for Infrastructure Projects**

This chapter aims to provide comprehensive understanding of risk management concept in order to build foundation for MRUMP development and application. General review of conventional RMP is firstly provided. Then, overview of multi-party risk management process (MRMP) development and application is explained. The MRMP has been previously developed by incorporating involved parties in the scope. It is important to be aware that each party may have different viewpoint towards risks and uncertainties, which can constitute ‘problem’ due to difference of perception associated with project goal. Finally, further risk management literatures have been reviewed to identify unresolved areas in risk management.

### **Chapter 3: Post-evaluation and Limitations of (M)RMP**

The discussion of the applicability of MRMP based on post-evaluation study of MRMP application is provided in this chapter. The post-evaluation study aims to follow up how major risks were actually managed in case study, to compare the actual ways of risk management and those suggested from the MRMP, and to study reasons for limitation of the MRMP if there is any. As a result of post-evaluation study, the fundamental and technical limitations of (M)RMP could be identified.

## **Chapter 4: Risk/Uncertainty Map and Hierarchical Structure of Risk and Uncertainty**

To overcome the fundamental limitation regarding inattention on ‘uncertainty,’ this research develops risk/uncertainty map for an infrastructure project financed by international lender. Moreover, to overcome technical limitation regarding little established risk structuring and analysis procedures, this research develops “standard” and “organized” risk structuring diagram called hierarchical structure of risk and uncertainty (HSRU) framework. The developed risk/uncertainty map aims to assist practitioners in better dealing with risks and uncertainties by accumulating the experience and lessons from past projects and updating the structure. In HSRU framework, the cause and effect events are hierarchically separated. This chapter provides explanation of common risk/uncertainty map and development of HSRU framework.

## **Chapter 5: Duration Valuation Process**

To overcome the fundamental limitation regarding interpretation difficulty of dimensionless output, this research develops duration valuation process (DVP) providing logical and systematic assessment procedure of probability and impact and offering dimensional presentation of output in form of cumulative distribution of project duration. The developed DVP consists of four main processes: development of HSRU, assessment and transformation of probability, assessment and transformation of impact, and simulation by using Monte Carlo simulation. The assessment of probability in the DVP is implemented by using questions designed based on basic probability theory such as conditional probability and multiplication rule. Productivity concept, work breakdown structure and scheduling concept, and classification of delay (total delay, date delay and progress delay) are employed as basis in quantification of impact in terms of delay. This chapter provides explanation of DVP and its demonstration.

## **Chapter 6: Multi-party Risk and Uncertainty Management Process**

To overcome the fundamental limitation regarding insufficient involvement of multiple parties, this research attempts to improve the previously proposed MRMP by integrating multiple parties’ views. From the MRMP application, each party’s view for mutual

‘reference’ could be obtained. However, to obtain ‘reference’ is just the first step to manage risk in a project. To complete risk management, it is necessary to go through following processes: problem awareness from knowing reference, problem identification through communication among parties, and problem solving by integration of multiple parties’ views. Therefore, this research develops a prototype tool called multi-party risk and uncertainty management process (MRUMP) aiming to assist all parties in systematically and efficiently managing risks and uncertainties and encouraging all parties to communicate each other, identify problem, and cooperatively solve the problem. The MRUMP consists of five main systematic processes ranging from risk and uncertainty management planning, identification and structuring, assessment and analysis, response, and control processes. A number of systematic procedures and tools such as risk/uncertainty breakdown structure and uncertainty checklist are also provided in the MRUMP. The MRUMP is presented in form of implementing manual for application purpose. This chapter provides explanation of the MRUMP manual.

## **Chapter 7: Application of MRUMP**

The application of developed MRUMP is discussed in this chapter. The MRUMP has been applied to an infrastructure project financed by an international lender as a case study located in a Southeast Asian country. Purpose of application is to discuss its applicability and to draw lesson for further refinement. The application of this case study was scoped to early stage of construction and during construction of project. The executing agency, contractor and consultant involved in the project are focused. The top managements in project level of each party have been selected as assessors and their perceptions have been investigated.

From the MRUMP application assuming at the early stage of construction, by developing ‘integrated HSRU’ and ‘risk/uncertainty impact chart,’ based on all parties’ views, the difference of each party’s view could be aware.

From error analysis, assessor’s experience, knowledge, position, and biases resulting in ignorance of risks/uncertainties and over and underestimation of probability and impact

could be identified as causations and types of error associated with each source of error. Additionally, based on comparison between each party's perception with actual status, we realize that error may be mitigated by integrating all parties' views. This research simulates a meeting among all parties for risk/uncertainty communication and problem solving. From the simulation of meeting, it enables all parties to communicate and identify the future 'problem,' which may occur due to different in their views. Finally, with integration of all parties' views, they are likely to derive the possible and constructive solution, which they are satisfied as much as possible. .

Based on second timing of application, the preferable reactive and proactive responses perceived by each party could be derived. By classifying response scenarios as common and unique responses, not only solution for specific case but also lesson learnt for further improvement of whole implementation system could be obtained.

According to practitioners' comments on the MRUMP, they perceived its usefulness in using as communication tool, problem preventing and solving tool, and post evaluation of project.

## **Chapter 8: Conclusion and Recommendation**

This chapter provides conclusion regarding MRUMP development and application, its contributions and recommendations for future research.



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# Chapter 1

## Introduction

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### 1.1 Introduction

From this time forth, development of infrastructure projects is expected to play more significant role in economic development and advancement in developing countries. Many large projects are being implemented and in plan to be launched in near future. It is desirable for all parties directly involved in a project, i.e., policy maker, lender, executing agency, consultant and contractor, to effectively and efficiently implement the project. Since failure to achieve project goals and failure to efficiently execute the project probably affect not only parties directly involved in the project but also other stakeholders such as tax payers.

Problematically, many infrastructure projects in Southeast Asian countries still could not have achieved good project goals sufficiently. One of the most frequent failures is severe project delay. One of its major reasons is existence of common external and internal risks and uncertainties that are inherent in all stages of project i.e., from planning, bidding, contracting to construction stage.

Within project management context, this research defines the terms ‘risk’ and ‘uncertainty’ as follows. ‘Risk’ means the event/condition that its occurrence is identifiable and provides negative effect to project objective, probability distribution of outcome is quantifiable, and it is controllable by one party. ‘Uncertainty’ means the event/condition that its occurrence is unidentifiable and may provide positive or negative effect to project objective, probability distribution of outcome is unquantifiable, or it is uncontrollable by one party. (The extensive description of the definition and distinction between risk, uncertainty, and opportunity is provided in Chapter 2.)

In infrastructure projects, political and economical uncertainties are common ones in the

external category. Unreasonable project objectives (e.g., time and cost), delay in awarding and contracting, unfair contract conditions, incapable executing agency, late land acquisition, delay in contractor's mobilization, incapable and inexperienced contractor, financial problem of contractor, adversarial attitude, inefficient communication, cooperation and coordination, poor project and risk management, claim, conflict and dispute are those common source and consequential risks and uncertainties in the internal category.

To cope with these risks, several risk management processes (RMPs) have been developed by many researchers (Al-Bahar and Crandall 1990; Wideman 1992; Flanagan and Norman 1993; Duncan 1996; Kahkonen and Huovila 1996; Chapman and Ward 1997; ICE 1998; PMI 2000, and Pipattanapiwong and Watanabe 2000). Generally, conventional RMPs consist of three main processes i.e., risk identification, risk structuring and analysis, and risk response. As far as the scope and application of conventional RMPs are concerned, there are three fundamental limitations and a technical limitation that is necessary to be addressed.

## **1.2 Fundamental and Technical Limitations of Conventional RMP**

To identify the fundamental and technical limitations associated with conventional RMPs, it is based on lesson learnt from development and application of previously proposed multi-party risk management process (MRMP) (Pipattanapiwong and Watanabe 2000) (overview of MRMP development and application is available in Chapter 2) and further extensive literatures review. Associated with (M)RMP, fundamental limitations, which are related to catastrophic event as 'uncertainty,' output interpretation, and scope, and technical limitation, which is related to process, have been identified and briefly summarized here (extensive explanation is described in Chapter 3).

### **1. Fundamental limitations**

As far as we concern about the application of conventional RMPs, there are at least

three fundamental limitations i.e., inattention on uncertainty (catastrophic event), difficulty in interpretation of dimensionless output, and inattention on involvement of multiple parties.

Inattention on catastrophic event (which is ‘uncertainty’ event) is the first fundamental limitation. In risk prioritization, risk management is designed for the events that have high probability and high impact (Smith 1999). Conventional RMPs normally prioritize risk by calculating expected impact. This results in redundant risk events and tendency in overlooking a risk event with very low frequency of occurrence but extremely high impact (catastrophic event which is ‘uncertainty’ event). In many cases, we may not have enough necessary experience to properly deal with this type of uncertainty because of insufficiency, inaccuracy, and inapplicability of historical data, and bounded rationality of human in subjective assessment.

The second fundamental limitation is realized in interpreting the output of conventional RMPs. Since output of conventional RMPs is normally presented as map of dimensionless expected impact and variance of impact, it does not represent how much project is delayed. With this dimensionless representation, it is considered difficult to interpret the output and use in communication.

Third, the conventional RMPs do not put attention on involvement of multiple parties. Conflict or problem among multiple parties often arises due to different in their views. Since the conventional RMPs basically consider only single party’s view in its scope and application, we may not be able to complete the problem solving process starting from awareness and identification of problem to solving the problem. They do not encourage and provide opportunity for involved parties to communicate and build atmosphere of ‘harmony’ among project parties.

## **2. Technical limitations**

By considering technical issue of conventional RMPs, there is little established structuring and analysis procedure. As a result, this technical limitation increases

possibility of large margin of error associated with the expected impact and variance of impact map.

Regarding risk structuring process in conventional RMPs, ‘unorganized’ structuring diagram, which does not clearly separate cause and effect events in diagram, is often obtained as the output. With this messiness, it is difficult to be used in further analysis and communication. In addition, the ‘ad-hoc’ way of analysis is another issue associated with this technical limitation. Due to this illogical way of analysis, the assessment of probability of occurrence of an event that is caused by other events and its impact to project objectives may not be estimated logically. Consequently, the precision of analysis output is lowered.

As an initial step to challenge the third fundamental limitation of conventional RMPs, Pipattanapiwong and Watanabe (2000) developed the MRMP considering the importance of multi-party environment in infrastructure construction projects by incorporating all parties into its scope. Since in general infrastructure projects multiple parties are involved, it is important to be aware that each party may have different view towards risks and uncertainties, which can constitute ‘problem’ and conflict negatively influencing project goals. Based on the MRMP application, each party’s view could be obtained for mutual ‘reference’. However, the MRMP could complete only the step of problem awareness in entire problem solving process.

To obtain ‘reference’ is just the first step to manage risk in a project. To complete risk management, it is necessary to go through following processes: problem awareness from knowing what is different as reference, problem identification through communication among parties, and problem solving by integration of multiple parties’ views. The communication function is also an important step stipulated in problem solving process available in risk management manual proposed by FIDIC (FIDIC 1997), nevertheless, its explanation is very limited to only statements of importance in keeping communication. It does not provide how to communicate among parties and does not tell what information necessary in communication.

It is indispensable for all involved project parties to timely be aware of risks and uncertainties and efficiently communicate those perceived exposure of risks and uncertainties among all parties. Then, all parties' views should be integrated, and they should cooperatively prepare both proactive and reactive measures in responding those prospective risks and uncertainties. In order to accomplish these tasks, tool, which can facilitate and assist all project parties in logically, systematically and efficiently managing risks and uncertainties by encouraging efficient communication, cooperation, and coordination among all parties throughout project implementation in a multi-party environment, is necessary.

### **1.3 Research Objectives**

The ultimate goal of this research is to overcome those stated fundamental and technical limitations associated with conventional RMPs and MRMP. In order to achieve this goal, the following objectives are examined:

1. to develop a prototype tool called multi-party risk and uncertainty management process (MRUMP) integrating all parties' views in its scope and processes for
  - better treatment of 'uncertainty,'
  - higher precision of output,
  - representation of output in terms of day
  - facilitation of problem solving by integrating multiple parties' views, and
2. to apply the MRUMP to a real world infrastructure project as a case study for discussing its applicability.

Associated with the first objective, in order to overcome the fundamental limitation regarding inattention on 'uncertainty,' risk/uncertainty map is produced by accumulating experiences and lessons learnt related to risks and uncertainties occurred in past similar projects to be used as 'knowledge base' for reference. Aiming to increase precision of output, a structuring framework called hierarchical structure of risk and uncertainty (HSRU) is proposed to be used in developing "organized" risk and uncertainty structure and assessing probability and impact.

To overcome difficulty in interpretation of dimensionless output, duration valuation process (DVP) is developed by providing logical probability and impact assessment procedure and dimensional presentation of output in form of cumulative distribution of project duration. Regarding issue of inattention on involvement of multiple parties, the previously proposed MRMP is improved by not just only incorporating involved parties but also integrating their views.

After HSRU framework and DVP have been developed, they are assembled as main parts of the MRUMP. The MRUMP is considered as a logical, systematic and concise tool for assisting practitioners e.g., policy maker, lender, owner, consultant and contractor in systematically and efficiently managing risks and uncertainties and encouraging parties to communicate each other, identify problem, and cooperatively solve the problem under risk and uncertainty condition and multi-party environment. For the purpose of application, the MRUMP is presented in form of implementing manual.

The scope of risk and uncertainty management discussed in this research is bounded to construction project environment with traditional contracting. To discuss the scope of application clearly, this research divides project implementation of this type of project into three main stages i.e., pre-construction stage (planning, bidding, and contracting), early construction stage (during construction preparation and during starting project after project commencement), and during construction stage. In this application study, the application is scoped to early and during construction stages.

In MRUMP application, this research adopted case study approach, because the application can be comprehensively studied and feasibly manageable. An infrastructure project financed by an international lender in a Southeast Asian region was used as a case studied project. Three main parties involved in the project including executing agency, contractor, and consultant were focused as main players in the application study.

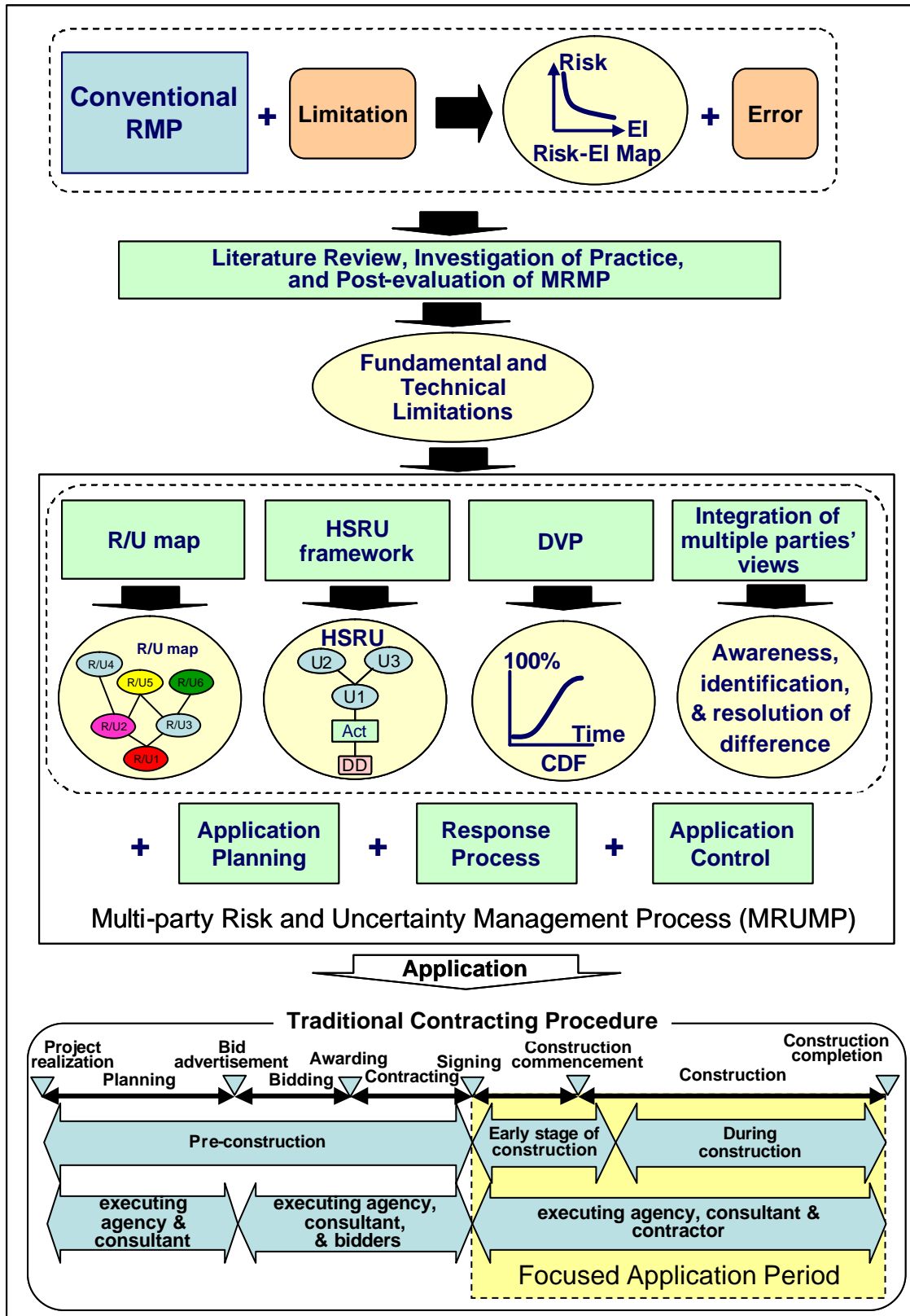


Figure 1.1: Research framework



By accomplishing these objectives within the boundary of research scope, the major premising deliverables of this research comprise of common risk/uncertainty map for an infrastructure project financed by an international lender, HSRU framework, DVP, MRUMP implementing manual, and lessons from real world practice of an infrastructure project financed by an international lender located in a Southeast Asian country.

Based on research objectives and scope, the framework of research is defined as shown in Figure 1.1.

## **1.4 Organization of Dissertation**

Based on methodological development of MRUMP, the contents of this dissertation are divided into eight chapters. The scope of each chapter along with phase of methodological development of MRUMP are presented in Figure 1.2 and briefly described as follows.

Chapter 1 provides general introduction and problem statement of infrastructure projects, definition of risk and uncertainty, research objectives, and organization of dissertation along with phase of methodological development of MRUMP.

The starting point of MRUMP development was originated from previous development and application of MRMP (Pipattanapiwong and Watanabe 2000). Then, further extensive risk management literatures were reviewed to identify the unsolved areas in risk management. Chapter 2 provides comprehensive understanding of risk management concept including general review of conventional RMP, overview of MRMP development and application, and summary of further review of risk management literatures.

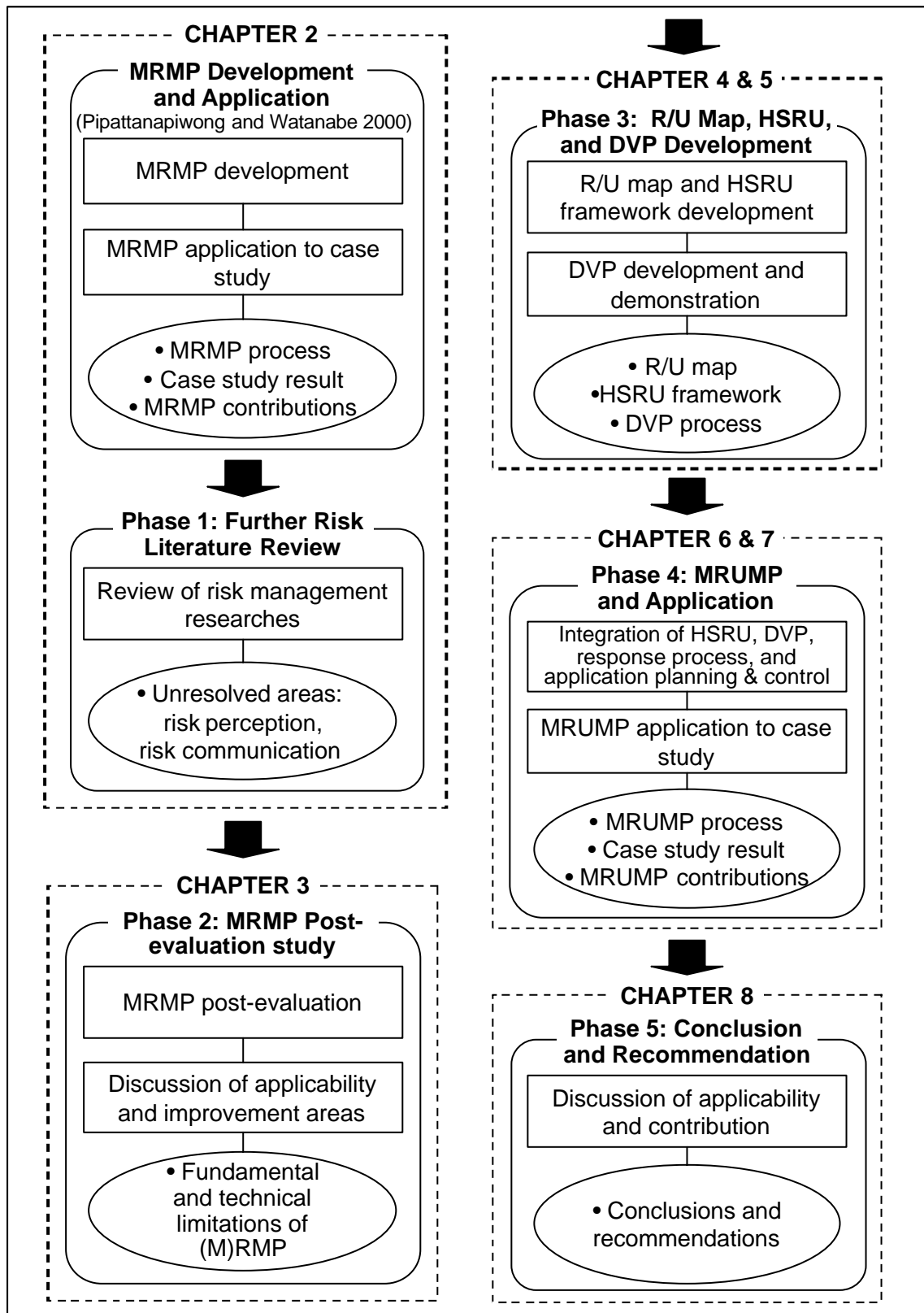


Figure 1.2: Organization of dissertation along with phase of methodological development of MRUMP

While the further literatures have been being reviewed, the post-evaluation study of the MRMP also was conducted aiming to discuss the applicability of MRMP and find improvement areas. According to these extensive risk literatures review and MRMP post-evaluation study, fundamental and technical limitation associated with (M)RMP could be identified. The discussion of the applicability of MRMP based on post-evaluation study and limitations associated with (M)RMP are provided in Chapter 3.

For better dealing with risks and uncertainties, the common risk/uncertainty map of infrastructure projects financed by international lenders, HSRU framework and DVP have been developed. Chapter 4 provides explanation of common risk/uncertainty map of infrastructure projects financed by international lenders and development of HSRU framework. Chapter 5 explains the development and procedure of DVP, and its demonstration.

Subsequently, in order to have complete and holistic view of application, the developed components were combined with response process, application planning process, and application control process to form the MRUMP. After the MRUMP has been developed, it was applied to a real infrastructure project to discuss its applicability. Chapter 6 provides the explanation of MRUMP implementing manual. Then, the application of developed MRUMP is presented and discussed in Chapter 7. Finally, conclusions and recommendations are provided in Chapter 8.

## **Chapter 2**

# **Reviews of Risk Management for Infrastructure Projects**

---

### **2.1 Introduction**

This chapter aims to provide the comprehensive reviews of risk management literatures mainly for an infrastructure construction project. The contents cover the general explanation of conventional risk management process (RMP), development and application of a previously proposed RMP called multi-party risk management process (MRMP) (Pipattanapiwong and Watanabe 2000), and unresolved areas on which the future research should put more attention.

### **2.2 Necessity of Risk Management**

Possible risks that are involved in construction environment include external risk such as economic risk, political risk, legal risk, weather risk, public risk, etc. and internal risk such as financial risk, contractual risk, construction design risk, technical risk, personal risk etc. The typical losses of these risks are generally relevant to project delay, project cost overrun, poor quality, loss of revenue, physical damage to project, physical harm to personnel, loss of reputation and business and so on (Papageorge 1988).

Thus, there is a considerable need to incorporate the risk management concepts into infrastructure construction practice in order to mitigate or eliminate risk consequence and enhance the performance of project.

Here, the risk management is examined in the context of project management. Initially, the clarification of terms of risk, uncertainty, and opportunity, definition of risk in various fields and characteristics and measurement of risk are described. The risk

identification, risk analysis and risk response in the risk management process are then explained, respectively.

## **2.3 Risk, Uncertainty, and Opportunity**

Oxford dictionary define terms ‘risk’ and ‘uncertainty’ as following (Hornby 1995): ‘Risk’ (noun) means 1) the possibility of meeting danger or of suffering harm or loss and 2) a person or thing that is a source of risk. ‘Uncertainty’ (noun) means 1) the state of being uncertain and 2) a thing that is uncertain or causes one to be uncertain. Whereas ‘uncertain’ (adjective) means 1) feeling doubt about something; not knowing something definitely; not sure, 2) not know definitely; that cannot be confidently predicted or described, 3) not to be depended on; unreliable, 4) likely to vary; tending to change frequently, and 5) not confident.

Risk is characterized by three components i.e. (1) *the risk event*: what might happen to the detriment or in favor of the project; (2) *the probability of occurrence*: the chance of the event occurring; and (3) *the potential loss/gain*: consequence of the event happening that can be specified as loss or gain. From the above characteristics, risk may be measured by multiplying probability of occurrence with its impact (Al-Bahar and Crandall 1990; Wideman 1992; and Raftery 1994). Careful attention should be put, however, in calculating expected value since measuring and ranking risks according to this calculated figure is sometimes misleading (Williams 1996). More detailed explanation of fallacy of expectation concept is available in later part of Chapter 3.

There are many researchers that define various definitions of risk. Al-Bahar (1990), Raftery (1994), Chapman (1997), Vaughan (1997), and PMI (2000) consider both down-side (loss) and up-side (gain) of risk. Niwa (1989), Chicken and Posner (1998), and APM (2000) consider only on the down-side of risk. Definitions that emphasize only down-side may not recognize the existence of opportunity.

Risk can be defined differently depending on fields. In insurance field, terms ‘risk’ is defined as follows: the chance of loss, possibility of loss, uncertainty, dispersion of

actual from expected results, and probability of any outcome different from the one expected.

In decision making, Flanagan and Norman (1993) stated that “a decision is made under risk when a decision maker can assess, either intuitively or rationally, the probability of a particular event occurring. By contrast, uncertainty might be defined as a situation in which there are no historic data or previous history relating to the situation being considered by the decision-maker.” With additional statement, the risky situation is the situation when the probability distribution functions of the potential outcomes are known. Uncertain situation is situation that the potential outcomes cannot be described in terms of objectively known nor subjectively known probability distribution (Haimes, 1998).

In project management context, Niwa (1989) and Wideman (1992) define project risk as the chance of certain occurrences adversely affecting project objectives. Considering definition defined by well-known organization in project management, Project Management Institute define terms project risk in PMBOK 2000 as “an uncertain event or condition that, if it occurs, has a positive or a negative effect on a project objective” (PMI 2000). In UK, Association for Project Management defines terms risk in its body of knowledge as “risks are those factors that may cause a failure to meet the project’s objectives” (APM 2000).

Normally, two variables i.e., probability of occurrence of an event and outcome including consequence (favorable or unfavorable) and its probability are keys for distinguishing between risk and uncertainty.

First, the probability of occurrence of an event is considered as the variable used to distinguish between risk and uncertainty. The uncertainty varies between certain, the case in which the probability of occurrence is 100%, and impossible, the case in which the probability of occurrence is 0%. From this viewpoint, the uncertainty exists when probability of occurrence of the event is not known (Jaafari 2001).

Second, the risk and uncertainty is distinguished by considering the knowledge of probability of outcome. In this distinction, risk exists when there is a range of possible outcome and the probability of outcome is known, whereas uncertainty exists when the probability of each outcome is not known (Smith 1999).

Third, uncertainty is realized when both the probability of occurrence of event and the consequence and probability of outcome are not known.

Considering the terms opportunity, the opportunity is realized when there is possibility that the outcome of event may turn to be favorable. This illustrates the distinction among uncertainty, risk and opportunity.

This research characterizes risk and uncertainty into three components i.e., 1) risk/uncertainty event, 2) probability of occurrence, and 3) outcome: potential loss/gain. Practically, the definition of risk and uncertainty are basically different based on 'position' of parties in project. Since this research considers the importance of integration of multiple parties' views in the scope, we also consider this issue in defining definition of risk and uncertainty here.

Based on risk components and 'position' of parties, this research grounds on three characteristics of event/condition including 1) identifiable/unidentifiable, 2) quantifiable/unquantifiable and 3) controllable/uncontrollable in defining the terms 'risk' and 'uncertainty.'

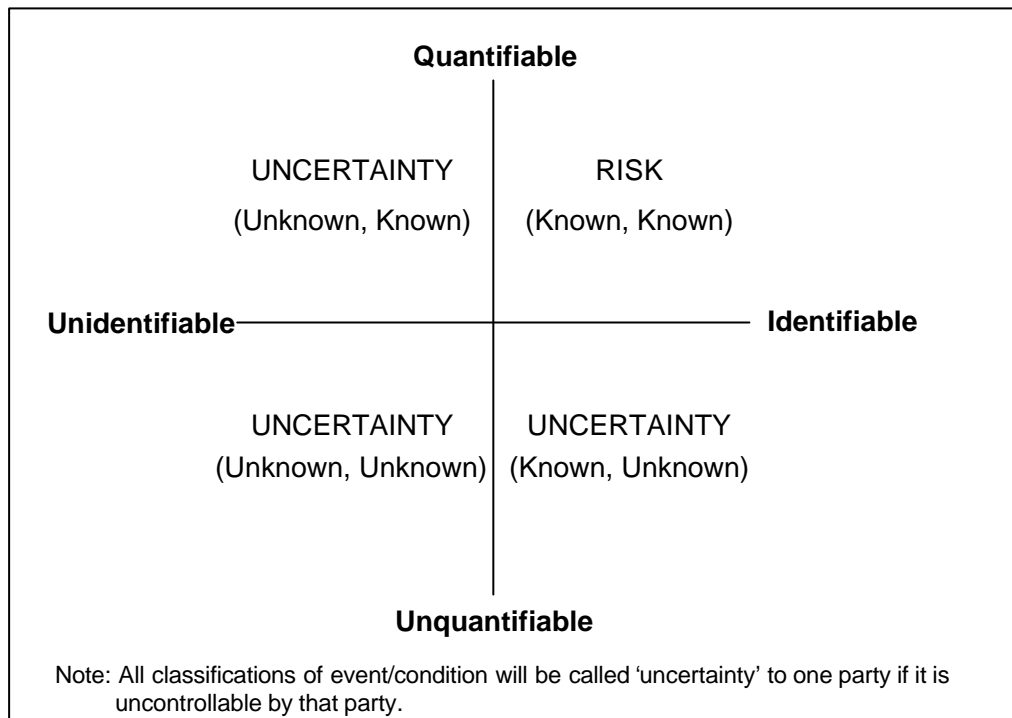


Figure 2.1: Classification of risk and uncertainty based on 'identifiable/unidentifiable' and 'quantifiable/unquantifiable' characteristics

First, 'identifiable/unidentifiable' characteristic means that whether the occurrence of event/condition can be perceived or not. Second, 'quantifiable/unquantifiable' characteristic means that whether the probability distribution associated with outcome of event/condition can be assigned or not. Third, 'controllable/uncontrollable' characteristic means that whether event/condition itself can be manipulated by one's decision and action or not.

Within project management context, this research defines the terms 'risk' and 'uncertainty' as followings.

'Risk' means the event/condition that its occurrence is identifiable and provides negative effect to project objective, probability distribution of its outcome is quantifiable, and it is controllable by one party. 'Uncertainty' means the event/condition that its occurrence is unidentifiable and may provide positive or negative effect to project objective, probability distribution of its outcome is unquantifiable, or it is uncontrollable by one party.



According to this definition, for example, if how many days of delay of an construction activity caused by an event and its probability of occurrence and outcome can be estimated or quantified, this event would be called risk event rather than uncertainty event to one party if that party can control that event. On the other hand, if that event is not controllable by that party, the event is considered as uncertainty event to that party regardless its identifiable and quantifiable characteristics. The chart in Figure 2.1 presents the classification of risk and uncertainty based on ‘indefinable/unidentifiable’ and ‘quantifiable/unquantifiable’ characteristics (assuming that the event/condition is controllable by one party).

We can observe from the chart that the classified ‘uncertainty’ event/condition has different degree of uncertainty according to the classification. The word ‘known’ and ‘unknown’ is often used to represent the ‘identifiable/unidentifiable’ and ‘quantifiable/unquantifiable’ characteristics of event/condition as shown in Figure 2.1. Occasionally, this research also uses this expression in later chapters.

## **2.4 Risk Management Process**

Every risk evolves through three main phases: the potential risk, the actual occurrence, and the impact as shown in Figure 2.2 (Papageorge 1988). Risk should be perceived and treated early since risk will be probably developed to the last phase of its potential loss or harm.

Based on Figure 2.2, this research considers that the management of risk is not only proactive but it can be the reactive approach to manage risk when it is already occurred. Moreover, the risk management can be viewed as not only problem preventing tool but also problem solving tool.

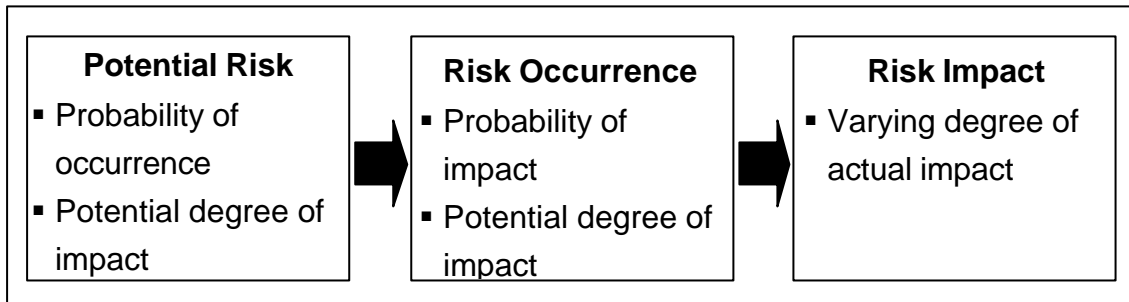


Figure 2.2: Phase of risk

There are two basic approaches to manage risks: informal and formal approaches (Smith 1999). The informal risk management approach views risks in a subjective manner. For example, to subjectively determine the contingency either in percentage or lump sum is considered a risk management technique of informal approach. Using solely the rule of thumb and intuition to deal with risk may not be sufficient. Thus, the risk management process (RMP) is introduced to assist a decision maker to better deal with the risk, although it does not totally replace the informal approaches. APM (2000) asserts that the project risk management is recognized as formal approach that opposes to an intuitive approach. RMP attempts to facilitate and utilize the decision maker's intuition and experience in a more systematic and effective way as its processes are systematic, rational, logical, preventive and priority based on significant risk (Al-Bahar and Crandall 1990 and Smith 1999).

The RMP has been discussed by various researchers in different contexts such as general context (Chicken 1996 and Vaughan 1997), project context (Wideman 1992; Duncan 1996; Chapman and Ward 1997; ICE 1998, PMI 2000; and APM 2000) and construction context (Al-Bahar and Crandall 1990; Flanagan and Norman 1993 and Smith 1999).

Generally, the RMP is described as a systematic approach to deal with risk. The RMP should establish an appropriate context; set goals and objectives; identify and analyze risks; and review risk responses. In project context, the project risk management is the art and science of identifying, assessing and responding to project risk throughout the life cycle of a project and in the best interests of its objectives (Wideman 1992). As described in PMBOK 2000 edition, risk management is defined as "the systematic

process of identifying, analyzing, and responding to project risk” (PMI 2000).

Regarding the processes in RMP, for example, PMI (2000) proposes six major processes in for risk management i.e., risk management planning, risk identification, qualitative risk analysis, quantitative risk analysis, risk response planning, and risk monitoring and control. Although detail of each conventional RMP (Al-Bahar 1990; Flanagan and Norman 1993; Kahkonen 1996; Chapman 1997; ICE 1998; and PMI 2000) is different in term of scope and number of processes, generally, they can be divided into three main processes i.e. risk identification, risk analysis and risk response. The descriptions of these three main processes are discussed in the following sections, respectively.

### **2.4.1 Risk Identification Process**

Risk identification is the process of systematically and continuously identifying, categorizing, and assessing the initial significance of risks associated with a construction project (Al-Bahar and Crandall 1990). The sources and type of risks are identified. Risk identification is ideally carried out during the appraisal of the project, although it can be carried out at any stage of the project (Smith 1999). Risk identification should be performed on a regular basis throughout the project (Duncan 1996). The inputs of risk identification process include the project objective, risk management scope and plan and historical data related to project. The project related document, project participants and events occurring in the scope of project are some sources of information used to identify risk (Aleshin 2001). It is desirable to identify risk based on the determined objectives, which are generally related to time, cost and quality aspects.

There are several tools i.e. questionnaire, risk checklist, expert system and techniques i.e. interviews, orientation, analysis of documents, inspection, and observation, which are used for identifying risk (Vaughan 1997). Additionally, checklists, assumptions analysis, and diagramming techniques can be used as tools and techniques in risk identification (PMI 2000).

The desirable output of risk identification is the identified risks involved with the project or determined objectives. These identified risks may be classified based on the sources of risks as following classification: dynamic or static, pure or speculative, and fundamental or particular (Vaughan 1997). The information related to identified risk can be recorded in forms of risk category summary sheet (Al-Bahar and Crandall 1990) or risk log (risk register) (Smith 1999) or risk standard data card (Aleshin 2001). By using these tools risk information are kept in the form of database.

### **2.4.2 Risk Analysis Process**

Risk analysis process is the vital link between systematic identification of risks and rational management of the significant risks. The risk analysis process aims to evaluate the consequences associated with risks and to assess the impact of risk by using risk analysis and measurement techniques (Flanagan and Norman 1993).

The main input to risk analysis process is the identified risks from risk identification process. The probability and impact of identified risks are two key variables in assessing the risk. In assessment of risk, there are two general types: qualitative and quantitative risk assessment (Flanagan and Norman 1993 and Smith 1999). A typical qualitative risk assessment usually includes the following issues:

- a brief description of the risk;
- the stages of the project when risk may occur;
- the elements of the project that could be affected;
- the factors that influence risk to occur;
- the relationship with other risks;
- the likelihood of risk occurring; and
- how risk could affect the project.

The direct judgment, ranking options, comparing options and descriptive analysis are also considered as the qualitative risk measurement (Flanagan and Norman 1993).

For quantitative risk assessment, probability analysis sensitivity analysis scenario analysis, simulation analysis, correlation analysis, portfolio theory, delphi method, influence diagrams, decision trees, are lists of available techniques (Flanagan and Norman 1993 and Smith 1999).

The ultimate deliverables of risk analysis process are probability of occurrence and impact level of risks. Figure 2.3 presents the conceptual flow diagram to quantify the probability of risk. Based on diagram in Figure 2.3, the proper way to quantify probability of risk (objective or subjective) depends on the recurring condition of project risks. Practically, the historical data that is necessary for conducting objective analysis is not available. Moreover, available historical data from past projects may not be applicable for currently analyzed project, since the project characteristic and environment are unique. In this case, it is inevitable to adopt subjective analysis, when we quantify the probability of occurrence. This issue is further explained in Chapter 3.

For the impact of risk, possible consequences of risk are defined and quantified in terms of (Smith 1999):

- increased cost: i.e. additional cost above the estimate of the final cost of the project;
- increased time: i.e. additional time beyond the completion date of the project through delays in construction;
- reduced quality and performance: i.e. the extent to which the project would fail to meet the user performance based on quality, standards and specification.

In conventional RMPs, after we quantify probability of occurrence and impact of risk, we will map these quantified probability and impact in probability-impact grid (Figure 2.4). By using this grid, we can obtain priority of risk that high probability and high impact will be considered high priority. This is how conventional RMP prioritize risk. This research does not totally agree with this way of prioritization, because they may overlook the importance of low probability and high impact risk. This research considers this as a source of error of conventional RMPs. More detailed explanation is available in Chapter 3.

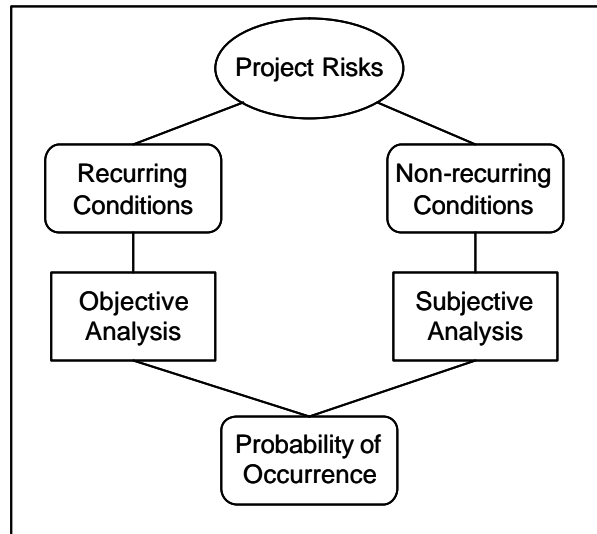


Figure 2.3: Quantification of probability

<b>IMPACT</b>	High	M	H	H	<div>H</div> High priority
	Medium	L	M	H	
	Low	L	L	M	
		Low	Medium	High	
<b>PROBABILITY</b>					

Figure 2.4: Probability-impact grid

### 2.4.3 Risk Response Process

Risk response process aims to provide the efficient response to the identified and analyzed risks. In risk response process, the decision maker considers how the risk should be managed, for examples, by transferring it to another party or retaining it (Flanagan and Norman 1993).

Response is an action or activity that is implemented to deal with a specific risk or combination of risks. Risk responses can be categorized into four different forms:

acceptance, reduction, avoidance and transfer (Flanagan and Norman 1993 and Vaughan 1997). All these risk response form are described in the following sections.

### **(1) Risk acceptance**

Risk acceptance or risk retention is the most common method to dealing with risk. Parties facing risks will not take any action to encounter with those risks if they employ this technique. When any risk response techniques including avoidance, reduction or transfer are not employed, the possibility of losses involved in that risk is retained.

The adoption of risk acceptance may be conscious or unconscious, as well as voluntary or involuntary. Conscious risk retention takes place when the risk is perceived and not transferred or reduced. On the other hand, when risk is not recognized, unconscious risk is retained. For voluntary risk, when risk is recognized implicit agreement to assume the losses is involved. Voluntary risk is retained because there are no alternatives more attractive. Risk is involuntarily retained when it is unconscious risk and also it cannot be avoided, transferred, or reduced.

Every party must decide which risks to retain and which to avoid or transfer on the basis of its margin for contingencies or ability to bear the loss. Generally, risks, which relate to small losses, should be retained.

Carter and Dohery (1974) described two retention methods, active and passive. Active retention sometimes is referred to as self-insurance, is a deliberate management strategy after a conscious evaluation of the possible losses and costs of alternative ways of handling risks. Second, passive retention, which sometimes is called non-insurance, occurs through neglect, ignorance or absence of decision. Flanagan and Norman (1993) stated that risks suitable for retention are those that occur frequently but have small losses.

### **(2) Risk reduction**

Risk may be reduced through loss prevention and control. Loss prevention attempts to deal with risk by preventing the loss or reducing the chance that it will occur. For

control techniques, the purpose is to control the severity of the loss if it does happen such as sprinkler systems. In some points of view, this technique is a desirable means to deal with risk. The risk would also be eliminated, if the possibility of loss could be completely eliminated. However, loss prevention can be considered insufficient to deal with risk, because it is impossible to prevent all losses and the cost of implementation loss prevention technique may be expensive than the losses themselves. An example of loss prevention is safety program or medical care. Baker, Ponniah, and Smith (1999) also added examples of risk reduction such as physical devices that can be improved by continually maintaining and updating the devices, which help prevent loss. Education and training within every department of a business are important, especially in reducing the harmful effects of risks within the working environment.

### **(3) Risk avoidance**

Avoidance is one method of dealing with risk. When an organization or parties or individual refuse to accept risk, then risk is avoided. This means the exposure of risk is not allowed to exist. For instance, if contractors want to avoid the risk associated with the ownership of some equipment, do not purchase this equipment but lease or rent it instead. If risk avoidance is used extensively, the opportunity to receive profit or achieve objectives may be decreased. A contractor not placing a bid or the owner not proceeding with project funding are two examples of eliminating risk totally. There are a number of ways through which risks can be avoided, for examples, tendering a very high bid, placing conditions on the bid, pre-contract negotiations as to which party takes certain risks, and not bidding on the high-risk portion of the contract (Baker, Ponniah, and Smith 1999).

### **(4) Risk transfer**

Risk may be transferred from one individual to a party who is willing to bear the risk. For speculative and pure risk, transfer may be applied. The process of hedging is an excellent example of the use of the transfer technique for dealing with speculative risks. Pure risks are often transferred through contracts. In construction practice, contractual transfers of risk are quite common. In addition, insurance is also a way of transferring risk. The normal concept of insurance is that a party offers specific payment (the



premium) for consideration, the second party contracts to indemnify the first party up to certain limit for the specified loss that may occur.

In addition, risk transfer can take two basic forms (Thompson and Perry 1992): (1) the property or activity responsible for the risk may be transferred, i.e. hire a subcontractor to work on a hazardous process; or (2) the property or activity may be retained, but the financial risk transferred, i.e. methods such as insurance. There are other ways of using insurance as a means of transferring the risk, for example, through risk sharing or establishing a captive insurance company. In risk sharing, transfer and retention are combined. When risks are shared, the possibility of loss is transferred from the individual to the group. When the risks are shared in the group, each member has to retain the risk that the other members in the group transferred.

Additionally, it is also useful to consider the timing of the response rather than being concerned too much about the type of response, which is whether the response is to be implemented before (proactive) or after (reactive) the risk occurrence.

## **2.5 Risk Efficiency Concept**

To find efficient responses is the key in the conventional RMP. It is important to understand how to move from a risky response to a less risky response and at the same time understand how to reduce the expected impact. Theoretically, the efficient response provides a minimum level of risk for a given level of impact and a minimum level of impact for a given level of risk as shown in the risk efficiency boundary in Figure 2.5 (Chapman and Ward 1997).

When a specific risk occurred, the possible responses are listed up and evaluated to find the efficient response. This efficient response is the final output of the risk response process. Additionally, other desirable output can be a risk management plan.

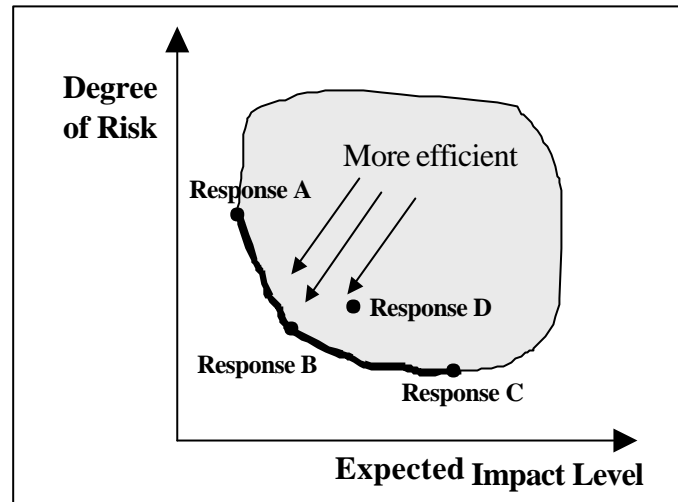


Figure 2.5: Risk efficiency concept

## 2.6 Risk Allocation

In the past, the cause of escalating cost in underground construction projects in US was identified as misallocation of risks. For major underground construction projects, risks are especially high because of incomplete knowledge of site geology and the possibility of unforeseen underground conditions. In US public and private construction projects, risks are enormously transferred from client to others parties i.e., contractors, designers, and consultants (Levitt and Ashley 1980).

Notably, one-sided attitude regarding risk allocation, which one party tries to dispatch all risks to other parties, probably result in unfavorable effect to both transferees and transfer him/herself.

Traditionally, in construction project, owners seek to pass most of all risks to the contractors. Another practice is that the architect/engineer would design a structure in its finished condition, and if any thought was given to the construction problems that might be involved in building it, considerable care was taken not to express their opinions on these matters in the contract documents. Risks themselves are not transferred. Actually, they transfer the responsibility of those risks. This one-sided attitude towards transferring risks foster parties who are imposed by the risks practically through contract to defend with some defensive strategies including (Levitt and Ashley 1980):

1. imposing contingency charges (either explicitly or in inflated unit prices),
2. adopting conservative approaches to construction design and construction methods,
3. refusing to utilize design alternatives involving new technology because of potential liabilities arising from undue cost or failure to perform, and
4. resorting to litigation or arbitration for any possible type of dispute, whether warranted or not.

Levitt and Ashley (1980) stated that allocation of construction risks between owners and their contractors has a significant impact on the total construction costs paid by owners. The owner may have to pay twice for risks, which the owner thought he/she already transferred to other parties mainly contractors. Because when the owner lost in court, the court will reallocate those risks to the owner. Eventually, the owner has to pay for his/her risks, whereas the contractors also are not making profit.

Up to this line, the past practice of risk allocation particularly in US is already addressed. Desirably, the importance of risk allocation should be recognized since unfair and misallocation of several inherent risks in construction contract inevitably affect all project parties most probably client, contractors, and consultant. In construction contracting practice, inappropriate risk allocation in contract has been still occurring. For example, unfair bid document causing unequal risk sharing is a typical problem in construction projects financed by the World Bank (Godavitarne 1995).

Inappropriate risk allocation, consequently, in this circumstance, all involved parties will suffer (Fisk 1997). Figure 2.6 describes the problematic issues related to risk allocation in contract along with bidding, contracting and construction processes.

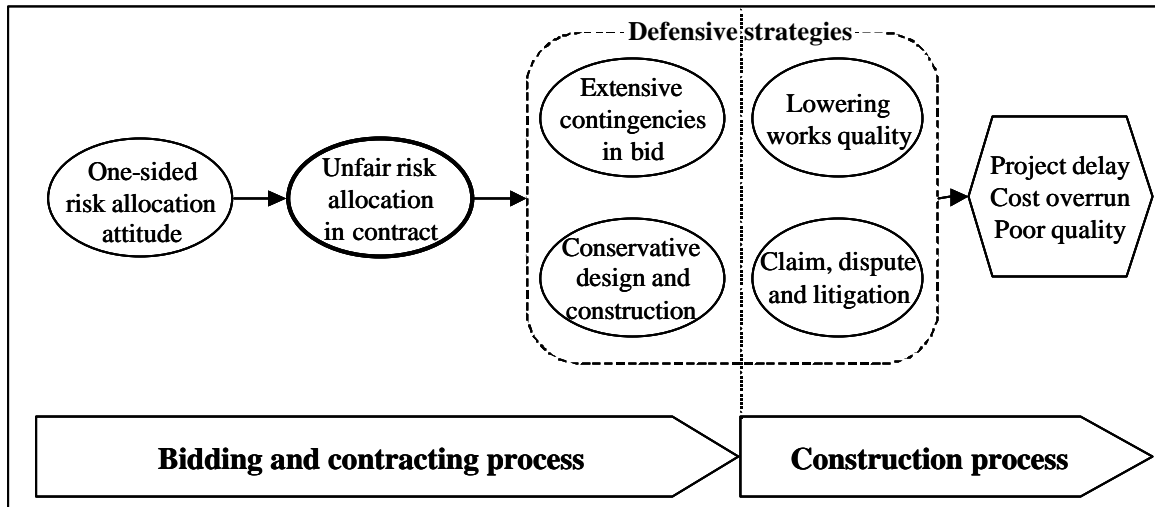


Figure 2.6 Problematic risk allocation diagram

In 1998, the Hong Kong government launched commission on reviewing the General Conditions of Contract (GCC) regarding allocation and management of risk in the procurement and construction. The purpose of the review was to enable the owner to make policy decisions on specific issues, and to facilitate a revision of the procedures and the GCCs, if necessary. The Hong Kong government assigned a famous lawyer, Jeese B Grove, to review its general conditions of contract for construction works (Loyd 2001).

This move illustrated that the importance of contract conditions concerning risk allocation has been recently realized. Basically, the principal means practically used for contractual allocation or reallocation of risks is the construction contract (Fisk 1997). It is important that the contract clauses allocating the risk are clear and unambiguous. The meaning the owner wishes to convey should be what the contractor interprets (Hartman and Snelgrove 1996). If owner and contractor lack clear understanding of risk allocation, the contractor will assume that the risk events or consequences are not contractor's responsibilities. Then, the risks may not be managed properly by contractor (Wang and Chou 2003).

The issue of risk allocation is tightly linked with how contents of construction contract are drafted. Therefore, appropriate balancing and allocating of risks through the contract

is necessarily required.

## **2.7 Practice of Risk Allocation**

In practice, many owners usually search for the way to dispatch most of risks to contractors. For instance, it is often indicated in the invitations to tender that the contractor is to ensure that the contract price should include all manner of risks. In reality, it is considerably very difficult. Unforeseen ground conditions, unknown utilities, and inclement weather are examples of typical construction risks facing problems regarding inappropriate risk allocation in contract occurring in practice (Macdonald 2001).

This section aims to disclose the practice of risk allocation in some countries by using examples of unforeseen ground conditions risk and utilities risk. The following explanation reveals the practice of allocating unforeseen ground condition and utility risks in some countries as examples based on previous literatures.

### **(1) Unforeseen ground conditions risk**

In infrastructure construction project, the unforeseen or unforeseeable effect of both physical conditions and artificial obstructions could result a devastating and dramatic impact on project progress and cost. At the design stage, it is impossible to do sufficient investigation of large infrastructure construction project sites to evaluate the possibility or probability of unforeseen circumstances (Elsden 2001). The contractor can only price these risks if he is given access to the relevant information that will allow him to assess potential impact of risks.

Moreover, parties who hold information such as geotechnical reports, services/utilities details, etc. will even deny the contractor to access this information. Because these parties consider that the contractor may later take action against them due to the misleading or inaccurate information. Within this case, if these parties wish to retain the knowledge of ground conditions they should also retain ownership of the risk and provide for an appropriate contingency in the stated cost of the project. On the other

hand, if the contractor is required to assume the risk, all information must be made available to ensure that the contractor is given every opportunity to assess the risk (Macdonald 2001).

Regarding Hong Kong case, according to Mr. Grove's report, since Hong Kong government does not follow international practice in this respect, the government was recommended to accept that risk and costs of unforeseen ground conditions risk. However, the Hong Kong government has rejected by the reasons that from past 30 years current practice had proved to be successful. The government also claimed that if the government accepts the risk, more contractual disputes are expected to occur and final project cost are likely to be higher. Nonetheless, the government tried to provide some solutions. Procedures to reduce the exposure of unforeseen ground conditions risk is introduced as a solution. It is to ensure that the design of every major project is reviewed by a panel of senior officials within the relevant department. A minimum amount (2 percent of the value of the works) will be specified for site investigation prior to tenders being sought. And all information will be made available to bidders including assumptions that had been made by the architect or engineer (Lloyd 2001).

## **(2) Utility risk**

Another example is practice of allocating utility risk. The interference from utilities apparatus has much greater significance in particularly infrastructure construction project than other types of project such as building. The utility risk caused by interference from existing or future utility apparatus is largely outside the control of the contractor and also this risk is not insurable.

In UK practice, the owner usually pays the utility agencies to undertake the diversions. If the contractors need temporary diversions, to accommodate their temporary works for example, then the contractors have to arrange with the utility agencies and pay for the diversion. If the utility apparatus is not in the location shown, or if additional utility apparatus appear, then there is a clause specified in the contract for contractor to claim for time and cost. In US practice, costs of necessary moves of existing utility apparatus will be paid by the owner. Moreover, the owner is liable to the contractor for time and

cost arising out of delays by the utility agencies (Elsdent 2001).

In case of Japan, most of risks regarding the existing utilities during construction of public works are principley taken by the owner. The contractor is not required to take such risks. The reasons why such risks are taken by the government are related to the characteristics of the contract ordering system and the general concept of public works contracts in Japan, the history of underground railways construction, laws, and regulation. The General Accounting Act was enacted in 1889 based on the concept that *everything should be strictly led by public agencies* (Ichikawa 2001).

The Japanese public agencies consider that such important utilities, which have been provided, charged and administered by them through the long history, should not be left entirely to be handled by private entitites i.e., contractors. This seems like a matter of pride. The Japanese public agencies also percieved that it is their responsibilities for removing disturbance to daily lives of citizens during construction. Furthermore, most utility agencies are not positive in dealing with matters associated with their utilities directly with contractors. As a result a clause written as “responsibility for unforeseeable conditions to be entirely assumed by the Employer” is stated in the Standard General Conditions for Public Works provided by the Central Government (Ichikawa 2001).

On the other hand, the practice in Hong Kong is different. The contractor has to be responsible for utility risk. Associated with this practice, the Hong Kong government is recommended to follow other practice such as in US and UK. The utility apparatus and its schedule should be specified in tender documents. Changes from the tender information and interference from unscheduled utility appratus is a risk that should be borne by the government (Elsdent 2001).

Table 2.1 shows the typical flow for dealing with utilities for construction of underground railway station in Tokyo, Japan (Ichikawa 2001).

Some remarks could be noted from the practice related to allocation of risk. According

to literatures reviewed in this chapter, practices in allocating particular risks are different based on countries i.e., US, UK, Japan and Hong Kong. Especially, with the Hong Kong case, it illustrates the difficulty in proving the appropriate allocation of risk in contract, when contract condition is reedited. The concept or model used for validating such contract conditions may be necessary in order to convince all contractual parties with the most efficient and desirable contract conditions.

Next sections explain the principle of risk allocation and previous risk allocation approaches proposed by preceding researchers.

Table 2.1: Practice of utility related works in Japan

<b>ITEM</b>	<b>WHO DOES</b>	<b>WHO PAYS</b>
1) Establish plan for utility investigation based on utility arrangement drawings (plan) provided and supplied by public road administration department of relevant authority	Contractor	Employer
2) Utility investigation	Contractor	Employer
3) Establish plan on how utilities to be dealt with - Diversion of obstacles/utilities - Temporary support for utilities during construction	Contractor	Employer
4) Consultation and agreement on how utilities to be dealt with between relevant utility undertakers, owners and/or public road administration departments	Employer (with cooperation by contractor)	Employer
5) Execution of utility treatment works - Utility diversions	- Excavation and backfill by contractor - Diversion by - Electricity, telecommunications, gas, water by specialist nominated by relevant utility agencies - Sewer by contractor	Employer
6) Temporary support for utilities during construction	Contractor	Employer



## 2.8 Principle of Risk Allocation

Construction risks are no longer to be conveniently transferred around. As explained in previous sections, for example, in case of ground condition risk, which owners most probably transfer to contractors as a matter of their policies, it is considered not an efficient and effective way of managing and allocating risk (Marriott 2001). Because it could adversely affect all project parties consequently.

In several literatures related to risk allocation, the authors would inevitably describe the common principle that “the risks in a project should be apportioned to those project parties who can best manage them” (Macdonald 2001), though, this principle is too conceptual.

The following described principle for risk allocation in construction is the very first proposed principle (Abrahamsan 1973), which has been discussed and referred by many successive researchers. The contracting party should bear the risk in any one of the following five cases:

1. if the risk is of loss due to his/her own willful misconduct or lack of reasonable efficiency or care,
2. if he can cover a risk by insurance and allow for the premium in settling his charges, and it is most convenient and practicable for the risk to be dealt with in this way,
3. if the preponderant economic benefit of running the risk accrues to him,
4. if it is in the interests of efficiency to place the risk on him,
5. if, when the risk eventuates, the loss happens to fall on him in the first instance, and there is no reason under any of the above headings to transfer the loss to another, or it is impracticable to do so.

Whereas this principle was widely supported to be a useful first step in discussing the issue of risk allocation, this stated principle still does not provide the complete solution (Ward 1991). It does not provide the guidelines as to how economic benefits (rewards) and risks ought to be matched. It just recognizes that these two terms should be matched.

It is ambiguous regarding the interest of efficiency (with respect to which party? and what objectives?) described in the fourth guideline. This principle ignores the pricing of risks and the differing risk attitudes of contractual parties. These guidelines provide a little assistance in allocating risks, which are uncontrollable and controllable by more than one party. In brief, this principle presupposes or assumes an atmosphere of trust between contracting parties, and a clear, mutual appreciation of all relevant project risks and their effects. In case either of these two conditions could not be met, the appropriate allocation of risks is often diverted to the investigation and clarification of the effectiveness of allocation mechanism such as through conditions in contract (Ward 1991).

Strauss (1979) discussed against the general principles of risk allocation that there are some risks that should be assumed by a solely perspective party. The risks that should be fully assigned to owner are as: site access and necessary right-of-way, accurate determination of quantities of work, changes initiated by the owner, unforeseeable and undisclosed conditions, unreasonable delay of earned progress payments, major catastrophes including flood and earthquakes. For the contractors, they should be fully responsible for the risks including: availability and costs of labor, materials, and equipment, timely completion, subcontractor and supplier failure, productivity of labor and equipment, construction mistakes and defective work, compliance with safety regulations, traffic maintenance as specified.

In addition to above principle, guidelines described by another researcher (Fisk 1997) that should be recognized as criteria used for sharing of risks inherent in a construction project are described as:

1. All risks are rightfully those of the owner unless and until contractually transferred to or assumed by the contractor or insurance underwriter for a fair compensation.
2. The principal guideline for transferring a risk is whether the receiving party has both the competence to assess the risk fairly and the expertise necessary to control or minimize it.

3. An additional guideline is the determination of whether the shift of the risk from the owner to another party will result in savings to the owner and the public.

In March 1998, Mr. Grove was asked by the Hong Kong Government to review the general conditions of contract for construction works. The following subjects in the conditions of contract were considered: ground conditions, physical impossibility, care of the works, delay caused by public utility works, fee and charges, new legislation, payments to sub-contractors and time bar provision in relation to claims. Mr. Grove identified the following common considerations related to risks allocation (Lloyd 2001).

- Which party can best control the events that may lead to the risk occurring?
- Which party can best manage the risk if it occurs?
- Whether or not it is preferable for the employer to retain and involvement in the management of the risk.
- Which party should carry the risk if it cannot be controlled?
- Whether the premium charged by the transferee is likely to be reasonable and acceptable.
- Whether the transferee is likely to be able to sustain the consequences if the risk occurs.
- Whether, if the risk is transferred, it leads to the possibility of risks of different nature being transferred back to the employer.

Mr. Grove thought that if these considerations were applied it should be possible to achieve clear and realistic terms that were acceptable to the owner and contractors. Thus, contractors would prepare tender of which the tender prices did not contain contingencies for unclear terms or for significant risks, which were not possible to estimate with some clarity or which were unlikely to materialize.

Hartman and Snelgrove (1996) also stated that it is important that the contract clause allocating the risk be clear and unambiguous. The meaning the owner wishes to convey should be what the contractor interprets. Therefore, a balancing of the risk should be sought amongst owner, contractors, and other parties in order to utilize the incentive

value of bearing a risk while minimizing the contingency charged for accepting the risk. There will be a particular allocation of risk between these parties, which will be optimum in terms of final project cost to an owner. Again these guidelines can be useful for initially allocating a risk; however, more detail of evaluation is required. It is with expectation of this research that the proposed risk and uncertainty management tool can be used as a means for risk allocation during contract formation.

## **2.9 Risk Allocation Approach**

Normally, owners allocate risks through contract clauses (in bid document) before contract is awarded to contractor. Contractor cannot influence how owner allocate risks through these clauses. Therefore, contractor needs to understand his responsibility of risks in contract (Wang and Chou 2003). Based on the conceptual principle on risk allocation, several approaches to risk allocation have been proposed. Since it is necessary to balance the risks among project parties actually occurring in practice and to eliminate the problems induced from misallocation of risk in construction. Theoretically, the approaches to allocate the risk can be classified into two main approaches i.e. qualitative and quantitative approaches (Yamaguchi 2001). The quantitative approaches objectively focus on quantification of magnitude of the allocated risks, which is the main difference and extension from the qualitative approaches.

### **2.9.1 Qualitative Approach**

A common qualitative approach is considered as standardized form of contract, which specify the obligation of contractual parties and some relief such as time extension for the party bearing the risk associated with the that obligations. Ashley (1977, cited by Yamaguchi et al. 2001) stated that the standardized form of contract provides a framework of risk allocation by a government owner based on the principle that each risk element should be distributed so that the total effect on the total expected cost is minimized (Yamaguchi 2001).

Commonly, risk allocation matrix is an output resulting from the development of

qualitative approach. The risk allocation matrix basically attempts to identify what type of risk is allocated to whom. Several studies (Erikson 1980; Kangari 1995; Snelgrove 1994, cited by Yamaguchi 2001) conducted the study to investigate the preference of involved project parties regarding the issue of who bears what construction risks in most commonly used delivery methods (Yamaguchi 2001).

Table 2.2: Risk allocation matrix

Type of Risk	Contractor	Owner	Consultant	Comments
<b>External Risks</b>				
Economic Disasters		♦		
Inflation	♦	♦		Sharing of escalation risk should be limited to 12 to 18 month span
Codes and Regulations		♦		
Weather	♦			Unusual inclement weather is the client's responsibility
<b>Internal Risks</b>				
Site Access		♦		
Subsurface Conditions		♦		Can be transferred to the contractor; however, client has obligation to undertake pre-contract exploration measures, and the designer has the responsibility to design for the conditions expected.
Quantity Variations	♦	♦		Contractor can be expected to assume risk up to 15 to 25 percent. Where quantities are dependent upon unforeseen subsurface conditions, client must assume the risk.
Financial Failure	♦	♦	♦	
Accidents at Site	♦			
Defective Works	♦			
Management Incompetence	♦	♦	♦	
Funding		♦		
Materials and Equipment	♦			
Labor Problems	♦			
Client-Furnished Equipment		♦		
Delays in the Work	♦	♦	♦	Usually the contractor's risk; however, client could incur some liability.
Defective Design			♦	

In addition, a research proposed the matrix presents the principal risk bearers in several types of procurement systems such as traditional, design and build, construction management, etc.,. Also, a graphical model was proposed to determine apportion of risk among project parties by percentage (Kumaraswamy 1997). Table 2.2 shows an

example of risk allocation matrix (Fisk 1997). This risk allocation matrix has been slightly modified from original source by reorganizing types of risk into two categories i.e., external and internal risks. The risk allocation matrix could be used for primary assisting in allocating risks to project parties. It should be noted that there is no fixed rule to allocate the risk to only one party; however, as shown in the table some risks could be shared.

## **2.9.2 Quantitative Approach**

However, the qualitative approaches are limited in addressing issues as to what extent the parties share risks and how to rank possible strategies of risk allocation according to their impact on cost, efficiency and satisfaction (Levitt and Ashley 1980). The quantitative approaches to risk allocation have been developed to overcome the limitation of qualitative approaches especially the issue of how much risk should be borne by each party. Most of quantitative approaches discussed their risk allocation model based on the optimality of allocating the risk. The quantitative approaches could be classified into two different concepts of optimality: cooperative and competitive risk allocation considering the different aims and views.

Cooperative risk allocation assumes that the stakeholders jointly search for an agreement that is mutually acceptable. Most cooperative risk allocation defined the optimum solution as where the total contingency costs of the project are minimized. Decision theory, computer simulation and cooperative game theory are examples of concept used in developing cooperative model. On the other hand, the competitive risk allocation is the allocation where each of the stakeholders employs the strategy that best achieve their own goals without any concern for the other stakeholders (Yamguchi 2001). The insurance theory for example is the concept, which the competitive risk allocation was relied on.

Another model considered that actual risk allocation is relied on the combination of cooperative and competitive allocation of risks. It means the solutions provide room for negotiation. The potential solutions together constitute the negotiation space. This

model linked the risk allocation in contract to insurance theory. Development of this model focused on the costs during construction and the profit during operation and maintenance in PFI project. This model shows theoretical bases of risk allocation in PFI projects such as feasible risk allocation, conditions of project parties' attitudes and assessment of a certain type of PFI projects and optimal risk allocation under the complete information (Yamguchi 2001).

The difficulties of this model are how to determine the allocation ratios of the varied costs during construction and the varied profits during operation and maintenance and the risk premium. Moreover, the optimal risk allocation of this model can be achieved under the assumption that all project parties have complete information. In practice such ideal situations where all project parties reveal their risk attitudes and assessment are rare. This model also does not discuss the optimal premium and government contribution. The author's disclaimers are that even this model may not be able to reflect real situations; however, it can be used as a 'benchmark' or 'best practice' to evaluate risk allocation. And to analyze the optimal premium, various types of cooperative game theory and premium calculation principles can provide such solution (Yamguchi 2001).

Additionally, to discuss the optimal risk allocation, this model used the negotiation space on the expected utility space between client and contractor. Then, the optimality is evaluated by using the concept of Pareto-optimal ratio (Yamguchi 2001). The concept of Pareto optimality is explained that the first objective can be enhanced only at the second objective is degraded (Haimes 1998). To use expected utility as the objectives in evaluating Pareto optimality may not be suitable, since to improve one's utility may not necessary degrade another one's utility. Furthermore, in many risky situations, people do not seem to behave in a way that is compatible with the maximization of expected utility (Shapira 1995).

## **2.10 Willingness to Take Risk**

Another issue associated with principle of risk allocation is the party's willingness to

take on risks. There are a number of factors that all parties will consider to bear the risks. The willingness to bear risk is appropriate only as it is based on a general attitude to risk, an adequate perception of project risk, a real ability to bear the consequences of a risk eventuating, and a real ability to manage the associated uncertainty and mitigate the risk. On the other hand, willingness to bear risk may be inappropriate when it is due to inadequate perception of project risk, a false ability to bear the consequences of a risk eventuating, a need to obtain work, and a false perception of the risk/return tradeoffs of transferring the risks to another party (Ward 1991).

## **2.11 Risk Perception**

*“A risk is any exposure to the possibility of loss or damage to people, property, or other interest...Before implementing a risk management plan, the risk manager must first learn to perceive risk in every aspect of doing business and offering services...The most hazardous risk impact occur when individuals are not aware of potential problems...”*  
(Papageorge 1988).

Above abstracted statement illustrates the risk definition and how important of risk perception from of business's or service's viewpoint with including construction. Every risk evolves through three main phases: the potential risk, the actual occurrence, and the impact (Papageorge 1988).

For a risk to exist there must be a hazard and the perception of hazard is entirely subjective, what is hazardous to one man may not be perceived to be so by others. The hazard perception, which is related to aspect of previous experience, cultural values and training in field of expertise, is described as the individuals subjective view of particular hazard (Greene, Root, and Thrope 2000).

There are researches related to risk perception in other fields such as psychology. Most of those past researches studied the perception of general risks influencing wide range general people such as nuclear weapon and reactor accident, AIDS, and so on.



Related to health and safety field, aiming to improve communication between policy maker and public, Slovic (1987) developed techniques called 'psychometric diagram' for assessing the complex and subtle opinions that people have about risk. The psychometric paradigm, which uses psychophysical scaling and multivariate analysis techniques to produce quantitative representations or "cognitive maps" of risk attitudes and perceptions, is famous technique in presenting risk perception and has been employed by many researchers.

Axelrod, Mcdaniels, and Slovic (1999) examined lay perceptions of ecological risk associated with natural hazards by using psychometric risk perception study to explore whether natural hazards are perceived to pose risk to natural environments. By exploring the individual difference on risk perception, Twigger-Ross and Breakwell (1999) examined the relationship between venturesomeness, past personal experience of specific hazards, and perceived characteristics of certain voluntary and involuntary hazardous activities of English adults in UK. Cha (2000) compared risk perception towards 70 environmental risks of three samples (Korea, Japan and US) by using psychometric diagram.

Risk characteristics i.e., known/unknown, calm/dread, controllable/uncontrollable, etc., have been identified and used as attributes in evaluating risk perception. Then, the perception of risk has been portrayed in psychometric diagram, of which each axis represents the characteristics of risk (Axelrod, Mcdaniels, and Slovic 1999; Twigger-Ross and Breakwell 1999; and Cha 2000). However, Fife-Schaw and Rowe (2000) identified limitations of psychometric diagram in monitoring changes in perceptions, the impact of risk communications, differences between groups, and other potentially more informative applications. Af Wahlberg (2001) evaluated three approaches to risk perception i.e., the psychometric, the Basic Risk Perception Model, and the social amplification of risk.

In risk management perspective, these previous researches seem to cover only the area of risk identification, which do not cover risk analysis and response processes. In field of construction, however, the area of risk perception is not intensively researched. To

understand risk perception will be beneficial for determining the risk attitude, which is a person's willingness to either take or avoid risks, and evaluating how to response risks in both proactive and reactive actions.

Nonetheless, when viewpoints of multiple parties have to be incorporated, only providing a set of efficient responses to them is probably insufficient. As a feature of the MRMP, the response characteristics evaluation enables the understanding of response characteristics to a risk perceived by involved parties, which is significant in a multi-party environment (Pipattanapiwong, Ogunlana and Watanabe 2003). However, to understand risk perception will be beneficial for determining the risk attitude, which is a person's willingness to either take or avoid risks, and evaluating how to response risks. Thus, it is necessary to investigate the risk perception of each involved parties towards responses portrayed in the degree of risk and expected impact map in order to determine efficient response that matches with the party's perception of risk. This is still not achieved by the MRMP.

Moreover, from the past literature review study, it was found that the area of risk perception is still not intensively studied in field of construction (Pipattanapiwong and Watanabe 2001), although there are a number of risk perception researches in other fields such as psychology, insurance and culture.

Infrastructure construction project is a one important stem for economic development particularly developing countries. Failure to achieve project performance according to several inherent risks inevitably affect all stakeholders i.e., public agencies, contractors, taxpayers and users. In infrastructure construction project, risks should be perceived by the stakeholders who are involving in the project, then the appropriate proactive or reactive risk response can be taken. If risk is not perceived and treated proactively, risk will be probably developed to the last phase of its potential loss or harm. In addition, when risk evolves to occurring stage, if its occurrence is perceived and it is treated by appropriate reactive risk response, its harm may be partly mitigated or totally eliminated. This emphasizes the importance of risk perception and risk management integration.

## **2.12 Advantages and Disclaimer of Risk Management**

The disclaimers of risk management are explained that risk management will not remove all risks, however, it will enable explicit decisions to be made which will mitigate the potential effect of certain risks. Risk management will also assist in rational, defensible decisions regarding the allocation of risks among the parties to the projects

Additionally, risk analysis is not a substitute for professional experience and judgment. Contrarily, it assists professionals to make use of the full extent of their experience and knowledge by liberating them from the necessity of making simplifying assumptions in order to produce deterministic plans and forecasts. Risk analysis is supplement to, not a substitute for, professional judgment (Raftery 1994).

On the other hand, Raftery (1994) summarized the benefit of risk management by referring many writers, consultants and users of risk management agreement.

- There is an overall reduction in risk exposure;
- Pre-planning should lead to the use of pre-evaluated and prompt responses to any risks which do materialize;
- More explicit decision making on the project;
- Clear definition of specific risks associated with particular project;
- Full use is made of the skill and experience of project personnel;
- Good documentation ensures that corporate knowledge of project risks accumulates over time and does not remain with individuals;
- Situations where there is little, no or unreliable data are not ones where it is not possible to carry out the analysis, they are situations where the analysis is more, not less, important.

## **2.13 Risk Management Summary**

Term risk can be defined differently based on fields of study such as project management, decision theory, or insurance. Traditional approach for risk treatment

relies mostly on intuitive and rule of thumb, which is not logic. Risk management process, which is systematic, rational, logical, and proactive approach, assists decision-maker to manage risk systematically and most efficiently. Main processes in risk management consist of risk identification, analysis and response. Risk management will not remove all risks, however, it provides explicit and better decisions for a decision-maker in making decision. Benefits of risk management process are as reducing of risk exposures, preplanning and providing prompt response to risks, incorporating experience in analysis, and offering more explicit decisions.

As a way to deal with complex characteristics of the infrastructure construction project itself and risks inherent in the external and internal of project, it is desirable to apply the concept of risk management into the practice throughout life cycle of infrastructure construction project. The chapter points out this necessity and summarizes the risk management concept including the clarification of uncertainty, risk and opportunity, definition of risk and overview of risk management process including risk identification, risk analysis and risk response processes. Additionally, practice and principle of risk allocation are also described in later parts.

Practically, the consequence of misallocation of risk in contract could adversely affect all involved parties as a result of high contingency, conservative design and construction method, lowering work quality, claim, dispute and litigation. This induces the issue of risk allocation should be put more attention. Some points could be noted from the principle and practice of risk allocation. The difference of risk allocation practice could be noticed in different countries like US, UK, Japan and Hong Kong. The risk allocation model used for validating contract conditions is necessary in order to convince all contractual parties with the fair contract conditions that can provide most efficient and desirable solutions.

The primary conceptual risk allocation principle is a useful first step in discussing the issue of risk allocation; however, this principle may not provide the complete solution. Several risk allocation approaches have been proposed based on the early conceptual risk allocation principle. Even though, those models could provide some ranges of

solutions, many assumptions are appended to those models. Sometimes, it could not represent the real situation in practice. Therefore, a risk allocation model, which can efficiently and systematically allocate the risks to all contractual project parties such in assisting validation of contract condition, is required. Development of such risk allocation model may be worthwhile for all contractual parties in infrastructure construction project in practice.

In the next sessions, the development and application of a RMP called multi-party risk management process (MRMP) is explained. This aims to provide more understanding of how RMP is developed and how RMP is applied.

## **2.14 Introduction to MRMP**

Infrastructure construction project financed by an international lender has been continuously important in public construction works in developing countries. In the sophisticated environment governed by the contract and involvement of many parties, managing risks through the sole intuition is probably inadequate. In order to assure the success of project; therefore, application of RMP is considerably useful.

Conventional RMP has been employed to assist decision-makers instead of using solely intuition. Nevertheless, as a fundamental limitation of the conventional RMP, only one party's view is generally considered and the objectives associated with multiple project participants may be overlooked in the analysis. Risk identification and response are considered and evaluated by one party. When a risk affects parties involved, it is important to answer the question of how to properly identify risk and what is the best response that is desirable for all parties.

Since responses to some risks taken by one party may create risks to other parties, risk-response-risk chain may be notified. The process of risk and response evaluation by involved parties is probably absent in the conventional RMP. In a multi-party environment such as infrastructure construction projects, the conventional RMP may

not be necessarily sufficient. A systematic process of managing risks in a multi-party environment is thus required.

Pipattanapiwong and Watanabe (2000) proposed a RMP entitled the multi-party risk management process (MRMP) that considers the several parties' views involved in project. The multiple parties involved in a project and their objectives are incorporated throughout the processes of the MRMP. Following sections summarize the development and application of the MRMP.

The MRMP has been developed and applied to a public bridge and elevated construction road project located in a Southeast Asian country as a case study. This case studied project was proportionally financed by local government (45%) and an international lender (55%). The aim of application was to demonstrate procedure and discuss applicability of the MRMP. In the case study, the procurement and construction stages have been studied. The perception of three main parties i.e., the executing agency, the contractor, and the consultant have been investigated.

## **2.15 Essence and Procedure of MRMP**

The proposed MRMP aims to assure decision-makers that risks are managed systematically and efficiently in a multi-party environment. The MRMP puts in consideration on the needs and constraints of involved parties. By considering the others' needs and constraints, it fulfills two Asian values (1) maintenance of harmony in group situation and (2) the pursuit of profit for all (Pipattanapiwong, Ogunlana, and Watanabe 2003). The underlying essence of the MRMP is based on the risk efficiency concept (Chapman and Ward 1997). In the analysis, risk is defined as the variance of impact from the expected impact of risk associated with the alternative responses. To find efficient responses is the key in the conventional RMP as well as the MRMP. Theoretically, the efficient response provides a minimum level of risk for a given level of impact and a minimum level of impact for a given level of risk as shown in the risk efficiency concept in Figure 2.5.

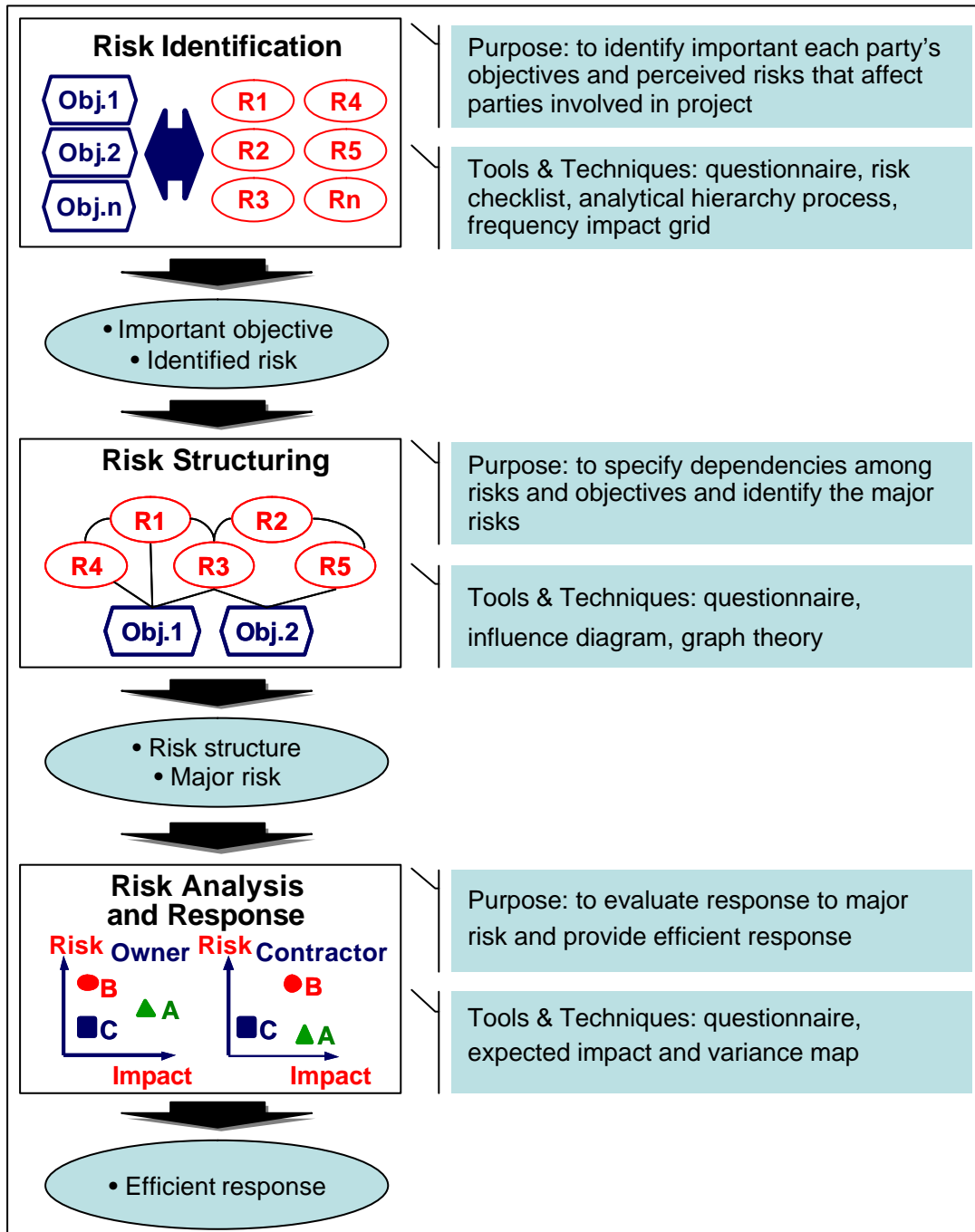


Figure 2.7: Three main processes in the MRMP

The proposed MRMP consists of three main systematic and logical processes as shown in input-process-output flow diagram in Figure 2.7. Associated with purpose of each process, the set of systematic and analytic tools and techniques such as analytical hierarchy process, risk checklist, frequency impact grid, graph theory, influence diagram, probability and impact analysis, and expected impact and variance map are employed as summarized in Figure 2.7.

IMPACT	Very High	2	2	1	1	1
	High	2	2	1	1	1
	Medium	3	3	2	1	1
	Low	3	3	3	2	2
	Very Low	3	3	3	2	2
		Very Low	Low	Medium	High	Very High
		FREQUENCY				
Note: 1= First priority; 2 = Second priority; 3 = Third priority						

Figure 2.8: Frequency impact grid in the MRMP

The multiple parties involved in a project and their objectives are incorporated in each process. Priorities based on significance of risks and objectives are considered. The MRMP relies on quantitative measurement and analysis as well as attempts to utilize the decision-makers' experiences and intuition in a systematic and efficient way.

The details of explanation of the MRMP process can be further reviewed in Pipattanapiwong and Watanabe (2000a and b) and Pipattanapiwong, Ogunlana, and Watanabe (2003). In the MRMP, after all practitioners identified risks and preliminarily assessed the frequency and impact of risks, their perceptions towards these two values are plotted in the frequency impact grid as shown in Figure 2.8. As we can see from frequency impact grid shown in Figure 2.8, the way MRMP prioritizing risk is similar to risk prioritization in conventional RMPs. Risk event that is assessed as more high frequency and more impact is regarded as more important.



To assess the probability, the scale is divided into five intervals from very low, low, medium, high and very high. Then, the simple number i.e., 1, 2, 3, 4, and 5 are assigned to each interval of frequency, respectively.

## **2.16 Application of MRMP**

The proposed MRMP has been applied in an infrastructure construction project. The case studied project was a bridge and elevated road construction project. Its route is of 6-lane carriageway including approximately 2,700 m. flyover bridge and 800 m. at-grade road. The initial construction project cost was approximately 396 million yen (including VAT). However, eventually, the final construction project cost was increased to approximately 432 million yen due to adjustment for quantity changes, variation orders, and price adjustment. Project duration is 900 days (around 30 months) plus 480 days for the two times extension making its total project duration became 46 months. Since this case studied project was evaluated by the lender as partly satisfactory; therefore, a primary objective of the case study was to find a way of better managing major risks in this project by applying the MRMP. The study period of the MRMP application was around three months starting from 31<sup>st</sup> month to 33<sup>rd</sup> month of total project duration.

The procurement and construction stages of this project have been studied. Three main parties have been investigated: (1) the executing agency, (2) the contractor, and (3) the consultant. The other related parties such as the lender, the borrower government, facility public agencies, subcontractors, suppliers, public residents and other stakeholders are not emphasized in the analysis although they are considered as sources of risks that can affect these three main parties.

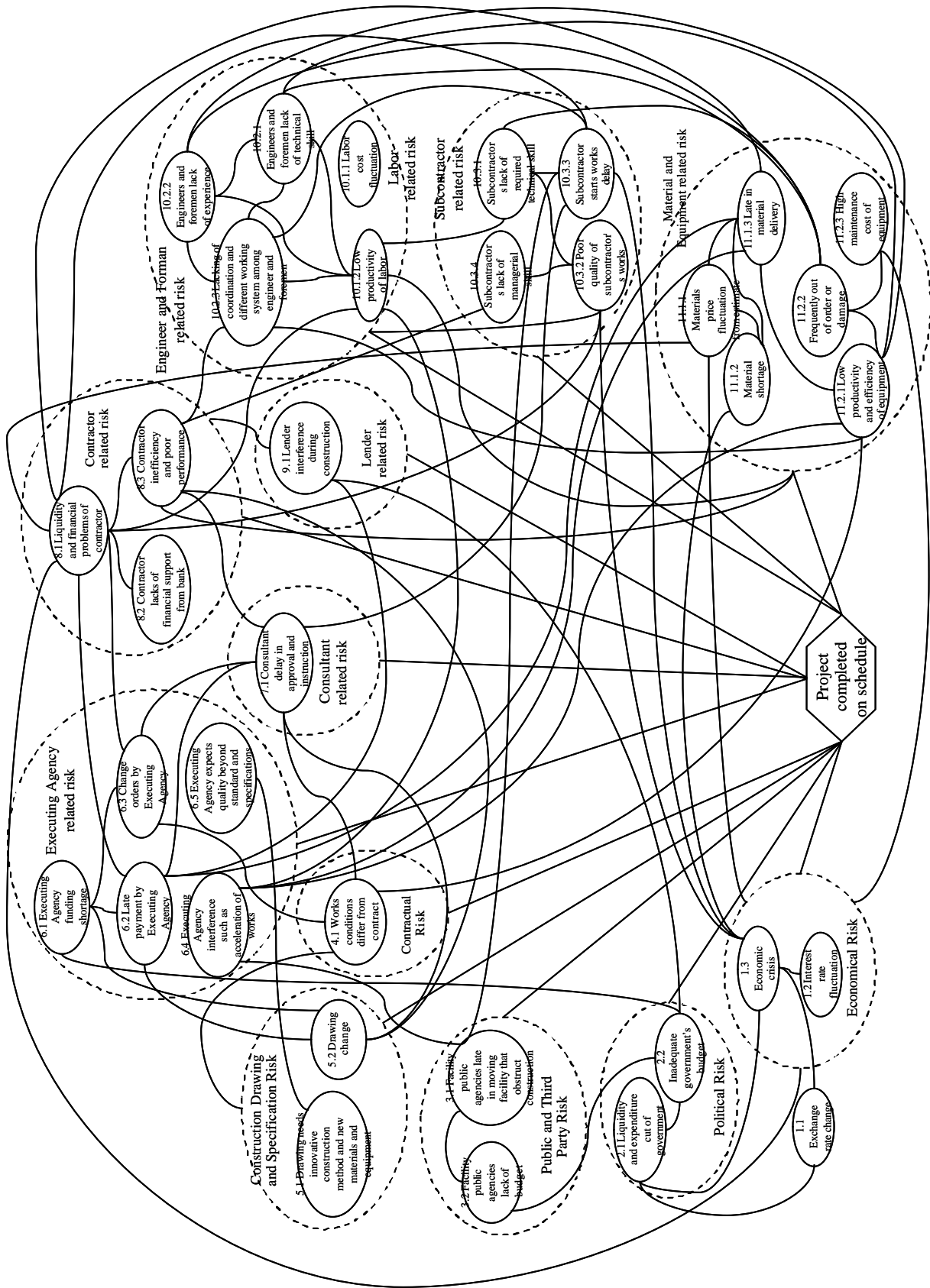


Figure 2.9: Example of risk structure diagram from the MRMP application

The project was ongoing in the construction stage during the application of the MRMP. It should be noted that results of the MRMP have different implications depending on when it is applied. In this case study, although the procurement stage has been already completed, it was assumed that the analysis was conducted at a later part of the procurement stage. The objectives of this analysis are to study whether major risk could have been managed more efficiently or not and to draw lessons for a similar project in future. For the construction stage, the analysis was assumed to be conducted when major risks were just occurring.

As an output of risk structuring process, an example of risk structure is presented as Figure 2.9 in order to enable us in understanding the picture of risk structure and how complexity it is. This example of risk structure is developed according to contractor's perception of risk against 'scheduling' objective.

Since all parties similarly identified "the contractor's liquidity and financial problem risk" as the major risk in the construction stage as well as its response evaluation yielded some interesting conclusions. Thus, the response evaluation of this major risk is further explained with the purpose to introduce how particularly the risk analysis and response process was implemented in case study.

According to the risk analysis and response process, response alternatives to the major risk are listed up. Then, the source and consequence risks of the major risk associated with each proposed response alternative are identified by each party. As a result of identifying such risks, the risk response diagrams associated with each response alternative are consequently developed as shown in Figure 2.10. The prototype of risk response diagrams includes diagrams for (a) "no-response," (b) "accept," (c) "proactive," and (d) "reactive" responses.

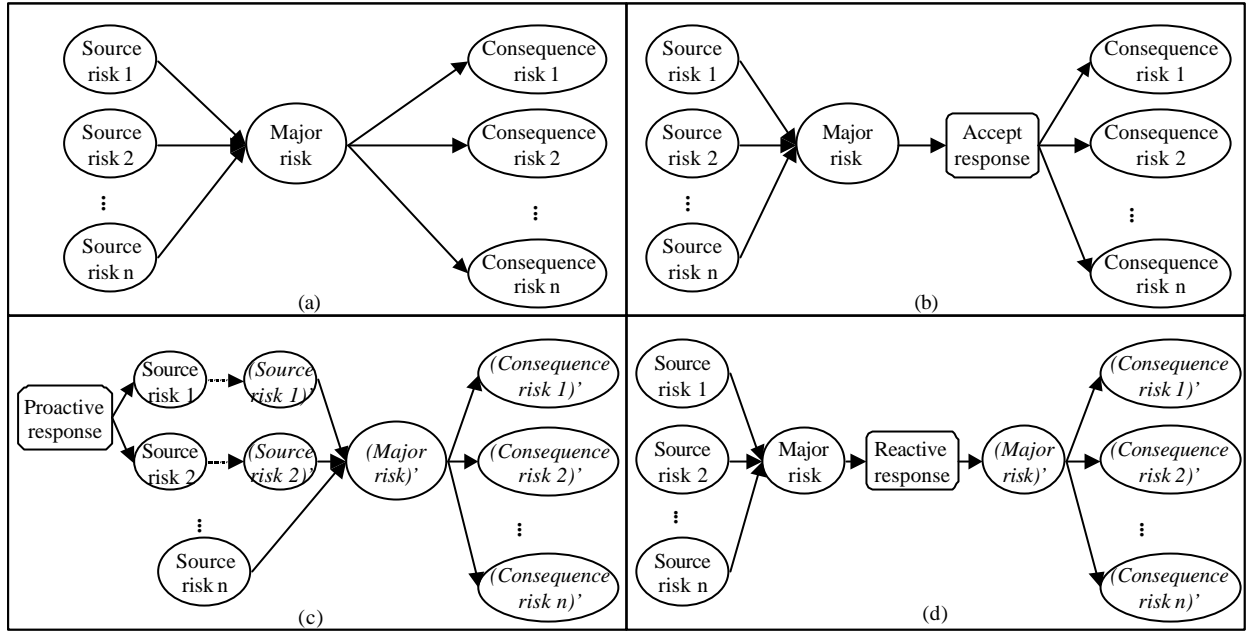


Figure 2.10: Prototype of risk response diagram in the MRMP

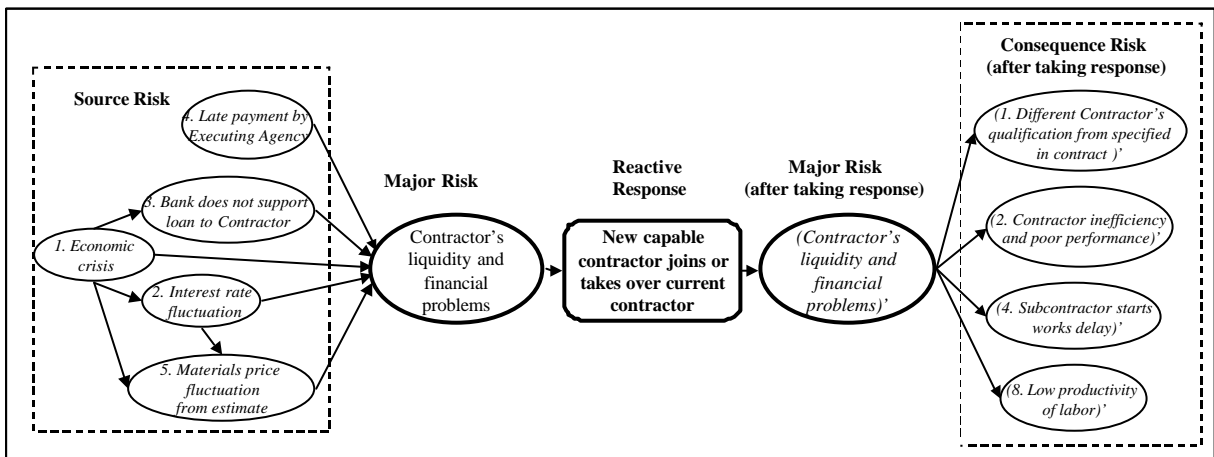


Figure 2.11: Risk response diagram of efficient response from contractor's perception

In case of “the contractor’s liquidity and financial problem risk”, the “accept” response and three more reactive responses have been proposed. The “accept” response was to accept the situation after the major risk occurred by not taking any action. Other three remaining responses were “new capable contractor joins or takes over the current contractor,” “bank provides financial assistance to the contractor,” and “the executing agency terminates the contract.”

Regarding the source risks, the economic crisis and bank does not support loan to contractor risks were source risks that have been identified by the all parties. Interest rate fluctuation, material price fluctuation and late payment by the executing agency risks were additional source risks identified by only the contractor.

The risk analysis and response interviewing sheet was used to investigate each party's perception toward the impact and probability of those risks. All parties identified almost the same set of consequence risks. However, for example, lender interference and cancellation of loan risks were additionally identified by the executing agency. Furthermore, both the executing agency and consultant specifically identified conflict among contractors risks as consequence risk if “the new capable contractor joins or takes over current contractor response” was applied. Remarkably, the executing agency and the consultant assessed only the impact of conflict among contractors risk as very high, whereas the contractor even did not perceive this risk.

For example, the risk response diagram of “the contractor's liquidity and financial problem risk” when new capable contractor joining or taking over current contractor based on contractor's perception is shown in Figure 2.11.

After each party's perception is investigated towards source risks, major risk, and consequence risks associated with each proposed response alternative, the evaluation result i.e., expected impact and variance of impact are calculated and plotted in expected impact and variance map. In the MRMP, the variance is employed to represent the degree of risk and the expected impact is employed to discuss the impact level of risk. The calculations of the expected impact and variance rely on the assumption that there are two possibilities of the major risk in each response scenario, i.e., “occur” or “not occur.” If the major risk occurs, the probability of occurrence is assigned. On the other hand, if the risk does not occur, the probability of occurrence is zero. The derived Eq. 2.1 and Eq. 2.2 are used for calculating expected impact and variance, respectively.

$$E[I] = I_n P_n \quad \text{Eq. 2.1}$$

$$\text{Var}[I_n] = (I_n^2 P_n)(1 - P_n) \quad \text{Eq. 2.2}$$

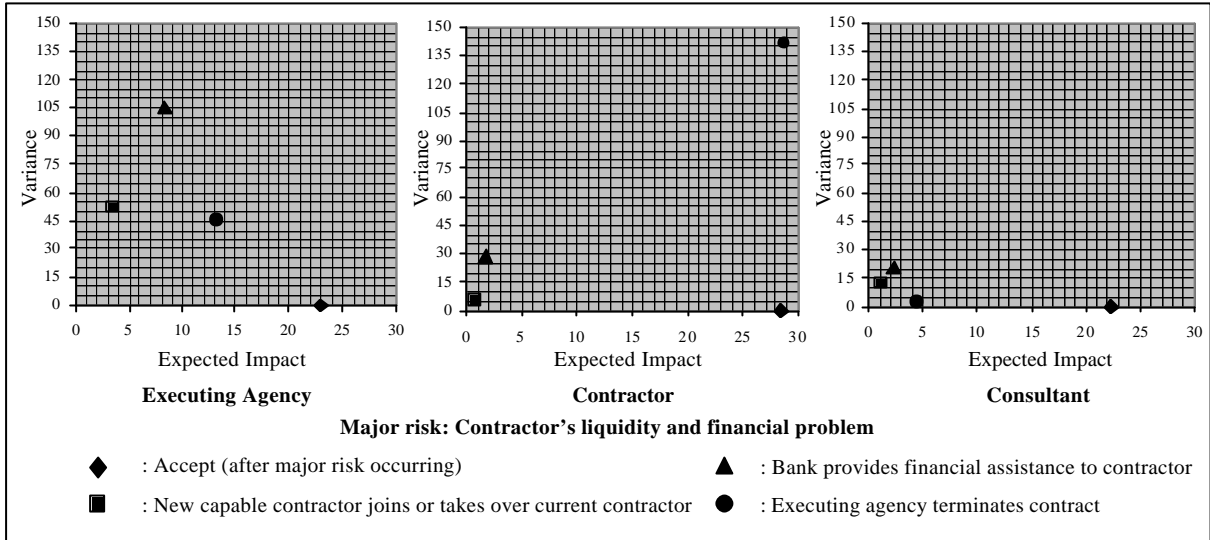


Figure 2.12: Expected impact-variance map of the major risk in construction stage

Table 2.3: Summary of research findings from MRMP application

Party	Objective	Major Risk	Efficient Response	MRMP Contributions
<u>Procurement stage</u>				
Executing Agency (EA)	Capable CT	- Delay in awarding contract	- Preparing clear bid document	- Response efficiency evaluation (same as conventional RMP)
Contractor (CT)	Contract price	- EA lacks experience in procurement process	- Capable and experienced CS assists EA in procurement process	- 'Objective' evaluation of each party
<u>Construction stage</u>				
Executing Agency (EA)	Schedule, Budget, Quality			- Multi-party risk-response-risk evaluation
Contractor (CT)	Schedule	- CT's liquidity and financial problem	- New capable CT joins or takes over the current CT	- Multi-party response efficiency evaluation
Consultant (CS)	Schedule			- Response characteristics evaluation

These equations are subjected to  $n$  = number of response scenario,  $I$  = total impact level of major risk, and  $P$  = probability of occurrence. The expected impact-variance map, which consists of two dimensions i.e., expected impact in the horizontal axis and variance in the vertical axis, is used to present the efficiency condition of responses and discuss characteristics of response in a quantitative and graphical format.

When a major risk influences multiple parties, the response to the risk should be desirably efficient for all parties. In case of response evaluation of “the contractor’s liquidity and financial problem risk,” from the expected impact-variance map in Figure 2.12, “the new capable contractor joins or takes over the current contractor response” seemed to be desirable response for the all related parties including the executing agency, the contractor, and the consultant.

After going through risk identification, risk structuring, and risk analysis and response processes in the case studied project, the results revealed the significant risks associated with each party in the procurement and construction stages and the efficient responses to each significant risk. According to the results, the MRMP contributions are provided accordingly. The overall results of the MRMP application are summarized in Table 2.3.

## **2.17 Discussion of MRMP Application**

Analyzing the results of the MRMP application, it was found that a number of contributions of the MRMP were extensively developed from the conventional RMP (as shown in the last column of Table 2.3). First, the chance of ‘objective’ evaluation of another party is offered. A party can notify the deficiency regarding the experience, technical or managerial skill, etc, of other parties involved in the project during the identification of risks. Second, risks to one party occurring from a response taken by another party can be notified, which is the multi-party risk-response-risk chain. Third, the multi-party response efficiency evaluation is provided. From this premise, in order to manage risk more efficiently, it is desirable to find a response, which is risk efficient to all related parties. Fourth, the response characteristics (i.e. risk avoiding, risk neutral, and risk seeking) associated with a major risk can be specified from the presentation of expected impact-variance map. This feature could assist decision-makers to find and select the most preferable response for all the parties. These illustrate advantages of incorporating multiple parties in the RMP.

Applying the MRMP will not remove all risks, however, it will enable decision making for mitigating the potential effect of certain risks, and providing the efficient response.

Improved project performance from such decision making will definitely bring the benefits to not only the main parties directly participating in execution of the project but also other stakeholders such as taxpayers and users of the infrastructure project.

According to the result of application, although the MRMP could provide extensive contributions from conventional RMP, there are still rooms for improvement. Regarding the subject of development and application of the MRMP, issues that should be further improved including complexity of risk structure due to inefficiency in structuring and quantification of probability of occurrence and impact of risk. Moreover, the application of the MRMP should be extended to discuss in issue of risk allocation in contract during contract formation stage.

## **2.18 Further Literature Review**

The development and application of MRMP are briefly explained in previous sections. This part discusses the intensive level of the past risk management researches in construction in order to reveal the possible study and unresolved areas for future risk management research in construction. The summary of past risk management literatures in this part is not going to claim that all risk management related researches have been exhaustively reviewed. Nevertheless, the effort attempts to provide a form of summary of risk researches have been conducted in construction field. The past risk management researches summary refers to the list of researches referred in a past study, which reviewed risk management researches in construction from 1960-1997 (Edwards and Bowen 1998).

Additionally, risk management related papers from 1997-2001 particularly published in main well-known journals in construction management field e.g., Journal of Construction Engineering and Management, Construction, Management, and Economics, International Journal of Project Management, Engineering Construction and Architectural Management and etc., were reviewed. The arrangement of review results of the summary in this paper and that past study (Edwards and Bowen 1998) is different.



This section summarizes the past risk management researches by considering the risk management researches in the areas of risk category, risk management process development, subjective issues in risk management, usage of risk management process in practice, and project type that risk management process was applied associated with each process in risk management: risk identification, risk analysis and risk response. A tentative summary of intensive level of past risk management researches in construction is shown in Table 2.4.

The intensive levels of previous researches, which are evaluated from the number of researches that specifically discuss areas within determined reviewing framework in risk management, are represented as high, medium and low, respectively. Noted that the contents in one paper can discuss more than one area.

Researches that studied the economic and financial risk, building, estimating and scheduling related risks, managerial risk, political and legal risks, cultural risk, social risk, health and safety risk, etc., are included in the risk category field.

Risk management process development field includes the researches that developed and proposed the process in risk management i.e., risk identification, risk analysis and risk response. Researches, which studied subjects related to subjective assessment, risk perception, risk attitude and risk communication, are included in the field of subjective issues in risk management. Researches, which conducted survey regarding usage of risk management in practice, are included in the survey of risk management usage. Researches, which focused on the application of the process in risk management to a specific type of project, are included in the field of type of application project.

From the tentative summary of past risk management researches in construction, the findings specify the areas of researches, which have and have not been intensively studied. Considering researches in risk category field, most of risk management researches in construction focused on risk identification and risk analysis to a specific risk i.e., economic and financial risk, bidding, estimating, and scheduling related risks. The reason why there are many researches intensively studied in identification and

analysis of these risks is probably because of the availability of objective data such as cost and duration, which could be simply used in conducting simulation or developing probability distribution for risk analysis. On the other hand, to conduct risk analysis of others risk categories such as managerial, political, cultural, social, design and so on, the objective data of these risks is unavailable or not simply to be quantified. To analyze these risks, the subjective judgment is essential.

The developments of risk identification and risk analysis process were intensively researched than the development of risk response process. There are several systematic tools and techniques available to be promptly used in risk identification. Several quantitative and qualitative techniques also are available for risk analysis. However, in risk response process, which includes the certain areas in risk response i.e., risk allocation, risk reduction, risk avoidance, risk retention and risk transfer, the less systematic and well developed frameworks have been provided.

Table 2.4: Summary of risk management researches in construction

Area of Risk Management Research	Risk Management Process	Risk Identification	Risk Analysis	Risk Response
<b>Risk Category</b>				
Economic, Financial, Bidding Risk		Medium	High	Low
Estimating, Scheduling Related Risk		Low	High	Low
Managerial Risk		Medium	Medium	Low
Political and Legal Risk		Medium	Low	Low
Cultural Related Risks		Medium	Low	Low
Health and Safety Risk		Low	Low	High
Social, Design, Force Majeure Risk		Low	Low	Low
<b>Risk Management Process Development</b>		High	High	Low
<b>Subjective Issues</b>				
Subjective Assessment		Low	Medium	Low
Risk Perception		Low	Low	Low
Risk Attitude		Low	Low	Low
Risk Communication		Low	Low	Low
<b>Survey of Risk Management Practice</b>		Low	Medium	Medium
<b>Type of Application Project</b>				
BOT		Medium	Low	Low
Infrastructure Project		Low	Medium	Low

The intensive level of past researches related to subjective issues in risk management such as subjective assessment, risk perception, risk attitude and risk communication seem to be tentatively low. The past researches rarely incorporated the subjective related issues such as risk perception, risk attitude and risk communication with the process in risk management. It seems also that there is no clear and systematic framework in quantifying for example perception to risks. In addition, the application of risk management to infrastructure construction project seems to be less intensive than other types of project scheme such as BOT project.

## **Chapter 3**

# **Post-evaluation and Limitations of (M)RMP**

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### **3.1 Introduction**

As explained in previous chapter, to overcome the limitations of the conventional risk management process (RMP), a new RMP entitled multi-party risk management process (MRMP) is proposed by Pipattanapiwong and Watanabe (2000). This chapter aims to discuss the applicability of the MRMP based on results of post-evaluation of its application at the case study (Pipattanapiwong and Watanabe 2002). Moreover, the explanations of identified fundamental and technical limitations associated with conventional RMPs and MRMP are provided in later part of this chapter.

### **3.2 Objective of Post-evaluation Study of MRMP**

To discuss applicability of the MRMP, post-evaluation of the MRMP application was conducted twice. The first time was six months after the application; and the second time was just after completion of project. The post-evaluation study aims to:

- 1) to follow up how major risks were actually managed,
- 2) to compare the actual ways of risk management and those suggested from the MRMP, and
- 3) to study reasons for limitation of the MRMP if there is any.

In the post-evaluation, the evaluation result of response towards “the contractor’s liquidity and financial problem risk” was particularly focused in the construction stage. The data were mainly collected from the secondary data such as a final project report and unstructured interview with respondents from the same groups as those when the MRMP was initially applied: the executing agency, the contractor, and the consultant.

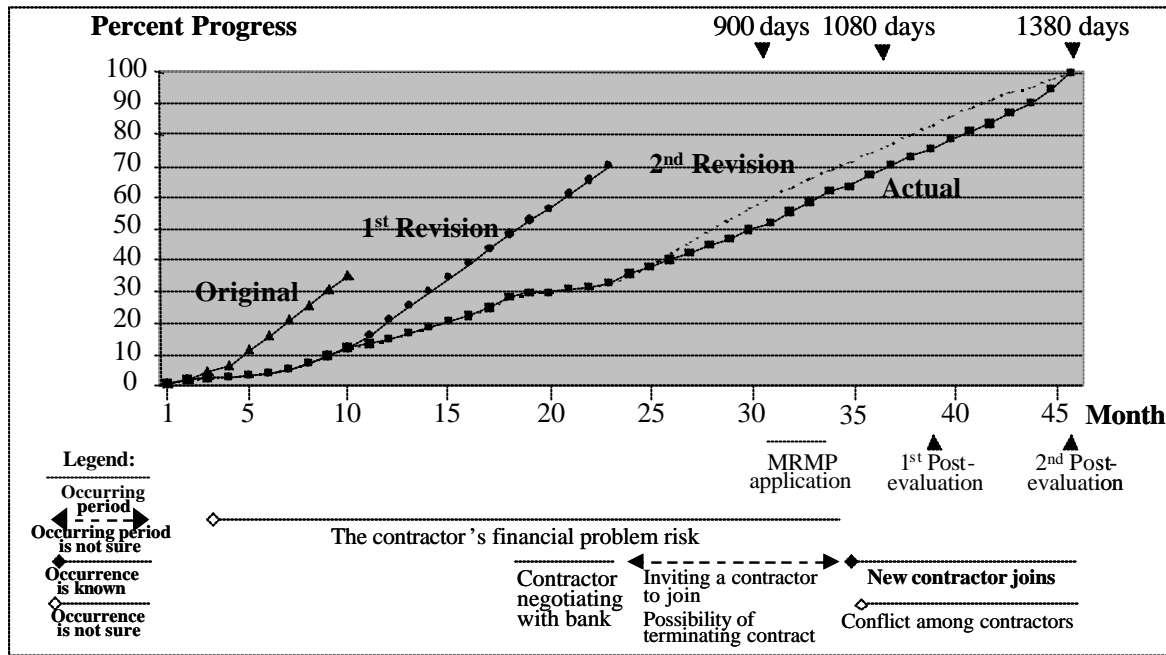


Figure 3.1: Project progress of case study in the MRMP

The entire project progress and important events regarding “the contractor’s liquidity and financial problem risk” occurred during project construction are presented in Figure 3.1. In this project, the percent progress was measured by the amount of payment paid to the contractor. The estimated baseline schedules (including original, 1<sup>st</sup> revision, and 2<sup>nd</sup> revision versions) are presented in dotted line. The actual project progress is presented in the bold line.

### 3.3 First Post-evaluation Study

Findings from the first post-evaluation were as follows. From the MRMP application, the response that “a new capable contractor joins the current contractor” was obtained. This response was similar to the response actually taken. In the real situation, the new contractor has joined informally the current contractor as a subcontractor. According to project progress (Figure 3.1), the progress of project has gradually improved after the new contractor joined the current contractor. Despite improvement in the progress, however, the respondents from the executing agency and the consultant thought that conflict between the current contractor and the new contractor related to financial issues had been occurring. The project manager from the contractor responded that there was

difficulty in working together with the new contractor. The conflict was mainly related to financial issues such as the payment from the executing agency.

### **3.4 Second Post-evaluation Study**

It was found from the second post-evaluation that the project could be eventually completed according to completion date of the second revised project schedule. The final project cost exceeded the original value, but it was mainly because of variation orders issued by the executing agency and price adjustment based on cost indices specified in the contract. However, the both contractors were in deficit. They could not make claims for overrunning costs and had to absorb the loss associated with them. It was also found that the conflicts were occurring not only between the two contractors but also between the new contractor and the bank.

### **3.5 Applicability of MRMP**

From the MRMP, the response that “a new capable contractor joins the current contractor” towards “the contractor’s liquidity and financial problem risk,” the most significant risk in the construction stage, was evaluated to be risk-efficient for the all three parties: the executing agency, the consultant, and the original contractor. This response became undesirable for the both contractors; however, when it had been implemented. During the MRMP application, the three parties did not perceive the consequence risk of the conflict between the contractors significant after the response would be taken. The original contractor could not perceive this consequence risk at all. The executing agency and the consultant have perceived “conflict between contractors risk” as a consequence risk; however, they both asserted that the project could be smoothly completed because of excellent capability of the new contractor.

Underestimation of impact of this consequence risk, the conflict between the two contractors, is potentially caused by a bias associated with “wrong” timing of the MRMP application. When the MRMP was applied, “business” of the response that the new contractor joins the current contractor was in progress. In order for the respondents

to justify their response, therefore, they might have underestimated impact of the consequence risk associated with this response and overestimated that associated with other responses. It is definitely important to apply any risk management technique when no predetermined solution is being developed or implemented.

When the MRMP was applied, the new contractor was not incorporated as another player assuming that the new contractor had a similar perception to the original contractor. But this assumption was wrong. The new contractor had been encountering the difficulty due to conflict with the original contractor and the bank. The new contractor still pursued the works, however, for needing a job during no-works period, keeping a good relationship with the original contractor, and building-up a high reputation. Thus, the objectives of the new contractor may not be the same as those of the original contractor. It was additionally found from the post evaluation that the new contractor did not have correct information on the project status when the new contractor was joining the original contractor. The original contractor withheld necessary information related to the amount of remaining works. Analysis of the new player should be carefully done because she or he may have different objectives from existing players and not have correct or sufficient information on the project status.

In this case study, when risk occurred in practice, all parties used no “formal” or systematic risk management process. The practitioners made their decisions based on only experience; and risks were managed individually not collectively. The limitations of the MRMP identified in this study needs to be solved to make the MRMP more applicable to analysis of a real construction project. Commitment to risk management by all major parties from early stage of the project is desirable. The MRMP seems to have a potential to support such a desirable practice.

### **3.6 Limitations of (M)RMP**

Theoretically, the essence of the conventional risk management process (RMP) is based on the risk efficiency concept (Chapman and Ward 1997). The conventional RMPs typically compose of logical sequential processes i.e., risk identification, risk structuring,

risk analysis, and risk response processes. The aim of the RMPs is to assist decision maker in systematically and efficiently managing risks occurring in the project. Through the consisting processes of the RMPs, the expected impact and variance of impact are produced as outputs of the RMPs. These two values could be subsequently portrayed in expected impact-variance map to present the efficiency condition associated with each response. For example, the output of RMP plotted in this map can be seen from the result of the MRMP application in previous chapter (Figure 2.12).

Based on the study of conventional RMP, application and post-evaluation of the MRMP as well as the unresolved areas in risk management literatures, the detailed explanation of fundamental and technical limitations associated with conventional RMP and MRMP are provided in following sections. The contents of following sections are partly referred to Pipattanapiwong and Watanabe (2003).

### **3.7 Category of Limitations**

Any decision set obtained from analysis model is considered unreasonable for use and invalid generally because of at least two reasons. The model could not represent the real system and when the decision is made, outputs of that decision differ from outputs of real system over a tolerable limit for error (Haimes 1998). Although, previous proposed RMPs have been elaborately developed to encounter the various imperfections, the outputs are often distressed by errors. In order to minimize these errors, sources of error, which could falsify the outputs of the RMPs should be identified. In modeling, the sources of uncertainties and errors can be associated with at least six major characteristics: model topology, model parameters, model scope, data, optimization technique, and human subjectivity (Haimes 1998).

To identify the limitations associated with the RMP and MRMP, the literature review and post-evaluation studies of the MRMP have been conducted. Associated with (M)RMP, fundamental limitations, which are related to subjectivity, output interpretation, and scope, and technical limitation, which is related to process, have been identified.



### 3.8 Fundamental Limitations

#### 1) Inattention on ‘uncertainty’ event

Regarding the first fundamental limitation, the conventional RMPs normally use the probability-impact grid as a basic tool for risk prioritization and distinction by considering that if an event has higher probability and impact, that event has more priority as shown in Figure 2.4. However, to distinguish risks by using this tool could lead the decision maker to neglect the importance of low probability and high impact event, which is often called ‘uncertainty’ event.

Prioritization of risk based on the probability impact grid is discussed by several literatures (Al-Bahar, 1988; Williams, 1993; Chapman, 1997). The MRMP also employs concept of probability impact grid in distinction between major and minor risks.

This issue is directly related to the fallacy of expected value concept. As a simple example, associated with the process of risk analysis, generally the RMP employs concept of expected value. The expected value is the product of multiplication of probability and impact (e.g., in terms of cost). For example, event A, its probability is 0.1, its cost impact is 1,000 dollars. Then, its expected cost impact is 100 dollars. For event B, its probability is 0.0001, its cost impact is 1,000,000 dollars. The expected cost impact could be calculated as 100 dollars, which is equal to the expected cost impact of event A. If we adopt the concept of expected impact in prioritization, this means that the priority of these two events is same. Even though, event B is the rare event that has high catastrophic impact. Therefore, there is possibility that the conventional RMP may neglect importance of ‘ low-probability and high-impact ’ event and may mislead decision when this fashion of prioritization is adopted.

Smith (1999) stated that for the event that has high impact and low probability, the consideration might not be necessary since it is too remote. Notably, they seem to neglect the importance of low-probability and high-impact event. Although this type of event rarely occurs or even almost no-possibility to occur, its occurrence would

substantially damage the project. It usually has been proved in many real projects that this type of event could significantly make project suffering with substantial delays, cost overrun, project being suspended, or even being abandoned.

It could be further discussed about the application of risk management associated with the low probability and high impact event. Based on the risk prioritization, Smith (1999) explained that the risk management is designed to use for identifying, assessing, and managing the events that have high probability and high impact. Many risk analysis techniques, which have been developed to basically deal with the event that has high probability, because the historical data of this kind of event is usually available. On the other hand, for low probability event, its historical data is normally unavailable; thus, it is inevitable to rely on subjective judgment for assessing its probability of occurrence and impact.

Based on the condition of event in probability impact grid, the area of ‘risk analysis’ and ‘uncertainty analysis’ then can be distinguished as shown in Figure 3.2. The ‘uncertainty’ event is considered as the event that has low probability and high impact, because its occurrence is probably uncertain or even unknown. In this kind of event, we may not be able to assign the probability distribution by using historical data as doing in risk analysis.

According to the MRMP application and post-evaluation study, for example, the economic crisis risk, which could be considered as a low probability risk, actually occurred in the case studied project. It resulted substantially delay approximately 53 percent delay from its original contract duration. As an example, this could illustrate that the necessary attention should be put on this type of event. We should not discard this type of event during the risk prioritization and distinction, which is considered as one technical limitation in the conventional RMPs.

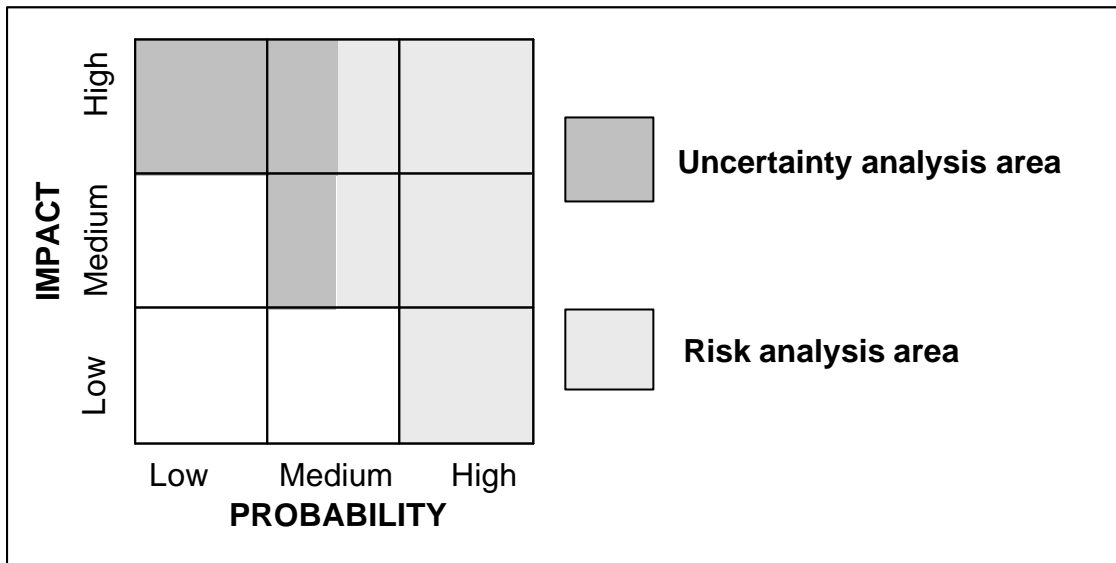


Figure 3.2: Distinction of uncertainty analysis and risk analysis

Furthermore, regarding this first fundamental limitation, we may ignore and may not be aware of significant risks and particularly uncertainties due to limited experience and bounded rationality of human in subjective assessment.

Most of the case, the historical data is usually unavailable and insufficient. In application of the MRMP, due to unavailability of objective data in evaluation of probability of occurrence and impact, the subjective assessment was inevitably adopted. Additionally, even for the high probability event that its historical data may be available and is possible to acquire; the issue of inapplicability of that available historical data is necessary to be considered. This data may not be accurate and applicable due to the uniqueness of project characteristic and environment. Because the project conditions and environment is usually unique, then the data from previous projects may not necessarily be applicable to current analyzed project. Therefore, the utilization of subjective data is indispensable when conducting both uncertainty and risk analysis.

In subjective assessment, bias is inevitable. The human judgmental ability is often defected by various biases, which distort the correct perception. The possible biases include availability, selective perception, illusory correlation, conservatism, law of small numbers, wishful thinking, illusion of control, logical construction, and hindsight bias (Flanagan and Norman 1993). Chapman (1997) stated that as a result of limited

information processing ability, people normally adopt heuristics when estimating uncertainty, which can lead to error in estimates. Three types of bias are listed up: adjustment and anchoring, availability, and presentational effects.

For example, from the MRMP application result, in construction stage of the case studied project, the contractor's assessment of probability of occurrence of economic crisis risk was distorted by availability bias. Since the contractor was suffering from the financial problem caused by economic crisis during the MRMP application study, the contractor then overestimated probability of occurrence of economic crisis risk as high, even though the economic crisis is considered as rare event.

Indeed, it is noted that the attention on the importance of low probability and high impact event should be drawn. We should not discard this type of event during the risk prioritization and distinction. Moreover, since it is difficult for practitioners with limited knowledge and experience to identify uncertainty, it is necessary to have a tool used for assisting practitioners for better treating uncertainty due to ignorance.

## **2) Interpretation difficulty of dimensionless output**

Theoretically, the essence of the conventional RMPs is based on the risk efficiency concept. As described by Chapman (1997), the output of the RMP based on risk efficiency concept is the tradeoff between two values i.e., expected impact, which is expected value of damage and preparation effort in terms of time or cost, and variance of this impact. For the MRMP, by relying on the risk efficiency concept, the major output of the MRMP is the expected impact-variance map used for graphically presenting the degree of risk by using terms 'expected impact' and 'variance' associated with each response scenario.

Inevitably, the MRMP relies on the subjective judgment in its processes, for the reason that the unavailability of objective data and the subjective issue could not be discarded from the risk management study. As a result, the terms 'expected impact' and 'variance' in expected impact-variance map are presented in dimensionless value. Although, when historical data is unavailable, to represent terms expected impact and variance in

dimensionless format is also common in other conventional RMPs. However, to further transform these values from dimensionless value to dimensional value such as in terms of duration and cost that can represent how project goal is achieved is desirable. This probably facilitates practitioners to interpret result simpler. For example, the impact is represented in terms of project delay and cost overrun associated with project duration and cost, the variance of impact means how much the actual project duration and cost is likely to deviate from expected duration or cost. Consequently, these two variables can be presented in the form of cumulative distribution function (CDF) as well as expected duration/cost-variance map.

### **3) Insufficient involvement of multiple parties**

Scope is particularly important where the system is controlled by many relatively independent decision makers, who usually have different objectives (Haimen 1998). Many researchers have proposed and discussed the RMPs to cope with risks occurring in construction project (Al-Bahar 1990; Flanagan 1993; Duncan 1996; Kahkonen 1996; Chapman 1997; and PMI 2000). However, these RMPs are discussed on the basis of one party's view in managing risks influencing his/her objectives. When a risk affects several parties involved in the project, particularly risk analysis and response evaluation processes in the conventional RMPs usually do not incorporate those involved parties' views. Since construction project is considered as a multi-party environment, which several parties are involved, by neglecting the importance of other parties' objectives and ways in managing the risks, this could increase degree of risk and difficulty in managing the entire project. Eventually, the project objectives can be deteriorated, and all parties will probably suffer.

Since the conventional RMP is a method developed to systematically obtain risk-efficient responses for a single party, it could be understood that the risk perception of other parties towards the response is beyond the scope of the RMPs. When a risk management study is undertaken from the viewpoint of one party, the most desirable response may be derived without significant difficulty (Pipattanapiwong, Ogunlana and Watanabe 2003). As explained in previous chapter, to overcome this limitation the MRMP has been proposed. Then, it has been applied to a real infrastructure construction

project to discuss its applicability. The basis of MRMP fulfills two Asian values: (1) the maintenance of harmony in group situations; and (2) the pursuit of profit for all involved parties. According to its application in a real infrastructure construction project, a number of features, which are extensively developed from the other conventional RMPs, include multi-party risk-response-risk, 'objective' evaluation of each party, multi-party response efficiency, and response characteristics evaluations (Pipattanapiwong, Ogunlana and Watanabe 2003).

The MRMP considered the involvement of multiple parties in processes; however, the views of involved parties were not fully integrated. Without integration of multiple parties' views, we may not be able to complete the problem solving process starting from awareness and identification of problem to solving the problem. In other words, MRMP does not sufficiently encourage and provide opportunity for involved parties to communicate and cooperatively solve problems.

### **3.9 Technical Limitation**

As far as academic literature is concerned, there is little established structuring and analysis procedure. Due to this technical limitation, two problematic issues are realized i.e., 1) unorganized risk structure diagram and 2) illogical probability and impact assessment.

Normally, conventional RMPs do not provide any structuring framework to facilitate practitioners in specifying dependencies among risks. Practitioners have to start in drawing risk structure from scratch. Due to this reason, practitioners may neglect important risks. Additionally, by starting from the scratch, practitioner may face difficulty and confusion in specifying the dependency among risks that can result in messiness and complexity of risk structure. Figure 2.9 shows an example of risk structure diagram as a result from MRMP application. As a result of messiness and complexity of risk structure, the cause and effect events are not clearly separated.

As formerly discussed, in construction project environment, it is inevitable to employ

subjective judgment in assessing probability and impact. In order to reduce this discrepancy, the logical procedure to subjectively assess probability and impact is necessary. Commonly, in conventional RMP, if subjective assessment is employed in the process, assessor is asked to assess the probability and impact by directly rating their value in the scale from very low to very high. With this way of rating, the assessment is not grounded on structuring framework and probability theory.

In summary, by considering this problematic technical issue of conventional RMPs regarding little established structuring and analysis procedure, this technical limitation increases possibility of large margin of error associated with the expected impact and variance of impact map.

### **3.10 Summary**

The MRMP has been previously developed to challenge a fundamental limitation of the conventional RMP. The MRMP incorporates the involved parties in project and their objectives in each process of analysis. Then, it has been applied to a real infrastructure project financed by the ADB located in Southeast Asian country as a case study. Several contributions of the MRMP, which is extended from conventional RMP, consist of: 'objective' evaluation of each party, multi-party risk-response-risk evaluation, multi-party response efficiency evaluation, and response characteristics evaluation. The post-evaluation of the MRMP application has been conducted to investigate the discrepancy between application result and real practice. Regarding the post-evaluation study, its result revealed areas, which the MRMP should be further improved, including the framework of risk perception and the improvement of risk analysis and response process. Additionally, risk allocation, which the MRMP was still limited in development and application, is another area that should be further studied.

It can be noted that there are some implication between results of application and post-evaluation of the MRMP application and results of risk management researches reviews in previous chapter. Based on the application and post-evaluation of the MRMP application, the issue of risk perception and risk response process development were

similarly pointed out to be improved or further studied. In addition, from the observation of risk management in practice particularly in the case study of the MRMP, the practitioners use solely their experience and subjective judgment in managing risks. It seemed that they do not have adequate understanding regarding the sophisticated risk analysis techniques. Therefore, the future risk management research should fulfill the gap in unresolved areas and also to satisfy the need in practice.

Even though, several RMPs have been developed and proposed, there are still fundamental and technical limitations associated with (M)RMP, which could falsify their consequent outputs. Based on the literature review and post-evaluation of the MRMP application, the fundamental limitations have been identified as inattention on catastrophic event (which is ‘uncertainty’ event), interpretation difficulty of dimensionless output, and insufficient involvement of multiple parties. Regarding technical limitation, little established structuring and analysis procedure has been pointed out. Considering the theoretical issues to further develop the new RMP, it is desirable to put consideration on these limitations. This research aims to overcome these limitations associated with (M)RMP.



## **Chapter 4**

# **Risk/Uncertainty Map and Hierarchical Structure of Risk and Uncertainty**

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### **4.1 Introduction**

Aiming to facilitate practitioners in better treatment of uncertainty and to establish a logical risk structuring and analysis procedure, this research develops 1) risk/uncertainty map as ‘knowledge base’ from similar experience in past similar project and 2) a common risk/uncertainty structuring framework called hierarchical structure of and uncertainty (HSRU). This chapter describes the development of these developed risk/uncertainty map and HSRU framework.

### **4.2 Development of Risk/Uncertainty Map**

As also mentioned by Ward and Chapman (2003), they suggested that the conventional project risk management is based on a threat and event-based perspective, which can result in a lack of attention to several important areas of project related uncertainty. They emphasize the concern with the understanding and managing all sources of project uncertainty. In this research, risk/uncertainty map is used to overcome ignorance of uncertainty by accumulating uncertainty from experience and periodically updating the structure.

This risk/uncertainty map has been developed based on the literatures related to construction field as well as experiences of real world project. Although, the scope of development of this risk/uncertainty map is initially bound to project financed by international lenders, it is also considered possible to be used as guideline in other types of construction projects.

Two main sources were used in developing prototype of risk/uncertainty map i.e.,

literatures for risks/uncertainties related to construction projects in general and experiences of three infrastructure projects financed by international lenders. Initially, the risk/uncertainty breakdown structure (RUBS) was developed. Then, the risks and uncertainties preliminarily collected from various literatures (Healy 1981; Perry and Hayes 1985; Al-Bahar 1990; Zhi 1995; Edwards 1995; Fisk 1997 and Pipattanapiwong 2000) were arranged based on the categories of uncertainty in RUBS to develop the checklist of risks and uncertainties.

Afterwards, to develop prototype of risk/uncertainty map, past experience of three infrastructure projects financed by international lenders including subway construction project, bridge construction project and hydropower construction project were used in identifying risks/uncertainties as well as their relationships. Various data collection methods were employed in acquiring experience of these case studies. Project document review, in-depth interview with practitioners on-site, and site visit and observation were conducted for the bridge and hydropower construction projects. For subway project, the experience was mainly acquired from secondary data such as project report and news with additional expert interview.

### **4.3 Risk/Uncertainty Breakdown Structure and Checklist**

Carr and Tah (2000) developed a common language for describing risks and remedial actions, which is grounded on taxonomy of risk based on a hierarchical risk breakdown structure. Hillson (2002) introduced the risk breakdown structure to structure information aiding comprehension and effective risk management. Both proposed breakdown structures of risk are developed only from contractor's viewpoint.

This research also considers the importance of those stated common language and comprehension of risk on a project. The RUBS has been developed with consideration of 'mutually exclusive' classification among risk/uncertainty categories. Based on integration of multiple parties, the risk/uncertainty categories related to all involved parties are also included in RUBS.

## Risk/Uncertainty Breakdown Structure

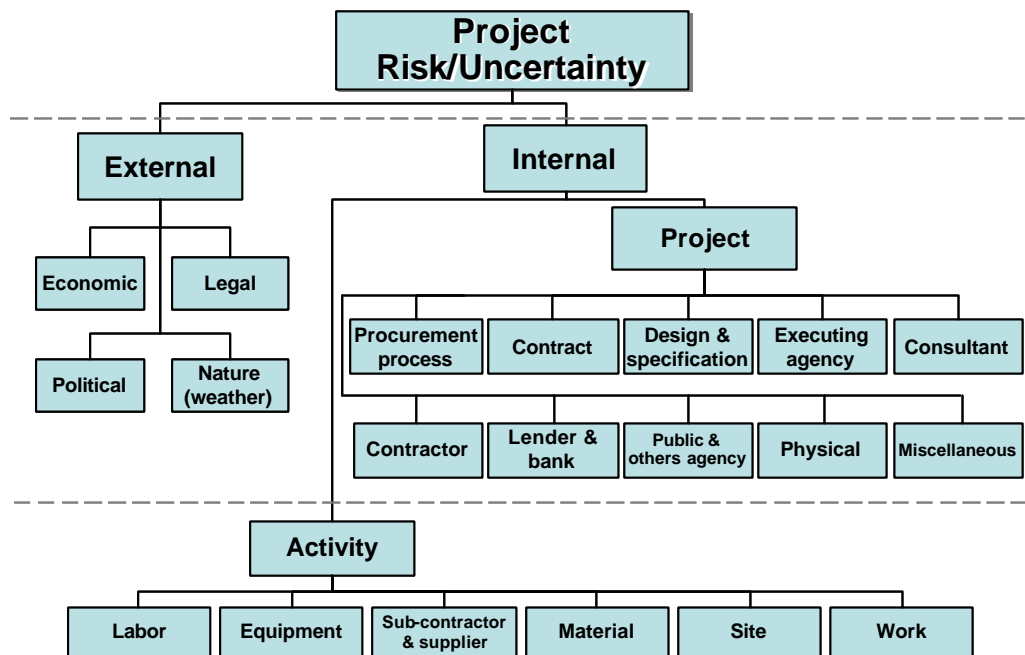


Figure 4.1: Risk/uncertainty breakdown structure

There are 20 categories of uncertainties in four levels in developed RUBS. The RUBS is presented in Figure 4.1. Based on the categories categorized in RUBS, the checklist of risks and uncertainties is developed. It is available in Appendix A. Moreover, both RUBS and risk/uncertainty checklist are two important tools used in risk identification and structure processes.

### 4.4 Risks and Uncertainties in Case Studies

Infrastructure construction project is an important stem for economic development of developing countries. Most of these projects involve several stakeholders i.e., public agencies, contractors, consultant, and users. Huge financial investment and long construction period are their common characteristics. Due to the scarcity of local government fund, as an alternative source of fund, international lenders such as Japan Bank International Cooperation (JBIC), Asian Development Bank (ADB), and World Bank has been providing assistance in the form of grant and/or loan for these countries in financing the projects. This type of project has been playing significant role in infrastructure development of the developing countries.

Due to complexities and several involved parties, risk and uncertainty are substantially inherent in this type of infrastructure projects. World bank (1990) figures show that for 1,627 projects completed between 1974 and 1988, they experienced the delay varied between 50% to 80% (Bordoli and Baldwin 1998). In recent years, failure to achieve project objectives is still an issue needing considerable care and attention. 50%-delay of completion of a bridge construction project in country A, one-and-a-half year delay of opening of subway project in country A, and one-year progress delay of a hydropower project in country B are some of real world examples illustrating present situation of projects.

The implementation process of the construction projects financed by an international lender is generally different from typical public construction projects. The international lender is involved and many rules and contractual procedures are determined. The project cycle generally starts from project identification, preparation, appraisals, loan negotiations, commitments, project implementation, project supervision and ends with post evaluation and monitoring after completion.

The international competitive bidding (ICB) is their typical project procurement method. The contractual arrangement is more or less similar to traditional contracting contract. The traditional contracting procedure normally consists of a number of stages including project planning, bidding, contracting, and construction. Many contractors and consultants from various countries can participate in project, since project is opened internationally for those eligible countries specified in lender procurement guideline. Normally, they are members of that particular international lender. This makes project environment become international. Additionally, several guidelines and rules are enforcedly annexed for project implementation in procurement and construction stages. All of these characteristics further increase the degree of uncertainty, complexity, and difficulty in project implementation.

In case of world bank projects, incomplete design and detailed engineering, lack of transparency and usage of ambiguous bid evaluation criteria, delayed contract awarding, unfair bidding documents and unequal risk sharing, incapability of lowest bidders,

insufficient supervision and contract administration and incapable contractor are typical problems, which have occurred in procurement and construction stages (Godavitarne 1995). For ADB financing projects in Thailand, insufficient institutional capability, late land acquisition and right-of-way problem, procurement difficulties and lack of efficient coordination among agencies are experienced problems influencing project performance (ADB's post evaluation report 1999). They cause serious delay in procurement process of ADB project (Hayashi 1986).

Moreover, common problems in infrastructure projects occurring along with the traditional contractual procedure could be shortly listed up below.

**Planning stage:**

- Insufficient study for determining project duration
- Relying on policy factor more than engineering factor in determining project duration

**Bidding stage:**

- One-sided attitude towards contractor in allocating risks in contract
- Insufficient information to contractor for preparing bid
- Insufficient time for provided bid preparation time
- Insufficient attention on contract condition regarding risk responsibility during bidding
- Inefficient communication about risk responsibility during bidding

**Contracting**

- Insufficient consideration on responsibility of risk allocated in contract condition during contracting
- Inefficient communication about risk responsibility during contracting
- Inappropriate timing of notice to proceed issuance

**Construction stage**

- Insufficient effort in planning and preparation of works before project commencement
- Delay in submitting base-line schedule during the beginning of construction stage
- Poor project scheduling, monitoring and control
- Inefficient communication among project parties

- Conflict among project parties
- Adversarial attitude towards others
- Poor cooperation and coordination among project parties

There are three case studies used in developing the prototype of risk/uncertainty map. All of them are projects financed by an international lender. The overview information of these three projects is summarized in Table 4.1.

Table 4.1: Project information of case studies

Items	Case 1	Case 2	Case 3
Type of work	Subway	Bridge	Hydropower
Lender	Lender A	Lender B	Lender A
Project cost	303 Billion Yen	3.6 Billion Yen	30 Billion Yen
Location	Country A	Country A	Country B

Brief description of risks and uncertainties occurred in these case studies are provided as following.

### **External risk/uncertainty**

#### **Economic:**

##### ***Economic crisis***

It results in fluctuation of exchange rate difficulty in project finance. Country A has been facing sever economic crisis. For foreign investors, it is inevitable to owe certain exchange rate risk. The projects had been awarded just before the announcement of local currency floatation, since then it has been devaluation so rapidly. It is assumed such economic movement might not have been taken much into account at tender stage and the contractors have been forced to adopt urgent hedging method for future economic risk. In addition, severe economic condition and cancellation of many infrastructure projects may cause the shortage of liquidation in the cash flow of this project and raise the cost of capital excessively. Moreover, the economic crisis was the main causation for contractor's financial problem.

## **Political:**

### ***Instability of government, late Cabinet's approval, and inconsistent policy***

When the government has been changed, most probably the policy is also changed accordingly. This instability affected the plan of project. Example of disturbance by frequent government policy change has been experienced in these projects. Since then policy changes relating to finance, the effect of conceptual design change has continued to disturb the implementation of projects. Furthermore, inadequate budget from the government, late the government's approval and inconsistency of the government policies also caused delay in awarding and signing contract. The impact of these causations could affect the executing agency's objectives such in procuring capable contractor and consultant and timely signing contract in the procurement stage.

### **Internal risk/uncertainty**

## **Procurement process:**

### ***Late procurement of contractor, concessionaire, and consultant***

Due to executing agency cannot procure the consultant and designated contractor as planned such as construction supervision consultant, lift and escalator, depot, track work, M&E concessionaire. Such delayed procurement caused problems regarding with design interface that made project delayed.

### ***Delay in signing contract among concessionaire contractors***

Due to the abrupt cancellation of the contract signing to purchase the trains and operating systems in concessionaire contract caused by disputes about stock allocation, the commercial service of subway was delayed. Consequently, the operation of whole project was likely to be delayed. .

### ***Delay in awarding contract***

During bidding stage, a project has been delayed around one and a half year. This awarding of contract has been delayed due to following factors: bidders' complaint,

unclear bid documents, late land acquisition, and late executing agency approval. The consequence associated with delay in awarding contract resulted in delay in signing contract and late commencement of work.

#### **Contract:**

##### ***Unclear contract***

This problem seemed to occur in both contracts between the executing agency and consultants and between executing agency and contractors. This ambiguous contract initiated a lot of problems during procurement and construction stage. The consultant did not know their duties clearly to perform their works. The possibility of conflict and dispute became high due to this problem. The design and construction contractual arrangement scheme between contractor and the executing agency might be the cause of ambiguous contract.

#### **Design and specification:**

##### ***Defective preliminary design***

In subway project, the alignment of route and design of tunnel system seemed to be inappropriate. The tunnel should be single tunnel system rather than separated tunnel system. This caused problem and difficulty in construction and operation stage such as in construction of cross over between two tunnels. During the operation stage, the train may not be able to service according to determined timetable.

#### **Executing agency:**

##### ***Inexperienced executing agency in procurement and construction***

Inexperienced executing agency in the procurement process created other problems such as unfair prequalification criteria, unclear bid documents, bidders' complaint and delay in awarding and signing contract. In case of subway project, due to this is the first subway project in Country A, the executing agency seemed to have not enough experience in subway construction, this resulted in delay in making decision.



### ***Late land acquisition***

In these projects, entire land could not be acquired before commencement of work. The problems of land acquisition then occurred in construction stage such in tunnel construction. For example, when the conflict arose between the executing agency and a hotel, it was took place about one year to settle the conflict. Finally, the executing agency had to pay for additional cost for redesigning and relocating one station and project was delayed.

### **Consultant:**

#### ***Incapable and inexperienced project consultants***

The executing agency had to employ the project consultant to act as his representative, and give consult to the executing agency. The capability of consultant that was considered significantly could influence the executing agency's decision. An ineffective preliminary design was an example of incapability of consultant problem. The role of consultant seemed to be crucial to project performance, when the executing agency did not have sufficient experience about project.

### **Contractor:**

#### ***Traffic management problem***

In subway project, the traffic problems always occurred in the area of station construction. Most traffic disruptions are created around the construction site of underground train stations as they are constructed through cut-and cover techniques.

#### ***Contractor's deficiency***

Difference in contractor's qualification from specified in contract, contractor's financial problem, failure to construct as drawing and specification and lack of coordination among contractors in joint venture were examples of contractor's deficiency. Particularly, the contractor's financial problem was the significant causations during construction stage.

### ***Lack of coordination among engineers and foremen***

This caused low efficiency during executing the project since they could not coordinate each other well. This impacted in schedule, quality and budget of project.

### **Lender:**

#### ***Less lender's participation***

Lender seemed to put more attention on procurement process and project financing. However, lender did not put much attention in preliminary design stage.

### **Commercial bank:**

#### ***Lack of financial support from bank***

In a case study, bank stopped to provide loan to contractor. This was a factor made the contractor difficulty in executing project due to inadequate financial support.

### **Public and other agencies:**

#### ***Public complaint***

In these case studies, the public often complained about their inconvenience and property damage in the immediate vicinity of construction work.

#### ***Lack of other public utility agencies' cooperation***

The executing agency often faced the difficult when working with other public utility agencies. During construction stage, some works were related to utilities diversion and traffic diversion, which were under various others authority's control. It needed huge effort to get approval from them. The working method and sequence had to be changed if such approvals are delayed.

The example of risk/uncertainty map of these three case studies are shown in Figure 4.2.

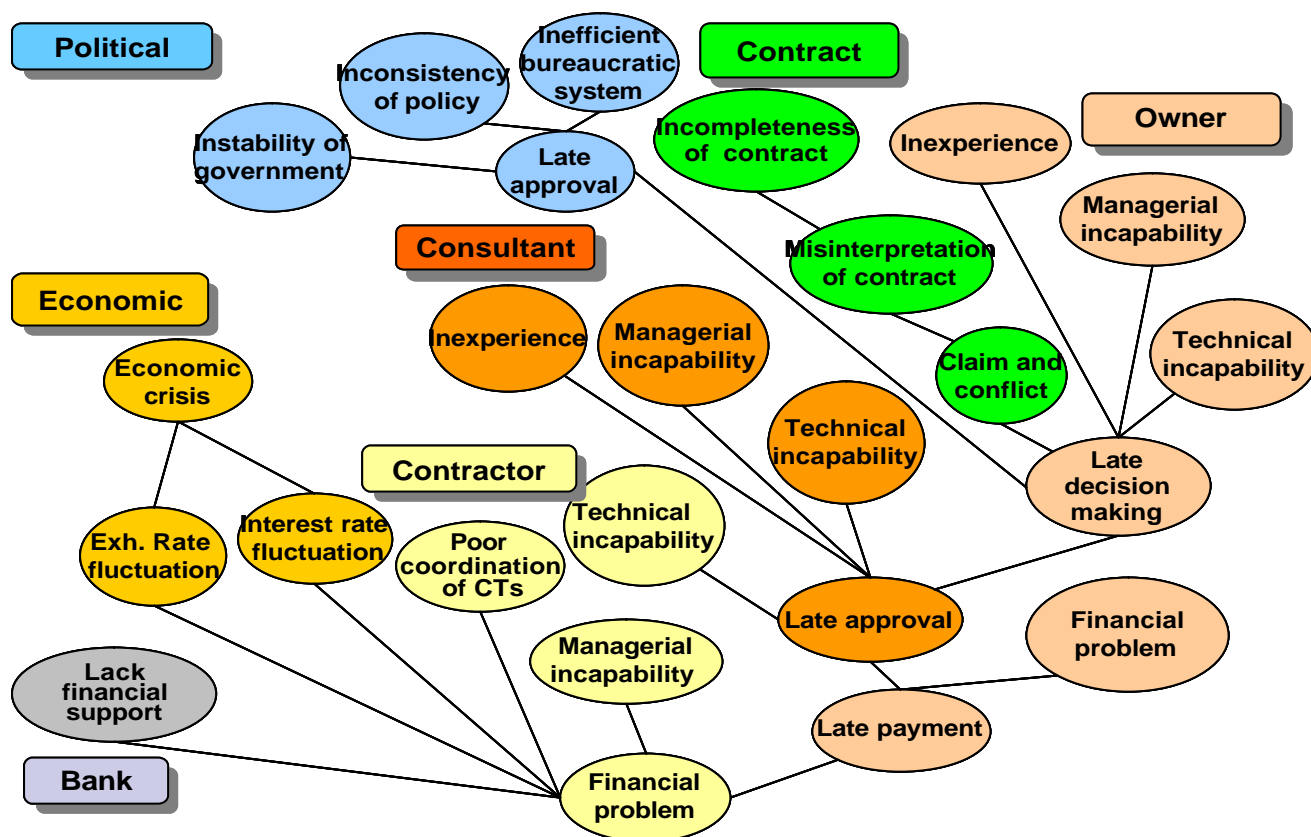


Figure 4.2: Example of risk/uncertainty map

From the literature review and experiences of past case studies, it is realized that there are many risks and uncertainties involved in the project throughout the project contractual procedure from project planning to construction. With the study of these past projects, they seem to experience some common risks and uncertainties. The risk/uncertainty maps based on the experiences of these case studies are provided in Appendix B.

## 4.5 Framework of HSRU

Attempting to identify uncertainty due to ignorance by employing risk/uncertainty map is considered as the important step in risk/uncertainty identification process. Then, to overcome the technical limitation of RMP in order to improve precision of output, this research develops hierarchical structure of risk and uncertainty (HSRU) framework to

be used as a basis in logically assessing probability and impact of risks and uncertainties. Figure 4.2 shows framework of HSRU.

HSRU is divided into four main layers based on hierarchical flow of source, consequence, occurrence, and outcome from upper to lower layer respectively. Source layer contains source of risk/uncertainty. Consequence layer contains consequent risk/uncertainty. Occurrence layer contains influential risk/uncertainty and influenced activity. Outcome layer shows type of delay. Based on the framework of HSRU, the cause event (including source and consequence layers) and effect event (including occurrence and outcome layers) can be obviously separated.

In the layer of cause event, multiple risks and uncertainties are connected as the flow of source of risk and uncertainty, intermediate consequent risk and uncertainty, and consequent risk and uncertainty. The risks and uncertainties in this layer are related to both uncontrollable condition called uncertainty condition such as political and economical issue, and controllable condition called risk condition such as mobilization of resource that is relevant to managerial issue.

In the effect event layer, it becomes more specific on a project, a work item, or an activity. The influential risk/uncertainty such as site accessibility, subcontractor availability, equipment availability, labor availability, work quantity and work progress are considered as the risk and uncertain condition directly influencing project, work item and activity. For the outcome layer, it presents the type and characteristic of effect such as date delay of an activity.

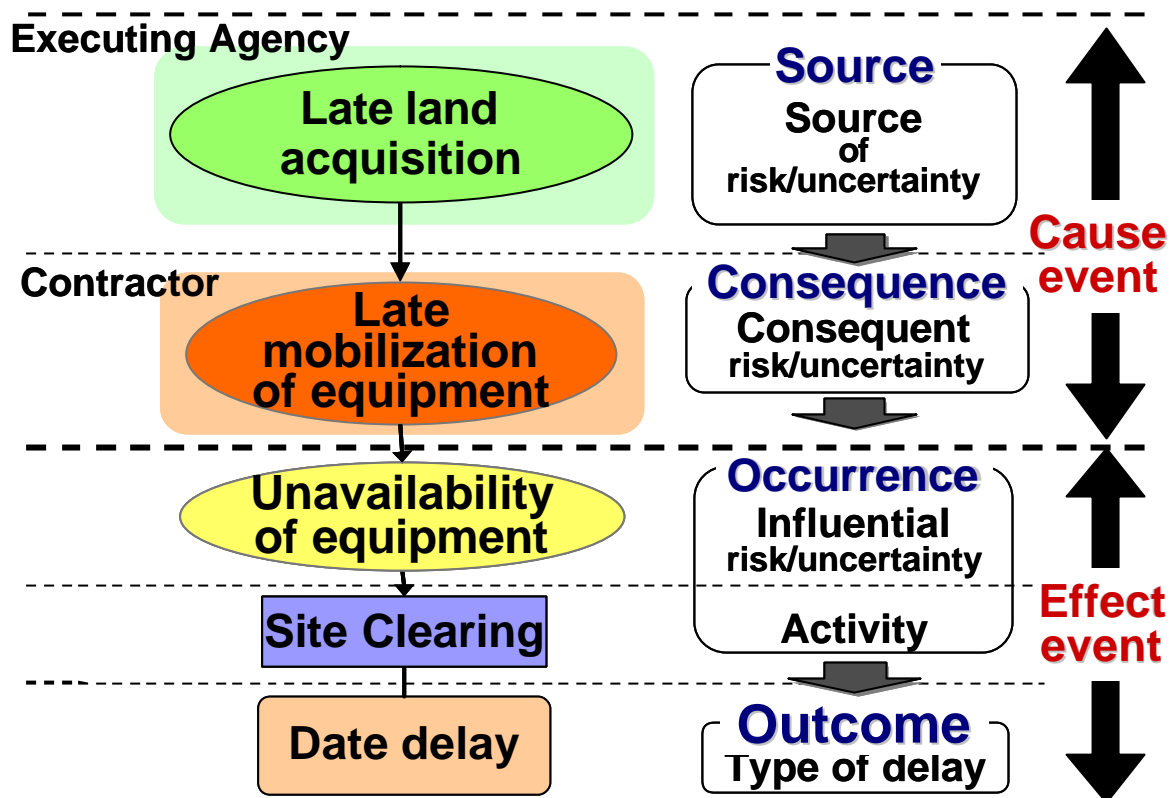


Figure 4.3: Example of framework of hierarchical structure of risk and uncertainty

## 4.6 Summary

In this chapter, the development of risk/uncertainty map and framework of HSRU are explained. First, risk/uncertainty maps of common risks and uncertainties from three infrastructure projects financed by international lenders. The risk/uncertainty map together with RUBS and risk/uncertainty checklist can be used as a tool for assisting practitioners in identifying and structuring risks and uncertainties in future project. Significantly, by accumulating the experience and lessons from past projects and updating the structure, the risk/uncertainty map is considered as 'knowledge base' used for better dealing with risks and uncertainties for both experienced and inexperienced practitioners. Second, by attempting to enhance the precision of RMP outputs, this research develops HSRU as structuring framework to be used as the basis in logically assessing probability and impact. With this framework, the cause and effect events are obviously separated. The HSRU framework is structured based on hierarchical flow of source, consequence, occurrence, and outcome.

## Chapter 5

# Duration Valuation Process

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### 5.1 Introduction

Even though several risk management processes (RMPs) have been proposed to deal with risks occurring in construction projects more systematically and efficiently, there are at least two types of limitation: fundamental limitation and technical limitation of the RMP in practice. These limitations could falsify consequent output of the conventional RMPs and make RMP inefficient. Outputs of the RMP are expected impact and variance of impact associated with each risk response. Since these outputs are usually dimensionless values, they do not directly represent how goals of the project, for example, time and cost, are achieved associated with each response.

The objective of this chapter is to challenge the interpretation difficulty of dimensionless output as a fundamental limitation by developing a duration valuation process (DVP) as a measure to produce output which is easily to be interpreted. Then, the DVP is demonstrated by utilizing application results of the MRMP.

Subjective assessment of probability of occurrence and impact of event is unavoidable in risk and particularly uncertainty management study. Impact of a risk event to a specific project goal is generally assessed “large, medium, or small.” Thus, variance of impact and expected impact, the two main outputs of the conventional RMPs as well as the MRMP, are inevitably represented in dimensionless values. In order to easily interpret results of the RMP or MRMP, therefore, it is desirable to further transform these dimensionless values to those with dimension such as time and present them in terms of the cumulative distribution function (CDF) of project duration. This is the motivation for developing the DVP. Most of description of this chapter is referred to (Pipattanapiwong and Watanabe 2003c).

## 5.2 Previous Risk Analysis Model

There are a number of researches have been conducted in the areas related to delay quantification, scheduling and risk analysis in construction projects. Some researches studied the delay quantification method for construction project (Bordoli and Baldwin 1998; Bubshait and Cunningham 1998; and Shi, Cheung, and Arditi 2001). Some researches focused on predicting the project duration and improving the classical scheduling technique like critical path method (CPM) (Chan and Kumaraswamy 1999; Lu and AbouRizk 2000). However, these researches do not consider and discuss the issue of risk in their models.

Various methods can be used for risk evaluation in the construction project. In general, they can be categorized as classical models i.e., probabilistic analysis and conceptual model i.e., fuzzy set analysis (Kangari and Riggs 1989). The recent models, which attempt to challenge the risk analysis study in variety of way, are shortly described as followings.

Hull (1990) described risk analysis models called Netbuild for time and Estbuild for cost developed by the Accountancy Estimating and Pricing Service (AEPS) of the Ministry of Defense Procurement Executive in UK. It is developed based on stochastic simulation network model with probabilistic node logic. Ranasinghe (1992) suggested an alternative analytical approach to simulation for quantifying risks in project time and economic variables built on the PNET algorithm and on the concept of a transitional correlation. The analytical approach was validated by using Monte Carlo simulation. The validation results demonstrated that the cumulative distribution functions for project time and economic variables generated by the analytical approach compare very favorably with those generated by Monte Carlo simulation.

Ogunlana, Chareonngam, and Tabucanon (1995) described a risk analysis model in proposed planning strategy for high-risk projects. It is based on the Analytical Hierarchy Process (AHP), because the project risks at the work package level are analyzed by incorporation of the subjective evaluation and the nature of risk factors is normally

subjective. Dawood (1998) proposed a methodology relied on risk management approach by considering the variations of activity duration and the dependence between activities and risk factors. Ben-Haim (1998) presented a new concept for improving the reliability of a project schedule influenced by uncertainty in the duration of its activities. The results showed that the technique applying the new concept requires minimal information, incorporates subjective information, is simple to use, and assists in the preparation of project schedules at a desirable level of reliability.

Chan and Kumaraswamy (1999) derived the model for predicting construction of housing project by applying multiple linear regression analysis of historical project data of a series of housing construction activity in Hong Kong. Mulholland and Christian (1999) discussed the development of a computer-based system for risk assessment in construction schedule, by adopting a HyperCard risk factor identification module and available statistical techniques in Excel spreadsheet. Wang and Demsetz (2000a and b) presented the simulation-based model called NETCOR focusing on the issue of correlation to evaluate schedule networks and demonstrated its application. By employing Monte Carlo simulation, Vuong and Watanabe (2001) developed risk analysis models used for quantifying uncertainty in project duration called T-RAM and cost called C-RAM and applied in Vietnamese construction projects. Isidore, Back, and Fry (2001) has pinpointed the importance of cost and schedule integration, then developed technique concerning the integration of range estimate and probabilistic scheduling by using a new procedure called the empirical cumulative density function (ECDF) technique in controlling the risks associated with projects.

Most of previous discussed risk analysis models adopted the probabilistic method and relied on the historical data used in simulation process (Dawood 1998, Mulholland and Christian 1999, Hull 1990, and Vuong and Watanabe 2001).

However, in real construction projects, the historical data used for risk analysis is usually fragmented or even unavailable. Moreover, although many recent models attempt to study both schedule and cost risk analysis in a variety of ways, these models did not explicitly quantify the impact of risk to activity duration. One of the reasons is that the dependency between risks/uncertainties and activities was not clearly identified.



In most of previous models, the activity duration is estimated directly and independently from risks and uncertainties. By concerning the issues of quantification of probability and impact, a further development of conventional risk analysis is desirable. The DVP incorporates these issues in its development. The overview of DVP and its demonstration by using result of the MRMP application are described in the following sections.

### **5.3 Overview of DVP**

To overcome the limitation regarding interpretation difficulty of the RMP outputs and improve quantification of probability and impact in the previous risk analysis models, the proposed DVP attempts to identify the dependency between risks/uncertainties and activities through the use of the hierarchical structure of risk and uncertainty (HSRU) framework as well as basic tool and technique in scheduling i.e., the work breakdown structure (WBS) and CPM scheduling technique. The hierarchically structured risks/uncertainties and the identified dependency between risks/uncertainties and activities can be used to facilitate in assessment of probability and impact of risks/uncertainties.

The DVP relies on the basic set and probability theory in subjectively elicitation of probability. To transform the impact of risk and calculate the delay of an activity, it is based on the productivity rate of work generally used in activity duration estimation and delay mechanism of particular activity caused by specific risk/uncertainty. Monte Carlo simulation in spreadsheet based on the CPM scheduling technique is employed in conducting simulation of project duration. This is a favorite tool used for presentation of risk and uncertainty such in the form of cumulative distribution. The DVP consists of four main processes as shown in Figure 5.1.

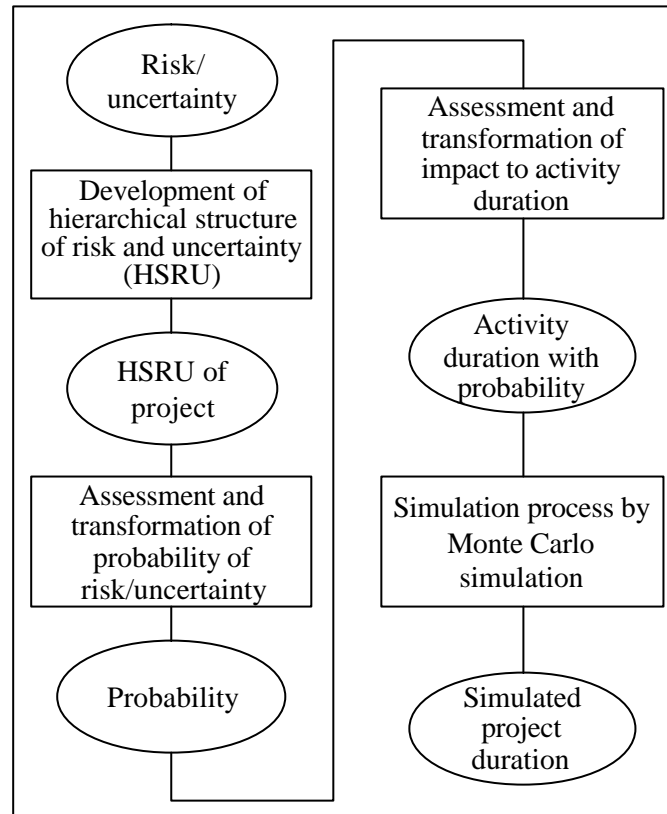


Figure 5.1: Input-process-output flow chart of DVP

### 5.3.1 Work Breakdown Structure and Network

The work breakdown structure (WBS) and scheduling network of the project are two major inputs of the first procedure of the DVP. The WBS is the important fundamental aid in project scheduling and control used to develop project activities and to assign responsibilities.

A network is a diagram showing interconnected activities together with their relationships. It is used to determine the project duration, to learn about the project, to perform “what if” analyses, and to analyze and settle issues such as claim matter (Griffis 2000). According to Grey (1995), network is used to find the critical or longest possible path from start to finish in conventional schedule planning. In schedule risk analysis, by examining it in the same way, it also allow for analysis of risk/uncertainty in the definition of the network, its durations and its logical structure.

Considering this benefit, in examining schedule risk analysis, the DVP relies its basis on the concept of the WBS and scheduling network based on CPM method. After the scheduling network of project is developed in the form of precedence network diagram, which is favorite type of network in recent project management software, it is then modeled in the spreadsheet software such as Excel in order to be used in simulation process later on. The schedule risk model developed in spreadsheet is modeled by concerning the flexibility in changing activity duration, relationship, start and finish date as well as any suspended period, which is based on the mechanism of delay caused by specific risk/uncertainty event. The mechanism of delay is explained in later section.

### **5.3.2 Risk/Uncertainty Structure Diagram**

To develop risk/uncertainty structure diagram, DVP relies on HSRU framework described in previous chapter. Based on identified risks as output from risk/uncertainty identification process, they are structured together to find the causality relationship. From the risk/uncertainty structure diagram, we would know what risks/uncertainties are the sources, which induce other consequent risks/uncertainties that impact any specific activity. The risk/uncertainty structure diagram also facilitate and increase understanding of the risk/uncertainty condition.

### **5.3.3 Risk/Uncertainty and Activity Influential Relationship**

As discussed in early section that the dependency between risk/uncertainty and activity was not explicitly specified in previous schedule risk analysis models. To fulfill this gap, the DVP is based on the activities listed in the WBS and diagramed in the network and the risk/uncertainty structure diagram to specify the influential dependency between activities and cause risks. It is important to understand the influential link between risks/uncertainties and activities in order to further discuss the impact and probability of risk/uncertainty and correlation of random variable, which are necessary inputs in simulation process. Figure 5.2 presents influential relationship between risk/uncertainty (influential risk/uncertainty in HSRU) and activity (activity listed up in WBS) is specified.

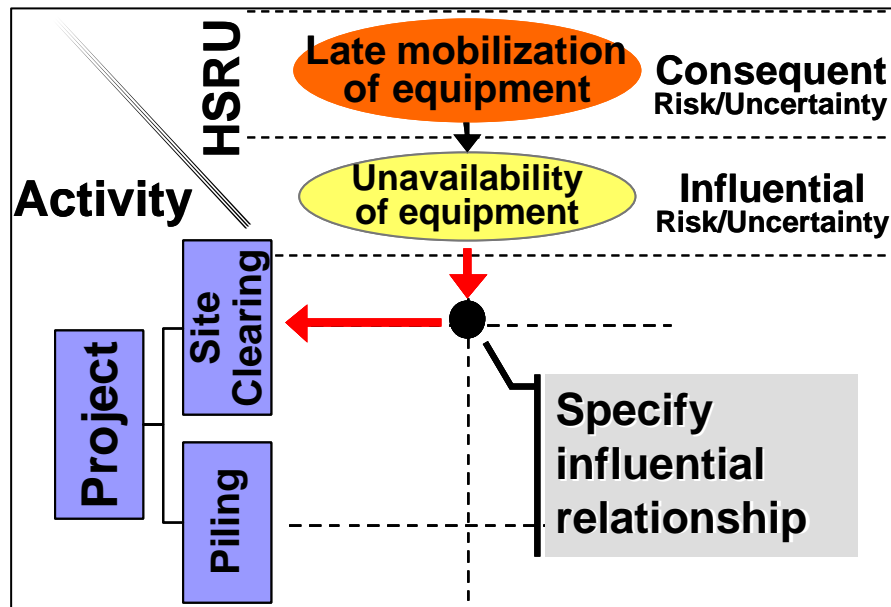


Figure 5.2: Influential relationship between risk/uncertainty and activity

### 5.3.4 Subjective Assessment of Risk/Uncertainty

To assess the impact and probability of risk/uncertainty event, as discussed in early session, the subjective assessment is necessary. The scale of assessment is generally expressed in linguistic terms as ‘large, medium, or small.’ Then, some scaling number e.g., 3, 2, and 1 is assigned to these linguistic terms in order to be used in calculation of expected impact and variance of impact. These calculated numbers are then represented in dimensionless values. Therefore, it is necessary to transform this number to dimensional value in terms of duration in order to facilitate in interpretation and increase understanding of outputs.

### 5.3.5 Mechanism of Delay

According to the main purpose of the DVP, to transform the dimensionless subjectively estimated impact of risk/uncertainty event to dimensional number in terms of duration, the DVP depends on the mechanism of delay of activity caused by identified risk/uncertainty event. In order to logically transform the dimensionless number, the delay mechanism of any dependency between risk/uncertainty and activity is necessarily to be identified and understood. Regarding the delay quantification method for construction project, Bordoli and Baldwin (1998) proposed a methodology, which allow the assessment of the progress of the project at the time the delay occurred; the

changing nature of critical path; and the effects of action taken to minimize potential delays.

Bubshait and Cunningham (1998) studied and compared three delay measurement processes i.e., as-planned method, as-built method, and modified as-built method. It is suggested that the use of delay analysis methodologies is based on the availability of project control data and one method may not be used universally over another in all situation.

Shi, Cheung, and Arditi (2001) also proposed the method, which consists of a set of equations, by contrasting the as-planned and as-built schedules. A purpose of these delay computation methods is to provide the information for determining responsibilities of delays, which can be used in claim settlement. However, a shortcoming of these methods is that they did not incorporate risk in computation.

Bordoli and Baldwin (1998) categorized delay to construction work into six types including date delay, total delay, extended delay, progress delay, additional delay, and sequence delay. Table 5.1 shows the description, example of event and simulation method of each type of delay.

Based on the types of delay categorized by Bordoli and Baldwin (1998), the DVP determines the mechanism of delay in network associated with each type of delay. This mechanism is used to calculate the duration of delay ( $\Delta T$ ) to be added up to base activity duration and any change due to additional and sequence delay. The Figure 5.3 summarizes mechanism of delay.

For the DVP, four types of delay i.e., 1) date delay, 2) total delay, 3) extended delay, and 4) progress delay are focused during specifying dependency between risks/uncertainties with activity and identifying characteristic of activity delay. Next sections provide brief description of each process in the DVP, respectively.

Table 5.1: Types of delay to construction work

Type of Delay	Description	Example	Simulation Method
A) Date delay	An activity cannot start (or finish) until a specific date irrespective of when preceding activities were carried out or were planned to be carried out	<ul style="list-style-type: none"> <li>- The delivery of plant or material scheduled for a specific date without which the work cannot proceed</li> <li>- The start of an activity determined by the availability of labor or a specialist subcontractor who are unable to start until a specific date</li> <li>- The release of information without which the activity cannot proceed</li> </ul>	The addition of an 'imposed date' to the relevant activity in the network
B) Total delay	Complete stoppage to all part of the works occurs	<ul style="list-style-type: none"> <li>- Strikes and lockouts</li> <li>- Postponement of the works</li> <li>- Inability to gain access to or egress from the works</li> <li>- Effects of weather not catered for in the original program</li> </ul>	Adjustment to the calendar for the relevant activities Additional 'holidays' representing the affected periods
C) Extended delay	Duration of an activity is extended	<ul style="list-style-type: none"> <li>- Increase in the work content of an activity</li> <li>- Change in the circumstances in which the work is being carried out resulting in lower productivity than planned</li> <li>- Restrictions in the supply of labor, plant or materials resulting in reduced overall output or intermittent working</li> </ul>	Increase in the duration of the relevant activity
D) Progress delay	Progress of the works was less than that planned	<ul style="list-style-type: none"> <li>- Inadequate labor, plant or materials</li> <li>- Output less than planned</li> <li>- Unscheduled breakdowns of plant</li> <li>- The effects of normal inclement weather</li> <li>- Vandalism</li> <li>- Re-working as a result of workmanship or materials not being in accordance with the specification</li> </ul>	The addition of progress data to the network
E) Additional delay	Additional construction activities are added to the planned work	- New or additional work incorporated into the project subsequent to the production of the original program	Adding activities to the network complete with logic links to existing activities
F) Sequence delay	Activities cannot be carried out in the sequence originally planned	- Changes in specification of materials or techniques which result in activities no longer able to be carried out concurrently	Alterations to the logic links in the network to reflect the new sequence

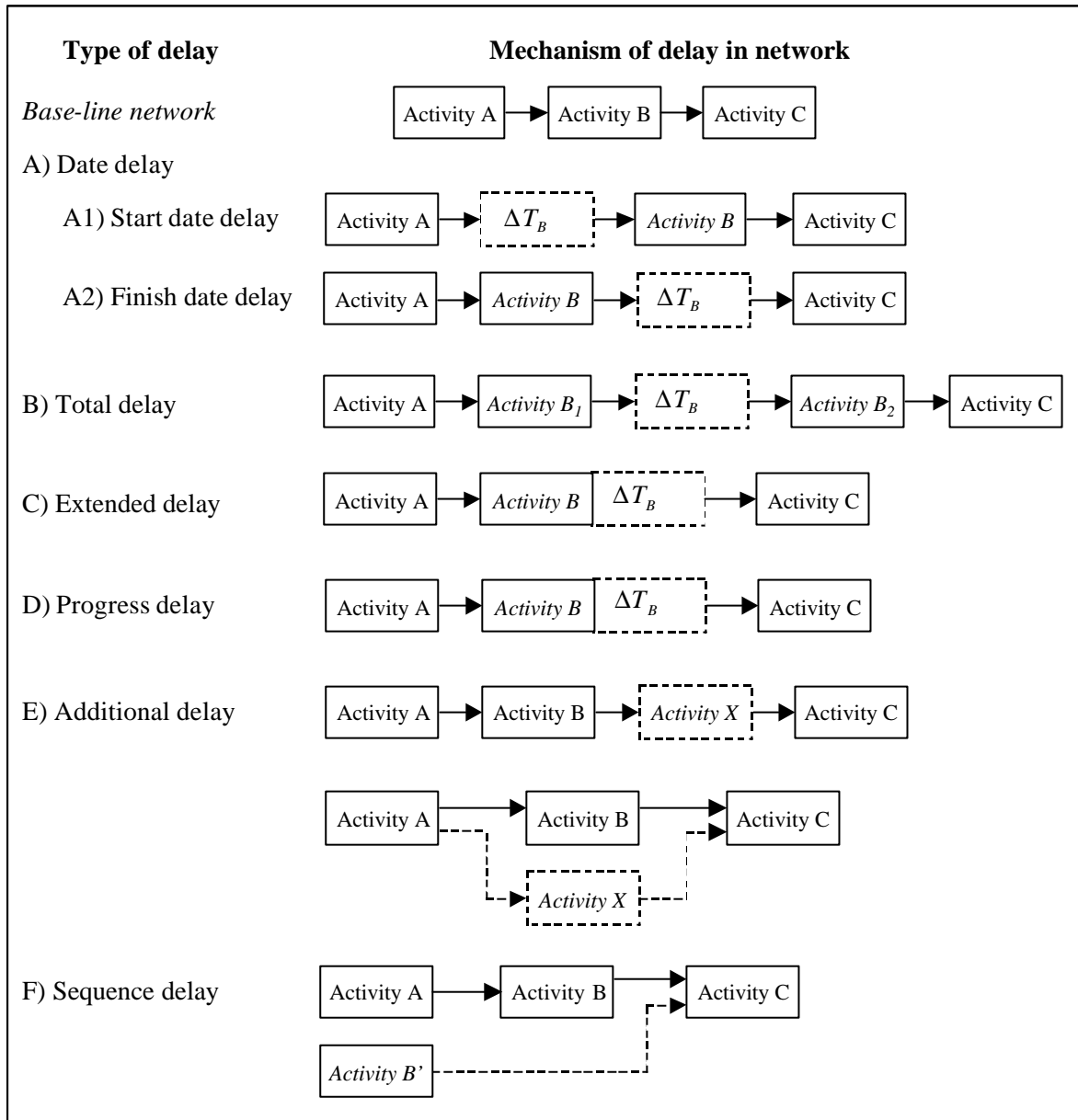


Figure 5.3: Mechanism of delay in network

## 5.4 Development of HSRU

This process aims to develop the structure of risks and uncertainties of particular uncertainty environment represented in form of hierarchical structure called the hierarchical structure of risk and uncertainty (HSRU). This structure aims to facilitate and enhance the understanding of the causality relationship and the transformation of risks/uncertainties. The HSRU is basically considered as a foundation and purposefully used as a main tool in assessment of probability and impact of risks/uncertainties.

Within this development process of the HSRU, two steps are undertaken. The first one is to identify risks/uncertainties based on the risk/uncertainty checklist categorized in accordance to risk/uncertainty breakdown structure (RUBS). The RUBS and the risk/uncertainty checklist have been developed from previous literatures and experiences from some past projects financed by an international lender. The mutually exclusive and collectively exhaustive issues amongst risks/uncertainties have been taken into consideration in the preparation of both the RUBS and risk/uncertainty checklist. Structuring risks/uncertainties is the successive step. The main idea is to find the consequential relationship amongst risks/uncertainties and represent in hierarchical flow from source of risk/uncertainty, consequent risk/uncertainty, influential risk/uncertainty, and types of delay. The developed HSRU is an important deliverable, which will be used in the successive processes.

## **5.5 Assessment and Transformation of Probability**

As discussed in early session, the subjective assessment is inevitable for probability assessment of risk/uncertainty. In order to obtain the reliable assessed probability, the DVP attempts to facilitate the decision-makers to comprehensively and comfortably assess the probability. The basis of probability assessment process theoretically relies on the set and probability theories. The developed HSRU is the main tool used simultaneously throughout the probability assessment process. Based on the developed HSRU, the risk/uncertainty space (sample space in the set theory) is specified. Each risk/uncertainty in the specified risk/uncertainty space is regarded as an event in the set theory. The probability of risk/uncertainty is assessed based on the conditional probability and multiplication rule in the probability theory. The detail explanation of set theory and conditional probability and multiplication rule in probability theory is available at Benjamin and Cornell (1970), Ang and Tang (1975), Holloway (1979), and Devore (2000).

To assess conditional probability, we do rely on the dependency among risks/uncertainties structured in HSRU.



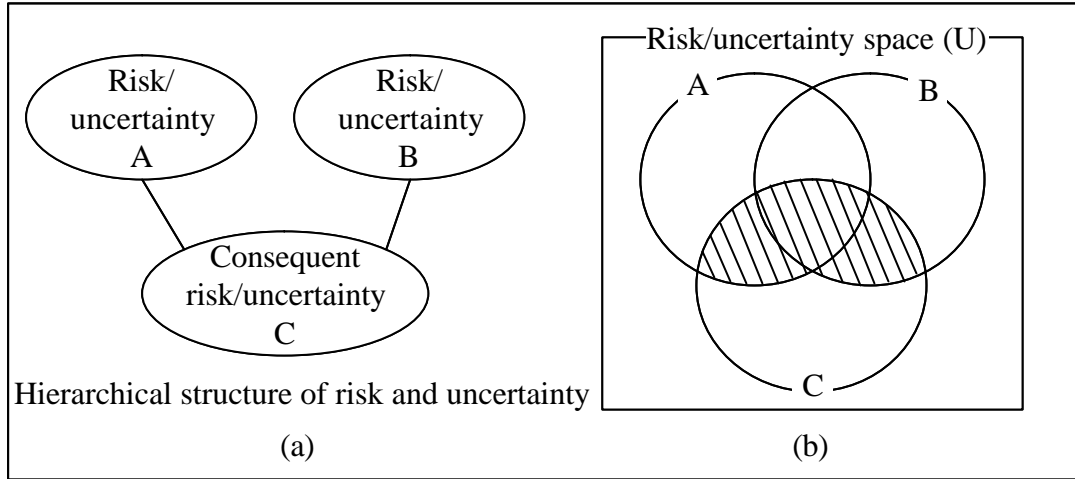


Figure 5.4: (a) Sample of hierarchical structure of risk and uncertainty and (b) based on the Venn diagram of the HSRU in (a) the shaded area shows  $\Pr(C \cap (A \cup B))$

Based on the sample HSRU and its Venn diagram presented in Figure 5.4, the probability of consequent uncertainty C could be derived as shown in Eq. 5.1.

$$\Pr(C \cap (A \cup B)) = \Pr(C | (A \cup B)) \Pr(A \cup B) \quad (\text{Eq. 5.1})$$

The assessment scale of probability is generally expressed in linguistic terms. One of expressions is ‘extremely unlikely,’ ‘very unlikely,’ ‘unlikely,’ ‘fairly likely,’ ‘likely,’ ‘highly likely’ as shown in Table 5.2 (ICE 1998). These defined linguistic terms represent the decision-maker’s perception of likelihood of occurrence, which will be transformed to the range from 0 to 1.

Table 5.2: Example of probability assessment expression and scale

Description	Scenario	Probability	Scale
Highly likely	Very frequent occurrence	Over 85%	16
Likely	More than evens chance	50-85%	12
Fairly likely	Quite often occurs	21-49%	8
Unlikely	Small likelihood but could well happen	1-20%	4
Very unlikely	Not expected to happen	Less than 1%	2
Extremely unlikely	Just possible but very surprising	Less than 0.01%	1

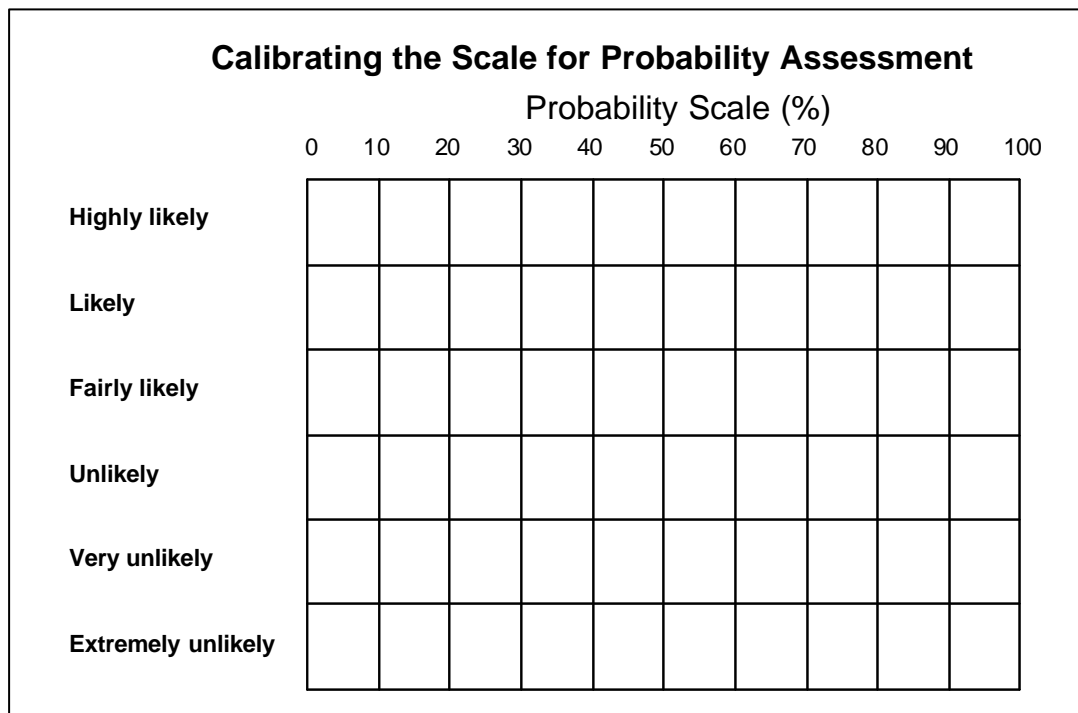


Figure 5.5: Example of calibrating scale for probability assessment

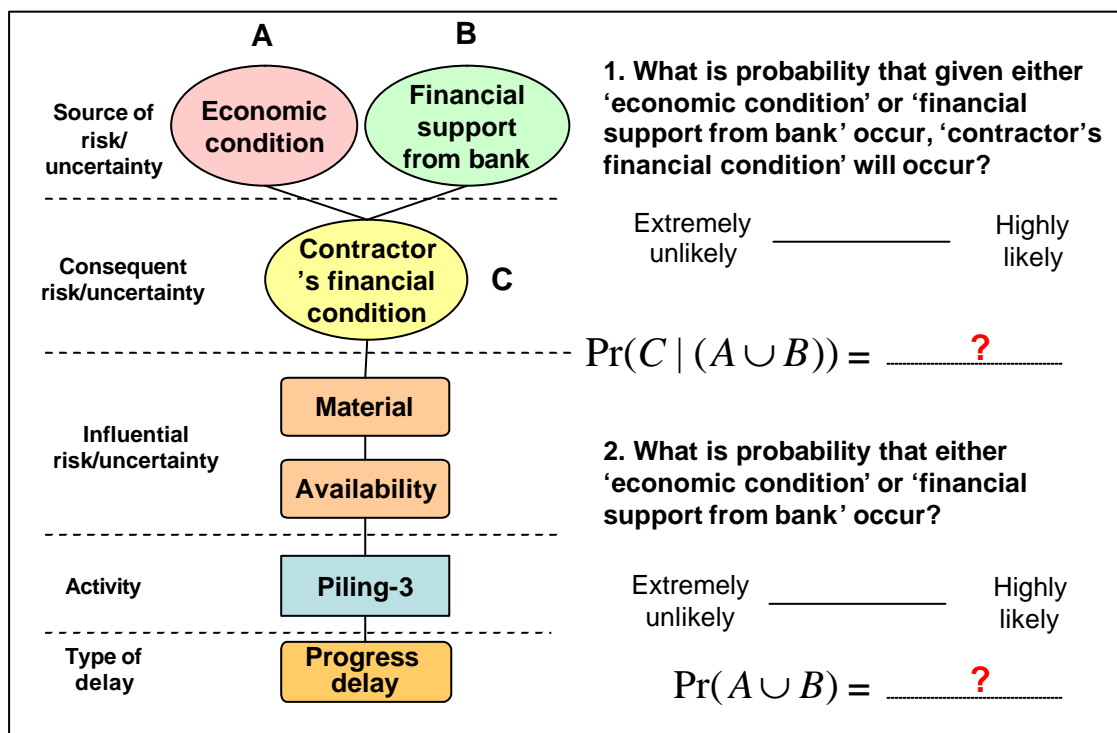


Figure 5.6: Example of questions in probability assessment

Since different assessor may have different perception towards the wording expression of probability scale, the probability scale then is previously calibrated before assessment. Example of calibrating scale of probability assessment is shown in Figure 5.5. After we calibrate the scale of probability assessment, the probability is elicited based on questions designed based on conditional probability and multiplication rule in probability theory. Figure 5.6 shows an example of questions in probability assessment.

## 5.6 Assessment and Transformation of Impact to Duration

It is important to understand the influential relationship between particular risk/uncertainty and specific activity in order to quantify the impact of risk/uncertainty in terms of activity delay. Based on the influential risk/uncertainty in HSRU i.e., the risks/uncertainties related to material, labor, equipment, subcontractor, work and site, the influential relationship between these risks/uncertainties and activities is linked. To subjectively quantify the impact and transform it to activity delay, the DVP employs the basis of the production rate basically used in estimating activity duration (Griffis and Farr 2000). The Eq. 5.2, which is the base equation in the calculation of delay, depicts the activity duration ( $d$ ) in terms of work quantity ( $w$ ) and production rate ( $p$ ). The impacted activity duration (or period from start to finish) ( $\bar{d}$ ) is calculated by adding activity delay ( $\Delta d$ ) with the original duration ( $d$ ) as shown in Eq. 5.3.

$$d = \frac{w}{p} \quad (\text{Eq. 5.2})$$

$$\bar{d} = d + \Delta d \quad (\text{Eq. 5.3})$$

In order to comprehensively assess and calculate the activity delay, it is desirable to clarify the type of delay. Because the impacted variables i.e., activity duration, work quantity, and production rate, vary according to types of delay. To quantify the delay, the decision-maker will assess the percent variation i.e.,  $\mathbf{a}$  for activity duration,  $\mathbf{d}$  for work quantity, and  $\mathbf{b}$  for production rate of each variable as shown in Eq. 5.4 – Eq. 5.6, respectively.

$$\Delta d = (1 + \mathbf{a})d - d \quad (\text{Eq. 5.4})$$

$$\Delta d = \frac{(1 + \mathbf{d})w}{p} - \frac{w}{p} \quad (\text{Eq. 5.5})$$

$$\Delta d = \frac{w}{(1 - \mathbf{b})p} - \frac{w}{p} \quad (\text{Eq. 5.6})$$

Based on the type of delay categorized by Bordoli and Baldwin (1998), the DVP adopts four types of delay including date delay, total delay, extended delay, and progress delay. The description, impacted variables, and assessed percent variation of each type of delay are summarized in Table 5.3.

Table 5.3: Type of delay, impacted variable and percent variation

Type of Delay	Description	Impacted Variable	Percent Variation
Date delay	Start and/or finish of activity is delayed.	Original duration ( $d$ )	$\mathbf{a}$
Total delay	Activity is stopped or suspended.	Original duration ( $d$ )	$\mathbf{a}$
Extended delay	Work quantity is increased.	Work quantity ( $w$ )	$\mathbf{d}$
Progress delay	Production rate is decreased.	Production rate ( $p$ )	$\mathbf{b}$

Similar to probability assessment, the assessment scale of impact is also described in linguistic explanation. One of expressions is described as ‘negligible,’ ‘marginal,’ ‘substantial,’ ‘severe,’ ‘disastrous.’ The decision-makers can assess the impact of uncertainty by determining the percent variation of each variable based on this scale. Figure 5.7 shows the impact assessment procedure. Additionally, the DVP employs three-point estimate i.e., optimistic, most likely, and pessimistic similar to PERT in defining triangular distribution of activity duration. However, in the DVP, these three points of duration are not directly assessed like in the PERT. Here, the optimistic duration is the original activity duration. The most likely duration is the expected impacted activity duration. Finally, the pessimistic duration is the original duration plus the delay.

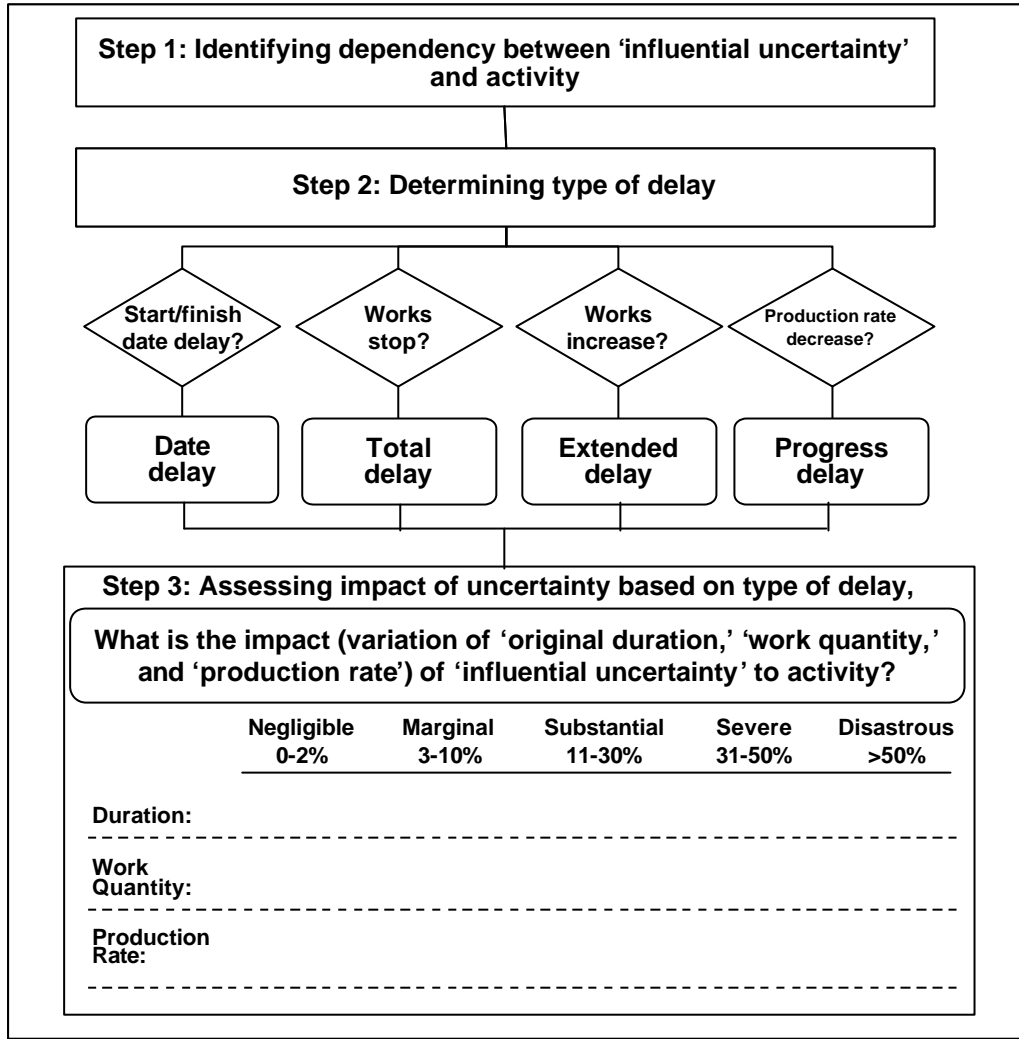


Figure 5.7: Impact assessment procedure

## 5.7 Simulation Process of Project Duration

The DVP adopts the probabilistic approach by using the Monte Carlo simulation technique. The random variable in simulation is activity duration. The assessed and transformed probability and impact of uncertainty are main inputs in simulation process. In the DVP, the simulation model based on the CPM method is shown in following equation.

$$\overline{D'} = \overline{d'_1} + \overline{d'_2} + \cdots + \overline{d'_n} = \sum_{i \in S} \overline{d'_i} \quad (\text{Eq. 5.7})$$

Where  $\overline{D}$  is the probabilistic project duration.  $\overline{d}_i$  is the probabilistic activity duration of the activities in critical path.  $S$  is the set of critical activity depending on realization of random variable. This simulation model is modeled in spreadsheet software. Simulation software is used in simulating the project duration.

## **5.8 Demonstration of DVP**

In this section, the DVP is demonstrated by using the result of the MRMP application and post-evaluation in a bridge and elevated road construction project financed by an international lender located in a Southeast Asian country.

### **5.8.1 Schedule Information**

Based on construction schedule proposed by contractor during bidding stage, three-levels WBS and scheduling network of project have been prepared. For the sake of simplicity in demonstration, this paper focuses on a work item in WBS i.e., flyover bridge-2. Its scheduling network diagram is shown in Figure 5.8.

### **5.8.2 Hierarchical Structure of Risk and Uncertainty**

The consequent risks/uncertainties, which influenced the activities in this work item consisting of ‘contractor’s financial condition,’ ‘supplier’s financial condition,’ and ‘technical capability of subcontractor.’ From the first process in the DVP, the HSRU, influential relationship between risks/uncertainties and activities, and types of delay are shown in Figure 5.9.

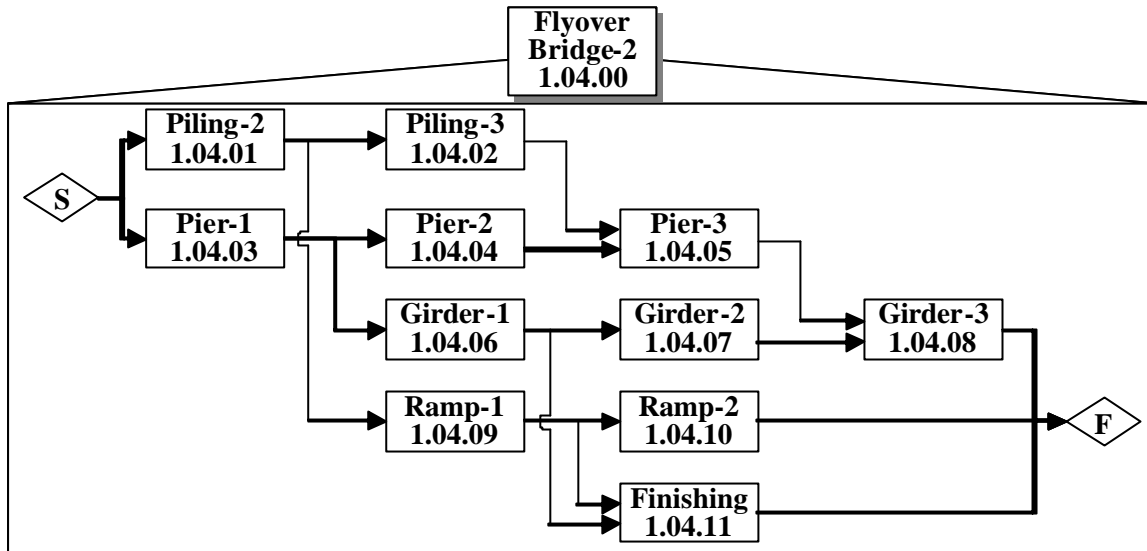


Figure 5.8: Scheduling network diagram of flyover bridge-2 work item

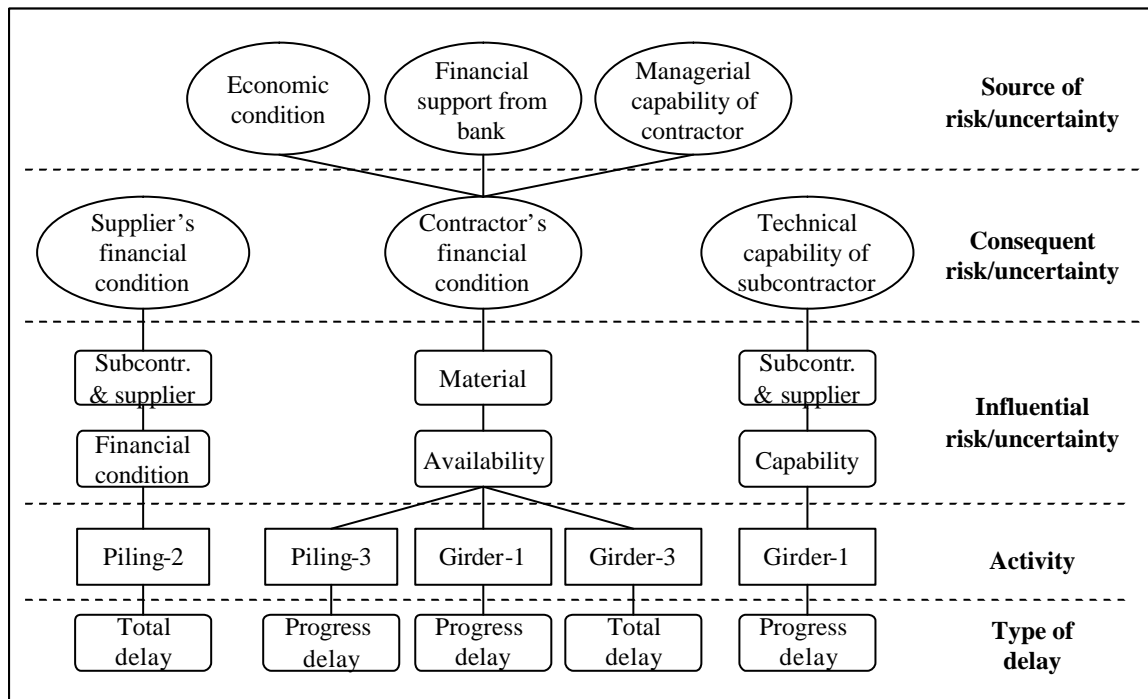


Figure 5.9: Hierarchical structure of risk and uncertainty, risk/uncertainty-activity relationship, and type of delay

### 5.8.3 Assessed and Transformed Probability and Impact

In the MRMP, the scale of probability and impact assessment was expressed as ‘very low,’ ‘low,’ ‘medium,’ ‘high,’ and ‘very high.’ For probability, the set of numerical value (i.e., 0.1, 0.3, 0.5, 0.7 and 0.9) are defined for ‘very low’ to ‘very high’ in assessment

scale respectively. The case studied project used in the MRMP was actually delayed approximately 50% of original contract duration. Thus, for impact assessment, the percent variation scale is defined as 10%, 20%, 30%, 40%, and 50% for ‘very low’ to ‘very high’ in assessment scale respectively. Table 5.4 summarizes the assessed and transformed probability and impact as well as three-point estimate of duration.

Table 5.4: Assessed and transformed probability and impact

Activity	Percent Variation			Delay Dd (days)	Probability	Optimistic (Original duration) (days)	Most likely (Expected impacted duration) (days)	Pessimistic (Impacted duration) (days)
	U1	U2	U3					
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Piling-2	-	$\alpha$ : Medium (30%)	-	18.3	0.5	61	70.15	79.3
Piling-3	$\beta$ : Very high (50%)	-	-	167.5	0.1	335	351.75	502.5
Girder-1	$\beta$ : Very high (50%)	-	$\beta$ : Medium (30%)	206.4	0.05 (0.1*0.5)	258	268.32	464.4
Girder-3	$\beta$ : Very high (50%)	-	-	106	0.1	212	222.6	318
U1 = Contractor's financial condition (probability = very low (0.1))					Delay (5) = $\sum$ (Percent variation (2, 3, 4) * Original duration (7))			
U2 = Supplier's financial condition (probability = medium (0.5))					Expected impacted duration (8) = Original duration (7) + [Probability (6) * Delay (5)]			
U3 = Technical capability (probability = medium (0.5))					Impacted duration (9) = Original duration (7) + Delay (5)			

## 5.8.4 Simulation Result

In the simulation, the triangular probability distribution is assigned for duration of activity. Subsequently, the Monte Carlo simulation was conducted by using simulation software. The probability and cumulative distributions of duration of flyover bridge-2 work item are shown in Figure 5.10 as the outputs of the DVP process.

Based on the deterministic scheduling, the duration of flyover bridge-2 work item is 669 days. On the other hand, from the result of the simulation (2,000 iterations) that taking the risks/uncertainties into consideration, it was found that the expected duration is about 805 days. The minimum duration is about 703 days. The maximum duration is about 951 days. Moreover, for example, there is 80% probability that this work item will complete not later than 844 days.



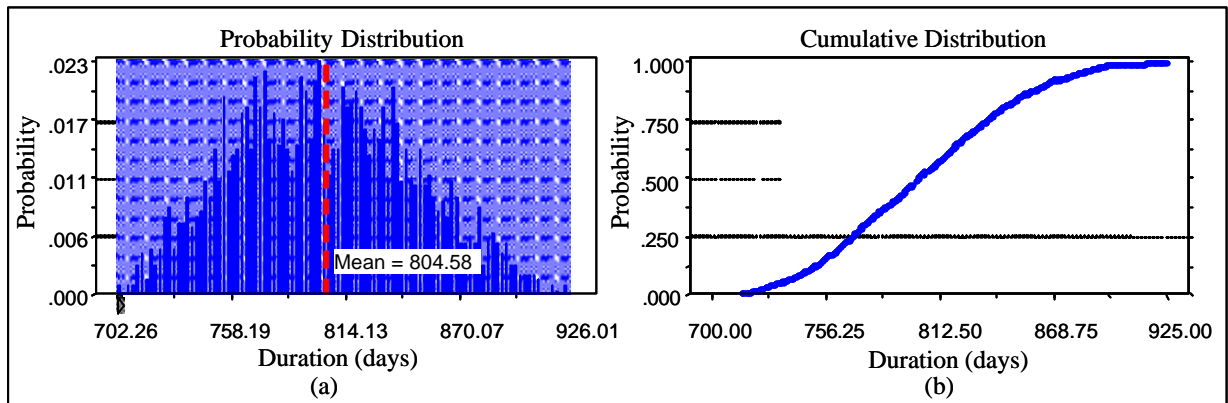


Figure 5.10: Probability and cumulative distributions of duration of flyover bridge-2 work item

## 5.9 Summary

This chapter aims to challenge a limitation regarding difficulty in interpretation of the RMP output due to its presentation in dimensionless values. The DVP has been developed. Overview of processes in the DVP is described in this chapter. Then, it is demonstrated by using results of the MRMP application and post-evaluation. From the result of demonstration, as an example, the hierarchical structure of risk and uncertainty, influential relationship between risks/uncertainties and activity, type of delay, and probability and cumulative distributions of work item duration could be obtained. By using the DVP in this case study, the dimensionless value of RMP outputs could be transformed to dimensional value in term of duration and presented in cumulative distribution. With this information, the DVP could be regarded as a decision making tool for producing useful information used in managing the project risk/uncertainty.

## **Chapter 6**

# **Multi-party Risk and Uncertainty Management Process**

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### **6.1 Introduction**

This chapter provides explanation of proposed risk and uncertainty management process called multi-party risk and uncertainty management process (MRUMP). The MRUMP is a logical, systematic, and concise risk and uncertainty management tool aiming to assist practitioners e.g., policy maker, lender, owner, consultant, and contractor in systematically and efficiently managing risk and uncertainty and encouraging all parties to communicate each other, identify problem, and cooperatively solve the problem. Similar to other formerly proposed RMPs, it possibly can be used by one party as decision-making tool under uncertainty and risk condition. Additionally, in multi-party environment with many parties are involved, it can be possibly employed as decision-making tool as well as communication tool in facilitating negotiation, preparing problem preventive measures and seeking problem solutions.

### **6.2 Overview of MRUMP**

The MRUMP is grounded on “logical and practicable” basis. Both conceptual framework and procedural steps necessary for hands-on implementation are main ideas in designing this implementing manual of MRUMP. Practitioners who aim to use this manual are encouraged to understand the overview of entire process of MRUMP. It is also encouraged to review the literatures related to risk management provided in Chapter 2 in order to build foundation and comprehension of risk and uncertainty management.

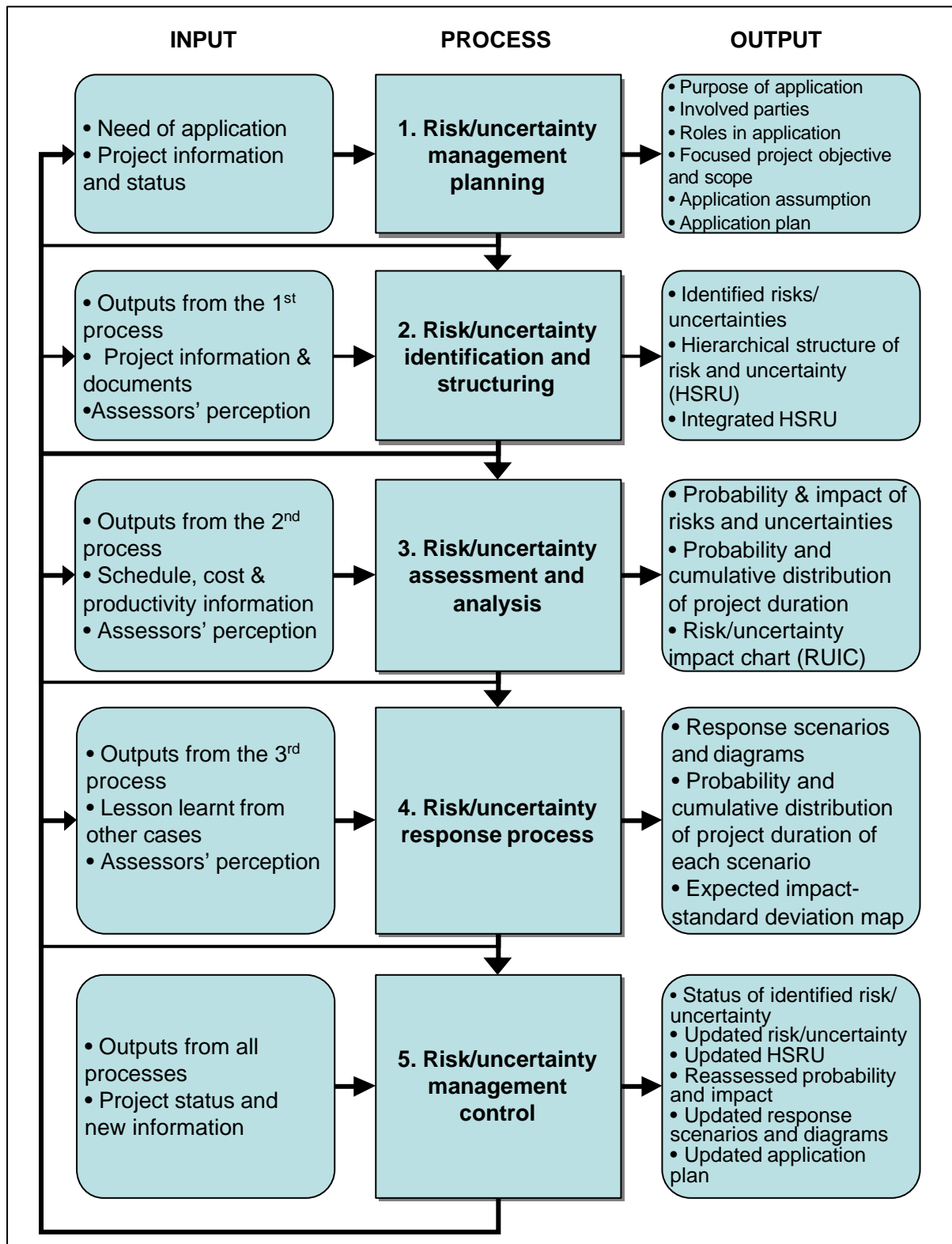


Figure 6.1: Overview of MRUMP

The MRUMP consists of five connective processes including:

1. risk/uncertainty management planning: is to set and define framework of application,
2. risk/uncertainty identification and structuring: is to identify and structure risks and uncertainties influencing project objectives,
3. risk/uncertainty assessment and analysis: is to assess and analyze identified risks and uncertainties based on developed HSRU,
4. risk/uncertainty response process: is to provide proactive and reactive response scenarios to risks/uncertainties, and
5. risk/uncertainty management control: is to administer, monitor, update and control risk and uncertainty management application.

The MRUMP is described based on the flow of input-process-output. The rectangular shape represents process and procedure. The rounded rectangular shapes represent inputs and outputs of process. Figure 6.1 provides overview of processes included in MRUMP. The following sections describe application framework, and step-by-step procedures together with tools and techniques of each process, respectively.

### **6.3 Application Framework of MRUMP**

The MRUMP considers both practical and theoretical issues in development. As mentioned previously, it is considered as a project performance oriented tool used for problem preventing and solving that encourages ‘harmony’ attitude and effective and efficient communication among all project parties. To define the purpose of MRUMP application, it is important to consider different objectives and roles of all parties in traditional contracting procedure.

In the framework of application, the issues regarding timing of application based on the traditional contracting practice, purpose of application, and available information are considered important because application of MRUMP is directly related these mentioned issues. In different stages of project, the availability and detail of information

is different. When the project further proceeds from planning, bidding, contract forming to construction stage, we are able to know more information such as in case of schedule and productivity information. Figure 6.2 describes the purpose of application and available information in practice in each stage of traditional contracting.

Based on application framework, project stage is divided into three main stages including 1) pre-construction stage (from planning to contract signing), 2) early stage of construction (from contract signing to beginning period of project commencement) and 3) during construction.

Since each party (i.e., owner, consultant, and contractor) has different objectives in each stage of project, the purpose of application is then depended on position of involved parties. During pre-construction stage, owner and consultant, owner and consultant may use the MRUMP to assist in determining reasonable project objectives (project duration and cost) and in drafting contract clauses. In this stage, usually only experience of past similar project and rough estimation information is available.

During the bidding, the bidders may use the MRUMP in assisting them to make bid/no bid decision and determine the contingency amount in bid proposal for risk and uncertainty. Based on the bid documents that normally contain description of work, determined project duration, specified contract clauses and bill of quantity (BOQ) items, with their experience and available in-house schedule and cost information, they usually have more detail information than owner and consultant in doing analysis in this stage.

When project proceeds to construction stage, at the beginning of project normally the contractor has to submit the work program (schedule) to owner and consultant for approval. Then, it will be used as base-line schedule for project monitoring and control during construction. This schedule and productivity information is considered important in conducting analysis in both early and during construction stages. For the purpose of application during construction, at the early stage of construction, all parties may use the MRUMP to proactively prepare the measures for schedule deviation and cost overrun. Then, if it is necessary, project schedule and cost may be revised in order to be

responsive for future prospective risks and uncertainties. In case if the project is suffering from delay, the MRUMP may be used in assisting in determining time extension and additional cost in both early and during construction stage as reactive action.

Furthermore, the timing of application is very important when we assess and transform the impact of risks/uncertainties. Because in transforming process we have to rely on the available information (schedule and productivity information) that is directly depended on timing of application. In planning stage, normally, the detail schedule and productivity information is not available. In this case, we are able to assess the impact of risks/uncertainties influencing work items only in upper level of work breakdown structure (WBS). We may not be able to assess impact of risks/uncertainties in very detail. For example, we may be able to assess the impact to duration of an activity in unit of month or year rather than in day or week. In construction stage, when we have more schedule and productivity information, we are able to assess the impact of risks/uncertainties to duration, work quantity or production rate of activity in lower level of WBS.

## **6.4 Risk and Uncertainty Management Planning Process**

The first process in MRUMP is related to planning activities of how the MRUMP is to be implemented. The risk and uncertainty management planning process aims to set and define framework of application including following issues: the purpose of application, involved parties, role in application, focused project objectives, scope of analysis, application assumption, and education of the MRUMP procedure.

### **6.4.1 Input of Risk and Uncertainty Management Planning Process**

As the starting point, the inputs of risk and uncertainty management planning process are related to needs of application, and available project information and status.

### ***1. Need of application***

The need of application is the first important input to entire process. Unless the need of application is clearly defined, we may not be able to set the framework of application. The need of application is related to purpose of application and is expressed as what that party(s) would like to obtain from the MRUMP application.

### ***2. Project information and status***

To understand available project information and current project status enable in setting scope and assumption of application. Project information means available information at the time of assessment such as schedule and productivity information in construction stage.

## **6.4.2 Procedure, Tool and Technique of Risk and Uncertainty Management Planning Process**

The procedural steps in this process are explained as follows.

### ***1. Defining purpose of application***

To define the purpose of application, we have to understand the need of application. In assisting this task, MRUMP provides predefined purpose of application along the project stage in traditional contract as shown in Figure 6.2. It is desirable to identify the need of application collectively in multi-party environment.

### ***2. Assigning role in application and decision-making***

Generally, in decision making process, three main roles are probably existed i.e., (1) experts or assessors, (2) evaluation analyst, and (3) decision makers (Schuyler 1996). Experts or assessors are ones who provide the judgments that is main input in the evaluation. The most knowledgeable people in the context we are considering should be seen as experts or assessors. Evaluation analysts are ones who have responsibility in developing analysis models that generate scenario outcomes and forecasts for each alternative. Decision makers' roles are to review the forecasts and judge the credibility of analysis. Then, they select the alternative and implement it. This is usually made by

accepting team's recommendation. This explains the common and general responsibility of three main roles in decision making.

#### ***4. Defining focused project objective and scope***

Project objectives are expressed in terms of project schedule and cost. Scope of application may cover entire project scope, particular work items, or particular activity in WBS of project. To define the project objective and scope, it depends on the purpose of application, available information at time of assessment and precision of result desired by practitioners. The framework of application shown in Figure 6.2 can be used as guideline in defining the focused project objective and scope.

#### ***5. Setting assumption of application***

After purpose of application, involved parties, role in decision-making, focused project objectives and scopes are defined, the next step is to set the assumption of application regarding time frame of assessment and timing of assessment. Time frame of assessment means time projection period for assessment of probability and impact of risk and uncertainty. Timing of assessment means the point of time, when assessors are assumed to assess the probability and impact of risk and uncertainty.

#### ***6. Educating overview procedure of MRUMP***

It is desirable for assessor, analyst and decision-maker to understand the contents of MRUMP process in order to be able to follow the procedure throughout the application. Group seminar and presentation may be used in educating all involved participants regarding the concept and procedure of MRUMP. It is preferable to educate participants all of procedures described in each process. However, it is not mandatory and sometimes difficult due to limitation of participants' background, knowledge and time. It also depends on the role and interest of particular practitioner. At least the overview of MRUMP (as shown in Figure 6.1) and summary tables of all processes should be provided.

Tool and techniques are used in facilitating each steps include:



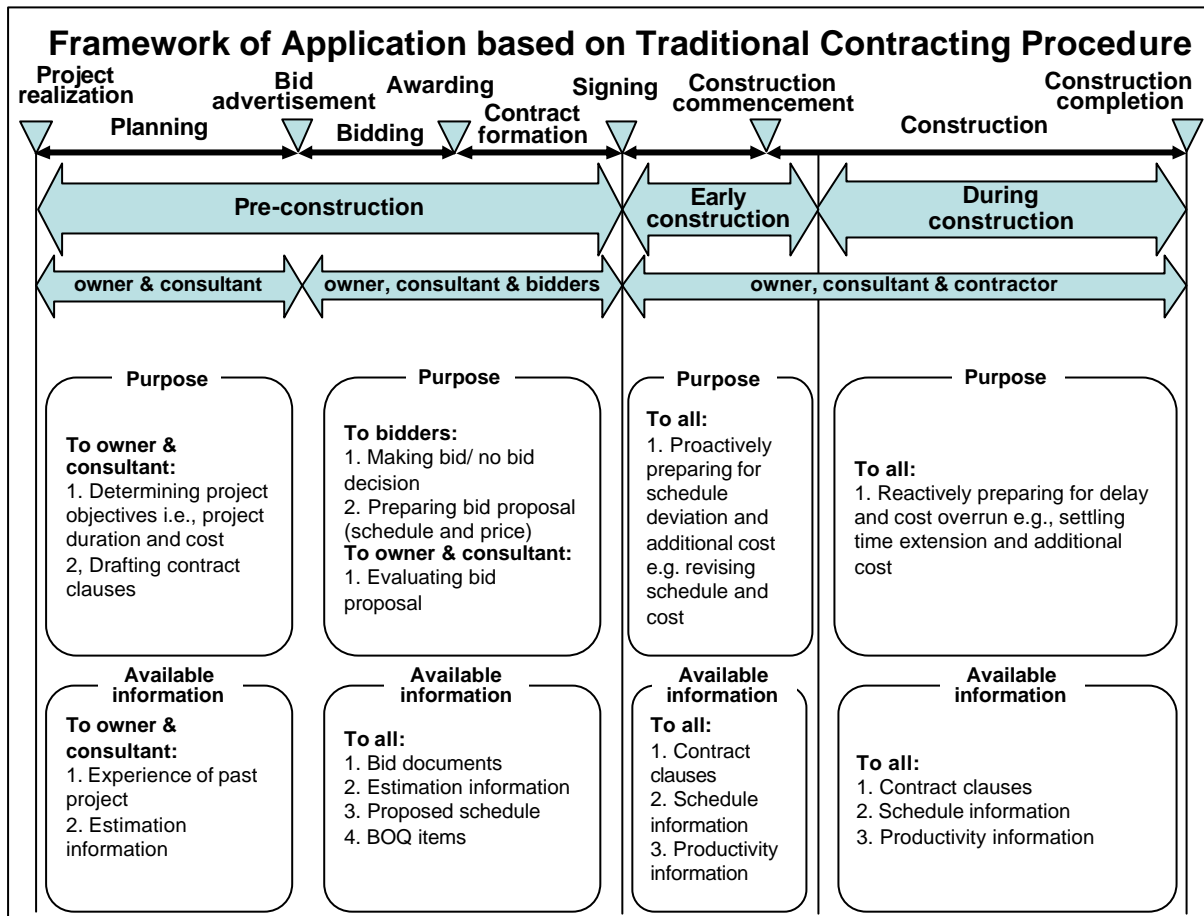


Figure 6.2: Predefined framework of application of MRUMP

### 1. Predefined framework of application

As shown in Figure 6.2, it explains the purpose of application of MRUMP together with common available information in each stage of project (based on traditional contracting) associated with each project party such as owner, consultant and contractor. This predefined framework of application is used for facilitating assessors, analyst, and decision-makers in defining purpose of application, focused project objectives and scope.

### 2. Overview MRUMP process diagram

This diagram aims to provide overview of input-process-output flow of each process in MRUMP. As shown in the diagram in Figure 6.1, even though each process is connected in process by process basis, the practitioners are encouraged to perform follow up and feed back loop when finishing each process. This is to confirm the reliability of

assessment. Moreover, it is encouraged to use this diagram in educating all involved participants of MRUMP.

### **6.4.3 Output of Risk and Uncertainty Management Planning Process**

The outputs of this process constitute the important implementing framework of following successive processes.

#### ***1. Purpose of application***

For example, the MRUMP may be used by owner and consultant for determining project objectives (time and budget) in the very early of project as well as drafting contract condition in pre-bidding stage. Bidders may use it for determining contingency in their bid proposal. These are examples of purpose of application based on individual perspective. In contract formation, it may be used as negotiation tool by all parties. During construction stage, it may be used as problem preventing tool at the early stage of construction and problem solving tool when problems happening during construction.

#### ***2. Involved parties***

It depends on the purpose of application and stage of project in defining involved parties. As explained in previous section, during the early stage of project, normally only owner is the main party to perform tasks with assistance of consultant. When project progresses to bidding stage, another party, the bidders, participates in bidding. In contract formation stage, this is considered the starting point of multi-party environment that involved parties should consist of owner, consultant and contractor.

#### ***3. Assessors, analyst, and decision-maker***

It depends on the purpose of application and project scope in determining assessors, analyst and decision-maker. For example, if we are going to quantify project delay at the early stage of construction project, assessors may be top management level of all parties. In case of analyst, the consultant may be an appropriate position in performing this task. Otherwise, external party may be employed. For decision maker, it depends on which response scenario will be implemented.

#### ***4. Focused project objective and scope***

If we would like to estimate time extension of project due to expected delay of some activities during construction stage, the focused project objective is project time (schedule) and expected activities are considered as scope.

#### ***5. Assumption of application***

The time frame of assessment is defined according to purpose of application and scope. For example, at the early stage of construction, if we would like to quantify impact of risk and uncertainty causing project delay during construction. The assessment time frame in this application is set as during construction of project.

#### ***6. Application plan***

The final output of risk and uncertainty management planning process is an application plan aiming to summarize detail of all outputs such as purpose of application, involved parties, roles in application, focused project objective and scope, and assumption of application in form of documentation. This is to enable all parties involved to have the same understanding towards framework of application.

The inputs, procedure, tool and techniques and outputs are summarized in Table 6.1.

Table 6.1: Summary of inputs, process, outputs of risk and uncertainty management planning process

INPUT	Examples			
1. Need of application				
2. Project information and status	Type, contract duration and cost, contract start and finish date			
PROCEDURE	An	As	DM	Tool & Technique
1. Defining purpose of application	-	-	P	1. Predefined framework of application
2. Assigning role in application and decision-making	-	-	P	1. Meeting
3. Defining focused project and scope	A	P	P, R	1. Predefined framework of application
4. Setting assumption of application	A	P	P, R	1. Predefined framework of application
5. Educating overview procedure of MRUMP	P	-	-	1. Group seminar 2. Presentation 3. Overview of MRUMP
OUTPUT	Example			
1. Purpose of application	Preparing preventive plan for schedule delay			
2. Involved parties	Owner, consultant, contractor			
3. Analyst, assessors, and decision-maker	Consulting engineer, site engineer, project manager			
4. Focused project objective(s) and scope	Duration of project, duration of activity, cost of project, cost of activity			
5. Assumption of application	During construction period			
6. Application plan				
<b>Remark:</b> ‘An’ is analyst, ‘As’ is assessor, ‘DM’ is decision-maker P: Prime responsibility, A: Assisting, R: Reviewing				

## 6.5 Risk and Uncertainty Identification and Structuring Process

When the framework of application and application plan are already prepared, it is the time to execute the plan. The next process is risk and uncertainty identification and structuring process aiming to identify risks and uncertainties, which influence project goals (e.g., time and cost), and to construct their hierarchical structure representing their hierarchical influential relationship based on each party's view. The identification and structuring of risks and uncertainties is the most significant task, which the effect of its correctness is crucial to successive processes and accuracy of final outputs. This is because the assessment and analysis of probability and impact to be conducted in subsequent processes is totally grounded on the identified risks and uncertainties and their hierarchical structure.

Significantly, this process attempts to challenge the 'unidentifiable' condition of uncertainty by trying to change 'unknown known' and 'unknown unknown' to 'known

known' and 'known unknown' respectively. It is not completely impossible to identify 'unidentifiable' uncertainty, when the proper and sufficient study is conducted with assistance of logical and systematic tool. With this elaborate study, the 'unidentifiable' uncertainty due to negligence, lack of experience, and inadequate knowledge is possibly identified and realized. The success of this effort probably induces high possibility in great reduction of uncertainty, if practitioners provide enough care and attention by further analysis and management after realization of what threat may occur.

The grounded concept of this risk and uncertainty identification and structuring process is based on the hierarchical structure of risk and uncertainty (HSRU) framework explained in Chapter 4 and the first process (development of hierarchical structure of risk and uncertainty) of duration valuation process (DVP) explained in Chapter 5. Therefore, the implementing procedures are mainly focused in this chapter.

### **6.5.1 Input of Risk and Uncertainty Identification and Structuring Process**

In addition to outputs from the previous process, the necessary inputs of risk and uncertainty identification and structuring process are follows.

#### ***1. Project information and documents***

As shown in framework of application (Figure 6.2), the available information is different in different stage of project. Examples of project information are type of project, contract duration, contract cost, contract starting and finishing date, current project progress and status. Much of this information is available in contract documents e.g., contract, contract condition and supplementary, specification, addendum, bill of quantity (BOQ), submitted schedule, and drawing. Status of project is tracked from project progress report, meeting minutes, schedule information (e.g. work breakdown structure (WBS) base line construction schedule, and actual schedule).

#### ***2. Assessors' perception***

In this step, the assessors' perception is the recognition regarding the possible

occurrence of risks and uncertainties and their hierarchical structure in specified time frame as defined in assumption of application.

### **6.5.2 Procedure, Tool and Technique of Risk and Uncertainty Identification and Structuring Process**

The procedure in risk and uncertainty identification and structuring process include:

- 1. Studying and reviewing project information and status*
- 2. Identifying risks and uncertainties*
- 3. Constructing hierarchical structure of risks and uncertainties*
- 4. Reviewing identified risks and uncertainties and their hierarchical structures*

The tools and techniques, which are used in assisting and facilitating analyst, assessor and decision-maker in this process, consist of:

- 1. Risk and uncertainty breakdown structure*
- 2. Risk and uncertainty checklist*
- 3. Hierarchical structure of risk and uncertainty*
- 4. Documents review and site observation*
- 5. Interview*

### **6.5.3 Output of Risk and Uncertainty Identification and Structuring**

After we have gone through the procedural steps above, following outputs are to be obtained.

- 1. Identified risks and uncertainties*
- 2. Description of risks and uncertainties*
- 3. Hierarchical structure of risks and uncertainties*
- 4. 'Integrated HSRU'*

Table 6.2 summarizes inputs, process, outputs of risk and uncertainty identification and structuring process

Table 6.2: Summary of inputs, process, outputs of risk and uncertainty identification and structuring process

INPUT	Example			
1. Outputs from the 1 <sup>st</sup> process	See Table 6.1			
2. Project information and documents	Contract duration, contract cost, contract documents			
3. Assessors' perception	Recognition of occurrence of risks and uncertainties			
PROCEDURE	An	As	DM	Tool & Technique
1. Studying and reviewing project information and status	A, P	P, R	P, R	1. Document review and site observation 2. Interview
2. Identifying risks and uncertainties	A	P	P, R	1. Risk and uncertainty breakdown structure 2. Risk and uncertainty checklist 3. Interview
3. Constructing hierarchical structure of risks and uncertainties	A	P	P, R	1. Hierarchical structure of risk and uncertainty 2. Interview
4. Reviewing identified risks and uncertainties and their hierarchical structures	A	P	P, R	
OUTPUT	Example			
1. Identified risks and uncertainties	Land acquisition risk and uncertainty, mobilization of subcontractor risk and uncertainty			
2. Description of risks and uncertainties	Late land hand over, late mobilization of subcontractor			
3. Hierarchical structure of risks and uncertainties				
4. Integrated HSRU				
<b>Remark:</b> 'An' is analyst, 'As' is assessor, 'DM' is decision-maker P: Prime responsibility. A: Assisting. R: Reviewing				

## 6.6 Risk and Uncertainty Assessment and Analysis Process

The risk and uncertainty assessment and analysis process is the successive process after we identify the occurrence of risks and uncertainties and structure their hierarchical influential relationship. The 'probability' and 'impact' are two main components characterized in risk and uncertainty event. This process aims to assess and analyze these two main components of risk and uncertainty based on their hierarchical structure.

The previous process tries to challenge the 'unidentifiable' condition of uncertainty. We obtain identified risks and uncertainties, which are 'known known' and 'known unknown' respectively. In this process, we attempt to challenge the 'unquantifiable' condition of likelihood of occurrence of uncertainty due to lack of knowledge and

information (in case of ‘known unknown’) or inapplicability of available information (in case of ‘known known’). Therefore, based on developed logical and systematic procedure in assessing probability and impact, this process tries to transform them to ‘known known’ condition and event.

Additionally, with the reasons of unavailability of historical data and inapplicability of available historical data, the subjective judgment is inevitable in assessing probability and impact of risk and uncertainty. This process also relies on assessor’s subjective judgment in quantifying probability and impact of risk and uncertainty.

Much of explanation regarding conceptual background of this process is already provided in description of probability and impact assessment processes in DVP available in Chapter 5.

### **6.6.1 Input of Risk and Uncertainty Assessment and Analysis Process**

The inputs of risk and uncertainty assessment and analysis process are as follows.

- 1. Outputs from the second process*
- 2. Schedule, cost & productivity information*
- 3. Assessor’s perception*

### **6.6.2 Procedure, Tool and Technique of Risk and Uncertainty Assessment and Analysis Process**

Procedures in risk and uncertainty assessment and analysis process are described step-by-step as followings.

- 1. Educating probability and impact assessment procedure*
- 2. Calibrating probability and impact assessment scale*
- 3. Assessing probability of risk and uncertainty based on developed HSRU,*
- 4. Assessing impact of risk and uncertainty based on developed HSRU and type of*



*delay*

*5. Transforming assessed probability and impact to dimensional value*

*6. Building analysis model*

*7. Conducting simulation*

*8. Preparing presentation of analysis result*

The provided tools and techniques to be used in this process include:

*1. Hierarchical structure of risk and uncertainty framework*

*2. Work breakdown structure and CPM method*

*2. Monte Carlo simulation*

*2. Structured Interview*

### **6.6.3 Output of Risk and Uncertainty Assessment and Analysis Process**

From the analysis, following outputs are obtained.

*1. Probability and impact of risks and uncertainties*

*2. Probability and cumulative distribution of project duration*

*3. Risk/uncertainty impact chart*

Table 6.3 summarizes inputs, process, outputs of risk and uncertainty assessment and analysis process

Table 6.3: Summary of inputs, process, outputs of risk and uncertainty assessment and analysis process

INPUT	Example			
1. Outputs from the second process				
2. Schedule, cost & productivity information	Base-line schedule, CPM, production rate			
3. Assessors' perception	Perception on likelihood of occurrence such as 'likely to occur' or 'unlikely to occur,' perception on impact such as 'disastrous' or 'negligible'			
PROCEDURE	An	As	DM	Tool & Technique
1. Educating probability and impact assessment procedure	P	-	-	1. Presentation
2. Calibrating probability and impact assessment scale	A	P	P, R	1. Example of scale
3. Assessing probability of risks and uncertainties based on developed HSRU	A	P	P, R	1. Structured interview 2. Example of scale
4. Assessing impact of risks and uncertainties based on developed HSRU and type of delay	A	P	P, R	1. Structured interview 2. Example of scale
5. Transforming assessed probability and impact to dimensional values	P	A, R	R	
6. Building analysis model	P	A, R	R	1. CPM method 2. Spreadsheet software
7. Conducting simulation	P	A, R	R	1. Monte Carlo simulation
8. Preparing presentation of analysis result	P	R	R	
OUTPUT	Example			
1. Probability and impact of risks and uncertainties				
2. Probability and cumulative d istribution of project duration				
4. Risk/Uncertainty Impact Chart				
<b>Remark:</b> 'An' is analyst, 'As' is assessor, 'DM' is decision-maker P: Prime responsibility, A: Assisting, R: Reviewing				

## 6.7 Risk and Uncertainty Response Process

After we have gone through the risk and uncertainty assessment and analysis process, the next process is the risk and uncertainty response process. In this process, we rely on the concept of scenario analysis and put in consideration on type and category of response and contractual issues. The procedure of risk and uncertainty response process is shown in Figure 6.3.

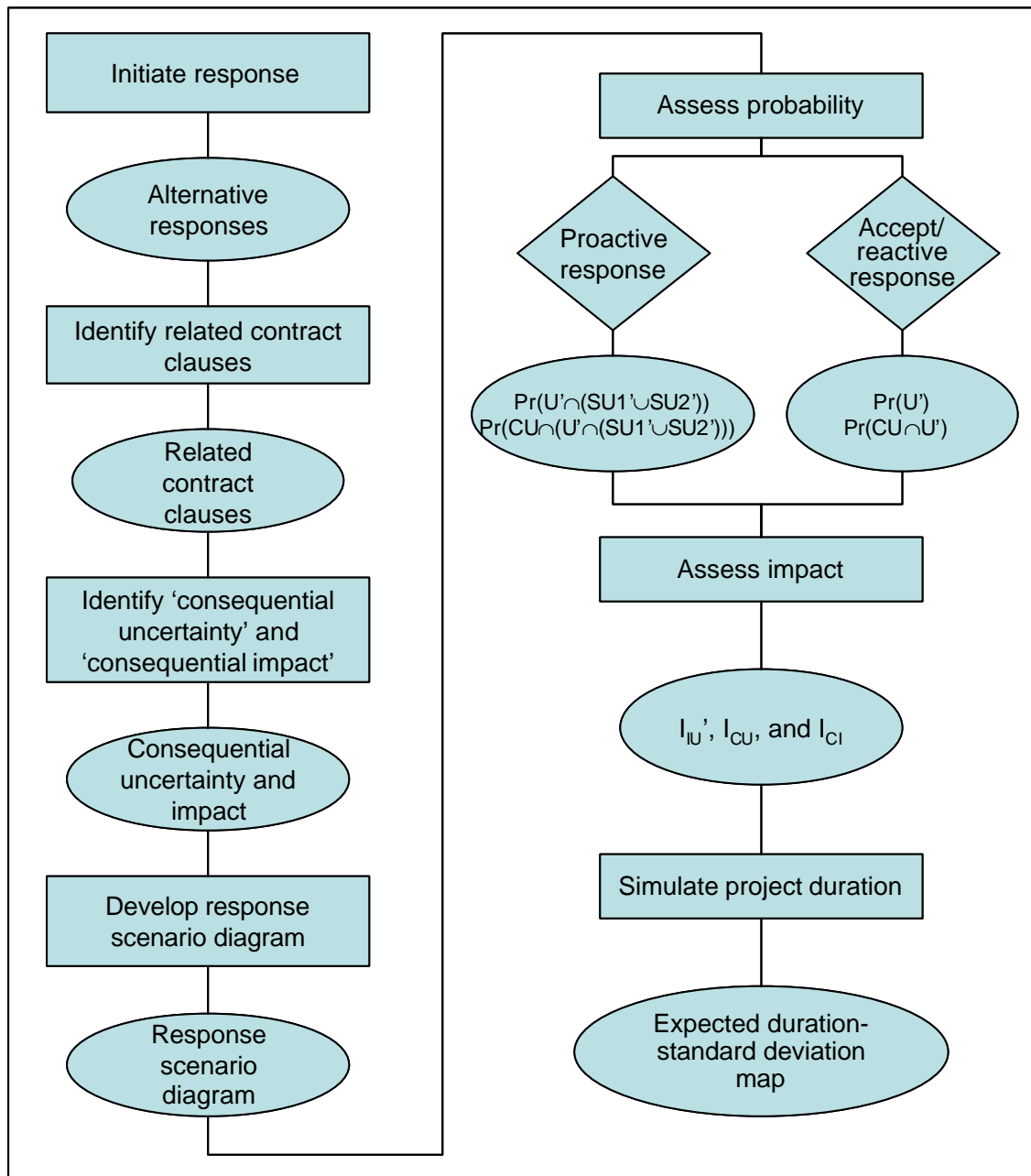


Figure 6.3: Procedure of risk and uncertainty response process

### Scenario analysis

Terms scenario is defined by Schuyler (1996) as “a possible sequence of events and a future state of the world.” In his definition of scenario analysis, he explained scenario analysis as “a planning technique focusing on plausible alternative futures and management responses.” With contrary to Schuyler, the adopted scenario analysis in this research will take the benefit of not only to develop insight about future threat to project but also to forecast how much extent project is likely to be affected.

Moreover, the MRUMP incorporates probabilistic analysis with scenario analysis. In developing alternative scenario, ‘influential risk/uncertainty,’ future ‘consequential risk/uncertainty,’ and ‘consequential impact’ associated with implementation of each alternative response are identified. Then, each identified risk/uncertainty is analyzed based on developed response scenario.

#### ***Type and category of response***

There are three types of response i.e., proactive, accept, and reactive responses defined based on timing of implementation. This is whether it will be implemented before (as proactive measure) or after (as accept and reactive measure) occurrence of uncertainty. By considering the category of response, there are four categories including avoidance, mitigation, transfer, and retention. To define category of response is directly depended on who is the decision maker.

#### ***Contractual issue***

The contractual issue is also put in consideration when analysis of response. We can define the ‘how to draft contract clause’ as decision variable during planning stage will be made by owner. Otherwise, after the contract is formed, the ‘contract clause’ is defined as nominal variable. This is directly related to timing of application of DVP in project and who is the decision-maker. Associated with each response scenario, related contract clauses will be identified.

### **6.7.1 Input of Risk and Uncertainty Response Process**

The inputs required by risk and uncertainty response process are listed up as follows.

- 1. Outputs from the third process***
- 2. Experience and lesson learnt from other projects***
- 3. Assessors’ perception***

## 6.7.2 Procedure, Tool and Technique of Risk and Uncertainty Response Process

The procedures in risk and uncertainty response process are explained as following.

*1. Initiating response scenarios*

*2. Constructing response scenario diagram*

*3. Assessing probability and impact of risks and uncertainties in each response scenario*

### *Probability assessment in case of proactive response scenario*

In this section, to reduce excessive wordings, uncertainty means risk/uncertainty. In case of proactive response scenario, two probabilities are quantified. First one is the new probability of ‘major uncertainty’. Second one is the probability of ‘consequential uncertainty.’ The probability of these uncertainties is assessed given the condition that particular proactive response is implemented. For the new probability of ‘major uncertainty,’ before the response is implemented, the conditional probability of ‘major uncertainty’ (U) given occurrence of ‘sources of uncertainty’ (SU) and probability of union between two ‘sources of uncertainty’ are  $\Pr(U/(SU_1 \cup SU_2))$  and  $\Pr(SU_1 \cup SU_2)$ , respectively. After assuming that response is taken, the conditional probability and probability of union are transformed to  $\Pr(U'/(SU_1' \cup SU_2'))$  and  $\Pr(SU_1' \cup SU_2')$ , respectively. Based on multiplication rule in probability theory, new probability of ‘major uncertainty’ ( $\Pr(U' \cap (SU_1' \cup SU_2'))$ ) is calculated by multiplying  $\Pr(U'/(SU_1' \cup SU_2'))$  with  $\Pr(SU_1' \cup SU_2')$ .

After new probability of ‘major uncertainty’ i.e.,  $\Pr(U' \cap (SU_1' \cup SU_2'))$  is obtained, we then assess conditional probability of ‘consequential uncertainty’ given the occurrence of ‘major probability’ i.e.,  $\Pr(CU/(U' \cap (SU_1' \cup SU_2')))$ . Finally, based on multiplication rule in probability theory, probability of ‘consequential uncertainty’ ( $\Pr(CU \cap (U' \cap (SU_1' \cup SU_2')))$ ) is calculated by multiplying  $\Pr(CU/(U' \cap (SU_1' \cup SU_2')))$  with  $\Pr(U' \cap (SU_1' \cup SU_2'))$ .

### ***Probability assessment in case of accept and reactive response scenarios***

With previously stated assumption, accept and reactive response is implemented after the occurrence of ‘major uncertainty.’ After reactive response is implemented, the ‘major uncertainty’ may be completely eliminated. Otherwise, it may reoccur with new probability of occurrence. With this assumption, in case when reoccurrence of ‘major uncertainty’ is realized, we reassess the new probability of ‘major uncertainty’ as,  $\Pr(U')$ .

For probability of occurring ‘consequential uncertainty,’ the assessment procedure is quite similar to case of proactive response. After  $\Pr(U')$  is obtained, then we assess the conditional probability  $\Pr(CU/U')$ . Finally, based on multiplication rule in probability theory, probability of ‘consequential uncertainty’ ( $\Pr(CU \cap U')$ ) is calculated by multiplying  $\Pr(CU/U')$  with  $\Pr(U')$ . We can assess  $\Pr(CU)$  directly, if the ‘major uncertainty’ is assumed not to occur again.

### ***Impact assessment***

Similar to the impact assessment procedure in DVP, the impact of ‘influential uncertainty’ to activity (the level of activity depends on how much schedule and productivity information available) is assessed. However, in each response scenario, we assess impact of ‘influential uncertainty’ based on following three uncertainties i.e., ‘major uncertainty,’ new ‘consequential uncertainty,’ and preparation effort in terms of time. To assess impact of each response scenario, we have to assess all these three types of impact.

Impact due to original ‘major uncertainty’ is the impact that already occurred ( $I_U$ ). When the reactive response is implemented, we have to reassess new impact of this ‘major uncertainty’ ( $I_{U'}$ ). In case of other types of impact, we have to assess impact of ‘consequential uncertainty’ ( $I_{CU}$ ) and preparation effort in implementing response ( $I_P$ ). To assess the impact, as similar to impact assessment in the DVP, we will assess the percent variation to activity duration, work quantity and production rate. However, mentioned in framework of application, in assessing the impact it depends on how much information available.

Table 6.4 summarizes basis of probability and impact assessment in each type of response scenario.

Table 6.4: Probability and impact of major uncertainty, consequential uncertainty and consequential impact

Response Scenario	Probability	Impact
<i>Proactive response scenario</i>		
Major uncertainty	$\Pr(U' \cap (SU_1' \cup SU_2'))$	$I_{IU}'$
Consequential uncertainty	$\Pr(CU \cap (U' \cap (SU_1' \cup SU_2')))$	$I_{CU}$
Preparation effort	-	$I_p$
<i>Accept and reactive response scenario</i>		
Major uncertainty	$\Pr(U')$	$I_{IU}'$
Consequential uncertainty	$\Pr(CU \cap U')$	$I_{CU}$
Preparation effort	-	$I_p$

#### 4. Conducting simulation of project duration in each response scenario

#### 5. Preparing presentation of analysis result

Tools and techniques used in this process are provided as follows.

##### 1. Prototype of response diagram

The prototypes of proactive, accept, and reactive response scenario diagrams are shown in Figure 6.4, 6.5 and 6.6, respectively. Response scenario diagram is used as the basis in probability and impact assessment. Its function is similar to HSRU framework in the DVP. How to assess the change of probability of pre-identified ‘source of uncertainty’ and ‘major uncertainty’ and probability of new occurring ‘consequential uncertainty’ is based on the structure of response scenario diagram and multiplication rule in probability theory. This basis is also similar to basis of probability assessment in the DVP.

##### 2. Structured interview

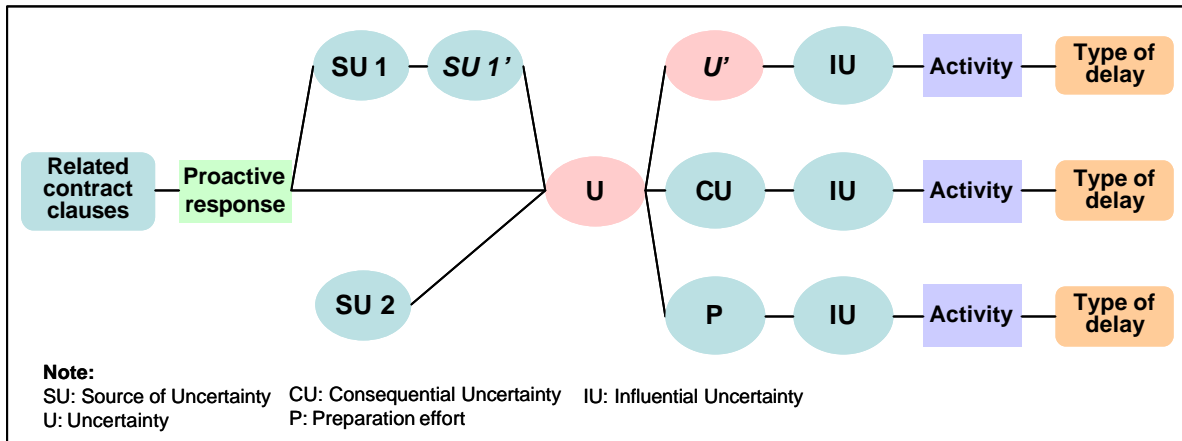


Figure 6.4: Prototype of proactive response scenario diagram

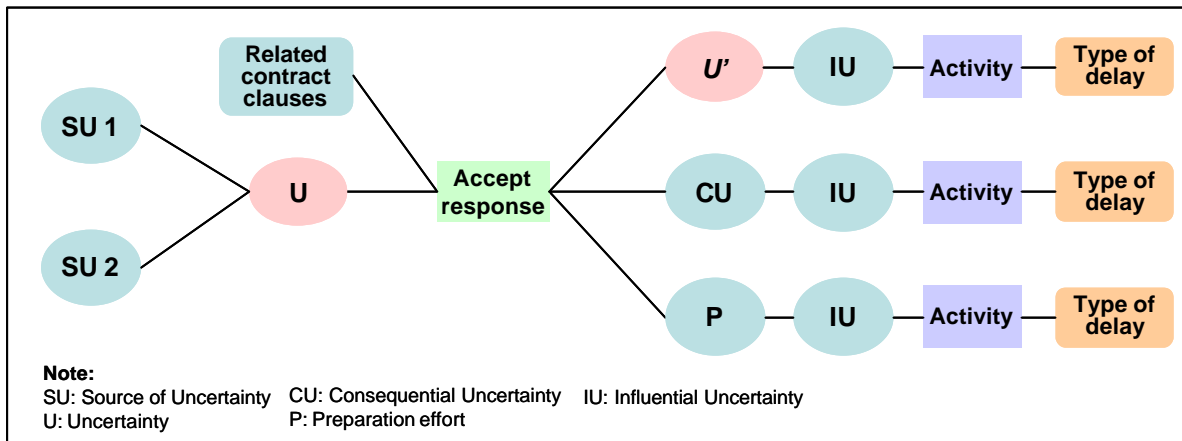


Figure 6.5: Prototype of accept response scenario diagram

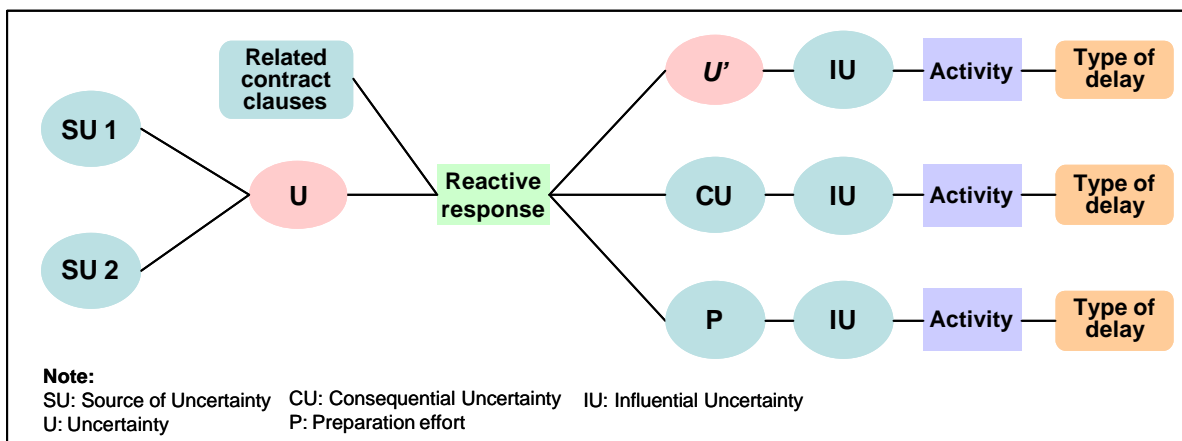


Figure 6.6: Prototype of reactive response scenario diagram



### 6.7.3 Output of Risk and Uncertainty Response Process

The outputs of risk and uncertainty response process are summarized as follows:

**1. Response scenarios**

**2. Response scenario diagram**

As previously mentioned, response scenario diagram is another important deliverable, which is mainly used in assessing probability and impact. Basically, it shows how condition (i.e., probability and impact) of risk and uncertainty will be changed when the response is implemented.

**3. Probability and cumulative distribution of project objective of each scenario**

**4. Expected duration and standard deviation map**

Table 6.5 summarizes inputs, process, and outputs of risk and uncertainty response process.

Table 6.5: Summary of inputs, process, outputs of risk and uncertainty response process

INPUT	Example			
1. Outputs from the third process				
2. Experience and lesson learnt from other projects				
3. Assessors' perception				
PROCEDURE	An	As	DM	Tool & Technique
1. Initiating response scenarios	A	P	P, R	1. Structured interview 2. Brainstorming
2. Constructing response scenario diagrams	A	P	P, R	1. Prototype of response diagram
3. Assessing probability and impact of risks and uncertainties in each response scenario	A	P	P, R	1. Structured interview 2. Example of scale
4. Conducting simulation of project duration of each response scenario	P	R	R	1. Monte Carlo simulation
5. Preparing presentation of analysis result	P	R	R	
OUTPUT	Example			
1. Response scenarios				
2. Response scenario diagram				
3. Probability and cumulative distribution of project duration of each response scenario				
4. Expected duration and standard deviation map				
<b>Remark:</b> 'An' is analyst, 'As' is assessor, 'DM' is decision-maker P: Prime responsibility, A: Assisting, R: Reviewing				

## **6.8 Risk and Uncertainty Management Control Process**

The final process is risk and uncertainty management control process. By considering holistic view of application, the MRUMP realizes the importance of control function of application. This process aims to assist practitioners in administering, monitoring, updating, and controlling risk and uncertainty management activities. The MRUMP is considered as iterative process not one-iteration process. The practitioners are encouraged to reapply the entire MRUMP process periodically, when more information becomes available.

### **6.8.1 Input of Risk and Uncertainty Management Control Process**

The inputs of this process are as follows.

- 1. Outputs from all processes*
- 2. Project status and new information*

### **6.8.2 Procedure, Tool and Technique of Risk and Uncertainty Management Control Process**

Followings are step-by-step procedures of risk and uncertainty management control process.

- 1. Monitoring and updating identified risks and uncertainties*
- 2. Reviewing and updating HSRU*
- 3. Reviewing assessment of probability and impact, and analysis of risks/uncertainties*
- 4. Reviewing and updating response scenarios, assessment and analysis*
- 5. Updating application plan*

### 6.8.3 Output of Risk and Uncertainty Management Control Process

The outputs of risk and uncertainty management control process are summarized as follows.

- 1. Status of identified risks and uncertainties*
- 2. Updated risks and uncertainties*
- 3. Reviewed HSRU*
- 4. Reassessed probability and impact*
- 5. Updated response scenario, diagram, and assessment*
- 6. Updated application plan*

Table 6.6 summarizes inputs, process, outputs of risk and uncertainty management control process.

Table 6.6: Summary of inputs, process, outputs of risk and uncertainty management control process

INPUT	Example			
1. Outputs from all process				
2. Project status and new information				
PROCEDURE	An	As	DM	Tool & Technique
1. Identifying and updating identified risks and uncertainties	A	P	P, R	
2. Reviewing and updating HSRU	A	P	P, R	
3. Reviewing assessment of probability and impact, and analysis of risks/uncertainties	A	P	P, R	
4. Reviewing and updating response scenarios, and assessment and analysis	A	P	P, R	
5. Updating application plan	A	P	P, R	
OUTPUT	Example			
1. Status of identified risks and uncertainties				
2. Updated risks and uncertainties				
3. Updated hierarchical structure of risks and uncertainties				
4. Reassessed probability and impact				
5. Updated response scenarios				
6. Updated application plan				
<b>Remark:</b> ‘An’ is analyst, ‘As’ is assessor, ‘DM’ is decision-maker P: Prime responsibility, A: Assisting, R: Reviewing				

## 6.9 Summary

To overcome limitations of conventional RMPs, the MRUMP has been developed. The MRUMP integrates all parties' views in scope and processes. The risk/uncertainty map, HSRU framework, DVP and other processes i.e., response process, application planning process, and application control process are assembled together to form the MRUMP. A number of systematic procedures and tools such as RUBS and risk/uncertainty checklist are also included in the MRUMP. The implementing manual of MRUMP is provided in this chapter. This manual is initially developed for application in construction stage. The overview of the MRUMP is summarized in Table 6.7.

Table 6.7: Summary of MRUMP

<b>WHAT:</b>	MRUMP is a logical and systematic tool assisting all parties to systematically and efficiently manage risk and uncertainty.
<b>WHO:</b>	MRUMP aims to assist practitioners e.g., policy maker, lender, owner, consultant, and contractor who involved with the project.
<b>WHERE:</b>	MRUMP is possibly used in both single and multi-party environment under risky and uncertain condition.
<b>WHEN:</b>	MRUMP is expected to provide assistance in policy making, planning and problem preventing at early stage of project and problem preventing and solving at later stage of project.
<b>WHY:</b>	<p>For better dealing with risks and uncertainties, MRUMP provides:</p> <ul style="list-style-type: none"> <li>- risk/uncertainty map as 'knowledge base' of risk and uncertainty</li> <li>- HSRU framework for producing higher precision output,</li> <li>- DVP for presenting dimensional output, and</li> <li>- processes in integrating multiple parties' views.</li> </ul> <p>MRUMP encourages parties to communicate each other, identify problem, and cooperatively solve the problem that increases possibility of project success.</p>
<b>HOW:</b>	<p>MRUMP consists of five main processes:</p> <ol style="list-style-type: none"> <li>1. Risk and uncertainty management planning</li> <li>2. Risk and uncertainty identification and structuring</li> <li>3. Risk and uncertainty assessment and analysis</li> <li>4. Risk and uncertainty response process</li> <li>5. Risk and uncertainty management control</li> </ol> <p>For application purpose, MRUMP is provided in form of implementing manual describing necessary inputs, step-by-step procedure, and outputs of each process.</p>

## **Chapter 7**

# **Application of MRUMP**

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### **7.1 Introduction**

This chapter demonstrates the application of MRUMP presenting how it has been implemented in a real world project as a case study. There are two objectives for conducting application study of the MRUMP. The first objective is to discuss the applicability of the MRUMP for further refinement and improvement. By applying the MRUMP to real world project, the second objective is to reveal how the project has been being practiced that is beneficial for both practitioners currently working on site and prospective practitioners of future projects.

As explained in previous chapter, the MRUMP consists of five major processes i.e., risk and uncertainty management planning, risk and uncertainty identification and structuring, risk and uncertainty assessment and analysis, risk and uncertainty response, and risk and uncertainty management control processes. The application of each process to the case study is provided in the following sections, respectively.

### **7.2 Overview of Case Study**

The case study is a bridge and road construction project proportionally financed by an international lender located in a Southeast Asian country. This project provides a new road and bridge network linking a major port with the existing roads and industrial areas. It aims to solve the traffic problem within the metropolitan and vicinity area. The employer, consultant, and source of funds are summarized in Table 7.1.

Table 7.1: The employer, consultant and source of funds of project

<b>Items</b>	<b>Description</b>
<b>Employer</b>	An executing agency in Ministry of Transportation
<b>Consultant</b>	Association of consulting engineers (four local consultants and a foreign consultant)
<b>Source of funds</b>	Budget from local government: 40% An international lender: 60%

The key information of project is summarized in Table 7.2.

Table 7.2: Key information of project

<b>Items</b>	<b>Description</b>
<b>Main works:</b>	Bridge (total length 3,400 m.), Junction, At-grade roads
<b>Contract cost (no VAT; rate at Jan/2004)</b>	7.2 Billion Yen
<b>Contract duration:</b>	1,020 days
<b>Contractor:</b>	Joint Venture A: (three foreign contractors and one local contractor)

## 7.3 Planning Risk and Uncertainty Management

### 7.3.1 Roles in Application

For the application in this study, since the MRUMP puts attention involvement of multiple parties in the process, all top managements in project level of each involved party in this case study i.e., the executing agency, the consultant, and the contractor, were selected as experts or assessors. These assessors consist of the chief project engineer from the executing agency, the project manager from the consultant, and the project manager from the contractor, who are knowledgeable in project context and able to perform assessor's role.

In this application, the author performed the role of evaluation analyst. As evaluation analyst, following tasks were performed i.e., educating assessors regarding introduction, objective and overview of process, preparing documents and presentation for facilitating assessors during interview, arranging appointment and conducting interview, summarizing assessment, analyzing data, and providing analysis result to all assessors.

Top managements of each party, who act as the experts or assessors, also perform the role of decision makers. It should be understood that the purpose of the MRUMP is to assist the assessors and decision makers in assessing the risks and uncertainties and providing risks and uncertainties information for making decision. Therefore, to finalize the decision it is totally depended on the decision makers' risk attitude. This is beyond the scope of the MRUMP. The outputs of the MRUMP are considered as additional information used in facilitating them in making decision. The party who is responsible for making decision is desirable to understand the situation and perception of other involved parties towards analyzed uncertainty and response scenario, which are provided by the MRUMP. Moreover, the MRUMP aims to encourage the harmony among all involved parties.

### **7.3.2 Timing Assumption of Application**

Based on framework of application, the application of this case study was scoped to two periods i.e., early stage of construction and during construction of project.

The first timing of application of the MRUMP is assumed as just beginning of project construction stage. The assessors were asked to identify the project uncertainties occurring from early stage to current stage of construction (around 25<sup>th</sup> month of project duration). For probability and impact assessment of project uncertainties it is assumed that the assessment is made at the early stage of construction. The assessors were asked to go back to the early stage of construction to do assessment, because the error analysis could be conducted by comparing their analysis result with known actual status of project up to current stage.

The second timing of application is from current stage to the end of construction. The assessors were asked to assess risks and uncertainties at the current stage. Figure 7.1 illustrates the first and second timing of application along with baseline and actual project progress.

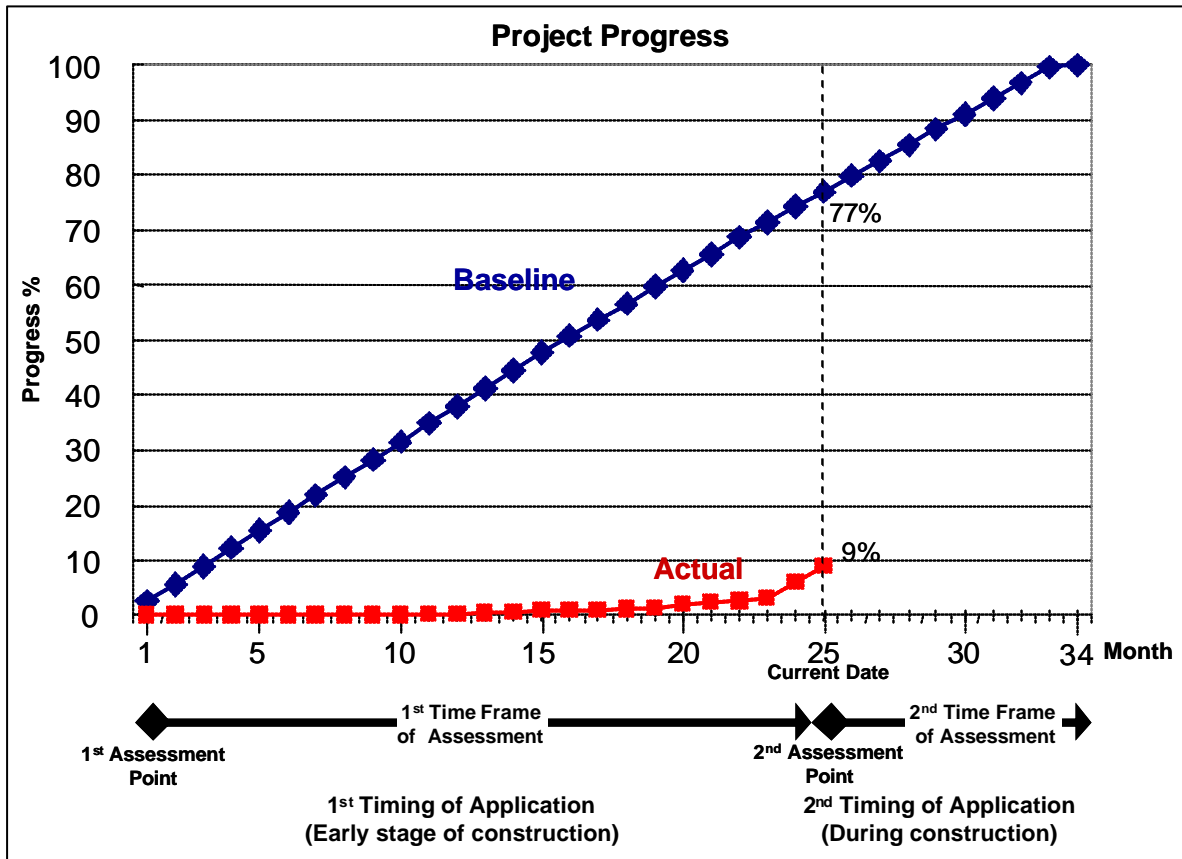


Figure 7.1: First and second timings of application along with project progress

### 7.3.3 Educating MRUMP

At the very beginning of application, the analyst provided explanation of overall procedures to all practitioners, who were supposed to be assessors formerly defined in previous step. This task has been done by using presentation together with supplementary documents. At this step, analyst attempted to enhance understanding of practitioners regarding overview of process and data collection procedure.

## 7.4 Identifying and Structuring Risk and Uncertainty

The second process is risk and uncertainty identification and structuring process.



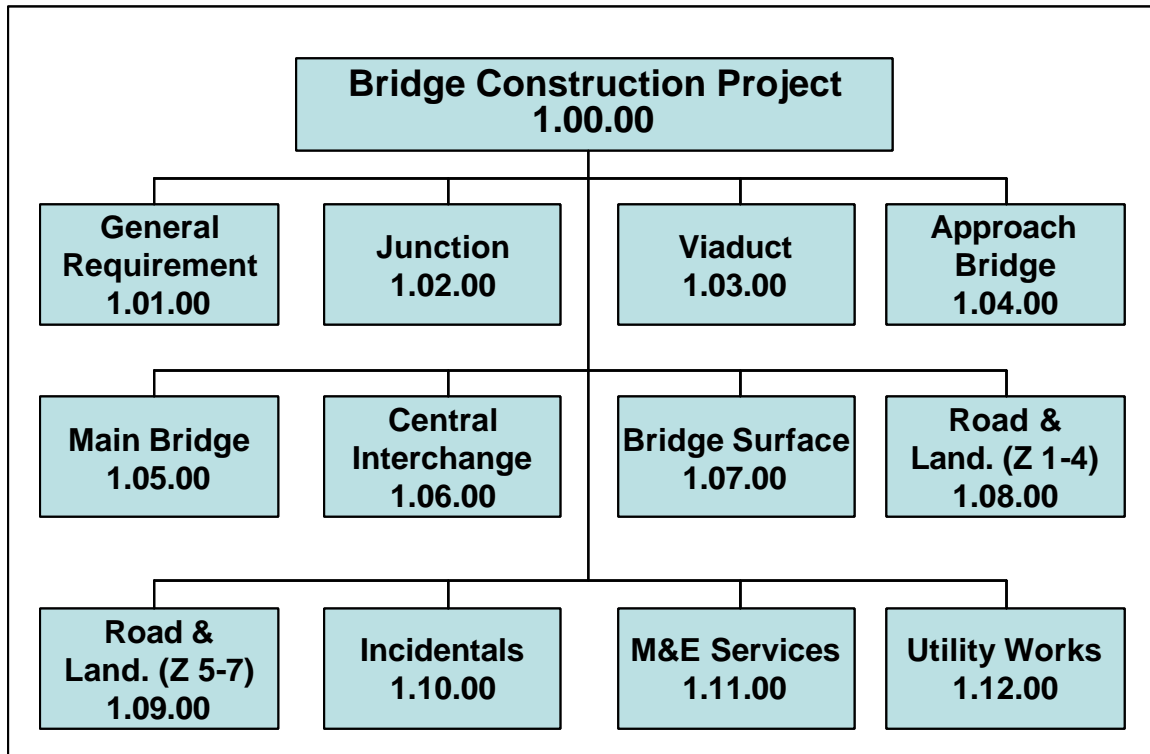


Figure 7.2: Work breakdown structure of project

#### 7.4.1 Gathering Project Information

The first task of this process was to gather project information such as general project description, contract information, and schedule information. The sources of this information were contract documents and progress report. By studying these documents, we could have understood the background of project and current status. The work breakdown structure (up to level 1) of this project is provided in Figure 7.2.

#### 7.4.2 Identifying Risks and Uncertainties

The next step was to identify risks and uncertainties. Assessors would be the main role in this step with analyst's assistance. After analyst conducted the in-dept interview with assessors, the identified project risks and uncertainties perceived by assessors from each party (top management level of executing agency, consultant, and contractor) working in the case studied project could be obtained and described in following sections. The facilitating tool used in this step included risk and uncertainty breakdown structure,

check list and hierarchical structure of risk and uncertainty framework. Following sections describe major risks/uncertainties based on assessors' perception of each party.

#### **7.4.2.1 Executing Agency's Perception**

##### **1. Land acquisition**

The total land could not be acquired before date of issuance of the notice to proceed. There were two sources of uncertainty, which caused the occurrence of this 'land acquisition' consequent uncertainty. The source of uncertainty through the first transition was initiated from the 'land price settlement' in the land acquisition procedure. The settlement of land price to residents was delayed. This then induced the 'cooperation from residents' uncertainty. The residents did not satisfy the offered price, which was derived from standard land price specified by a public agency that is responsible for determining standard land price. Moreover, due to the much different in land price of same characteristic of land, this made residents unsatisfactory. As a result, they delayed in moving out and relocating. The second source of uncertainty was related to 'budget approval from government.' The budget for compensation cost was delayed in approval. The 5%, 15%, and 30% of budget was approved in the first three years before issuance of notice to proceed. After the notice to proceed was issued, the remaining 45% and 5% was released in next two years respectively. Because of this late land acquisition, the contractor could not access to construction site and commence works.

#### **7.4.2.2 Contractor's Perception**

##### **1. Land acquisition**

Similar to the executing agency's and the consultant's views, the contractor also identified the 'land acquisition' uncertainty occurred during the construction stage. The contractor explained that this uncertainty was realized just before signing the contract. There were three sources of this uncertainty i.e., 'cooperation from residents,' 'timing of

project commencement,' and 'budget constraint for compensation cost.' The first source of uncertainty occurred when the respondents did not move out. The second source of uncertainty was perceived as improper timing in issuance of notice of proceed, while the substantial part of lands or necessary land according to proposed schedule still could not be acquired. The next source of uncertainty was the limited budget for compensation cost to residents.

## **2. Contractor's mobilization of subcontractor and equipment (availability and work progress)**

The next consequent risk, which was the result from 'land acquisition' uncertainty, is 'contractor's mobilization' risk. Since the contractor could not receive and access to the land, the contractor then decided not to mobilize the equipment, subcontractor and labor. This could delay the progress of entire project.

## **3. Contractor's mobilization of key staff (work progress)**

This consequent risk also was originated from 'land acquisition' uncertainty. The contractor did not mobilize the technical key staff to the project, since he could not start construction.

## **4. Technical capability of subcontractor**

The contractor pointed out the uncertainty of 'technical capability of subcontractor.' This was particular to the local subcontractor. Since the contractor was subletting most of the works to the subcontractor, this uncertainty could result in delay of entire project.

## **5. Coordination among contractors in joint venture (subcontractor and work progress)**

This consequent uncertainty could affect the work progress, availability of subcontractor and work quality. It was originated from the 'competitive condition in

bidding.’ Since the competition level in bidding was very high, the contractor had to bid in low price. This tight ‘contract price and budget’ resulted in difficulty in coordination among contractors in the joint venture.

### **7.4.2.3 Consultant’s Perception**

#### **1. Land acquisition**

The first uncertainty, which was identified by the consultant, was ‘land acquisition’ uncertainty. There were two transitions of uncertainty that resulted in ‘land acquisition’ uncertainty. The first one was originated from ‘restructuring of government system.’ During the land acquisition process, the local government had been in restructuring process. As a result, the ‘approval from executing agency’ was delayed, since responsible public officers were often changed. Furthermore, it resulted in late ‘appointment of land price settlement committee,’ which directly induced the ‘land acquisition’ uncertainty. The second transition was originated from ‘political influence.’ which caused the uncertainty in ‘commencement of project.’

#### **2. Contractor’s mobilization of equipment**

Due to the late land acquisition, the contractor then did not mobilize the equipment to the site at the early stage of project. Therefore, when the land could be sufficiently acquired, the contractor could not mobilize the equipment according to schedule. This caused the delay in availability of equipment.

#### **3. Contractor’s mobilization of key staff (work progress)**

The source of this uncertainty was ‘land acquisition’ uncertainty. Due to late land acquisition, the contractor did not mobilize sufficient key staff to the project. Therefore, there were not sufficient technically capable staffs. This made the contractor’s technical capability uncertain. This impacted the work progress of technical oriented activities.

#### **4. Coordination among contractors in joint venture (work progress)**

The consultant pointed out the coordination problem among contractors in joint venture. They could not cooperate each other well. The in-house communication in joint venture seemed to be problematic. The responsibility for shared works was unclear. The source of this uncertainty was due to tight 'contract price and budget' that resulted each contractor in strictly controlling their individual budget.

#### **5. Availability of suppliers and subcontractors**

Because this project was the first project, of which the lead contractor of this joint venture received the contract in this country. The consultant identified the uncertainty of 'contractor's local experience' as the source of uncertainty that might result in uncertainty of 'availability of suppliers and subcontractors.' This lead contractor might not have the business-network with local suppliers and subcontractors, which could make the procurement process of suppliers and subcontractors delayed.

### **7.4.3 Constructing HSRU and Assessing Probability and Impact**

Firstly, this section summarizes hierarchical structure called hierarchical structure of risk and uncertainty (HSRU) of identified risks and uncertainties. (Much explanation of HSRU is provided in Chapter 4.) These HSRUs were developed based on each party's perception. They are presented according to impacted activities (or in project level).

Subsequently, relying on the developed HSRUs based on each party's perception, the probability and impact of risks and uncertainties were assessed by the practitioners (assessors) of each party. Before starting the assessment process, probability and impact assessment procedure was explained to assessors. The procedures of assessment, example of probability and impact scale, and example of questions were included in the explanation.

The structured HSRUs together with the assessed probability and impact perceived by

each party are summarized and presented as followings.

#### **7.4.3.1 HSRU, Probability, and Impact based on Executing Agency's Perception**

According to the executing agency, only one uncertainty impacting project as a whole was identified. The HSRU presenting their relationship and probability and impact assessment result are shown in Figure 7.3 and Table 7.3, respectively.

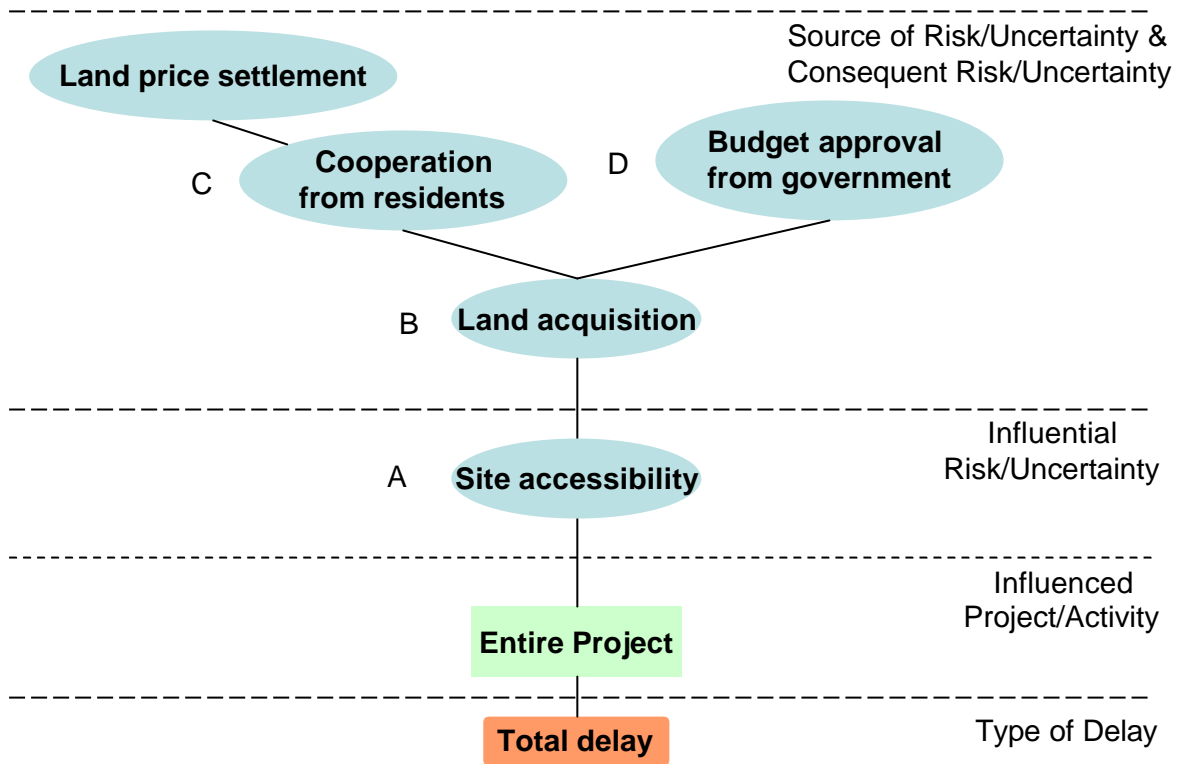


Figure 7.3: Hierarchical structure of risks and uncertainties impacting entire project (executing agency)

Table 7.3: Probability and impact assessment of risks and uncertainties impacting entire project based on Figure 7.3 (executing agency)

Event	Uncertainty	$P(B (C \& D))$	$P(C)$	$P(D)$	$P(C \& D)$	$P(C D)$	$P(B (C \& D))$	Impact
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
B	Land acquisition	0.95	-	-	-	1	0.95	20%
C	Cooperation from resident							
D	Budget approval from government							

Note: (7)=(4)+(5)-(6); (8)=(3)\*(7); (9) = Impact to project level

#### **7.4.3.2 HSRU, Probability and Impact based on Contractor's Perception**

The HSRU presenting relationship among risks/uncertainties and activity or project and probability and impact assessment result based on contractor's perception are shown in following figures and tables.



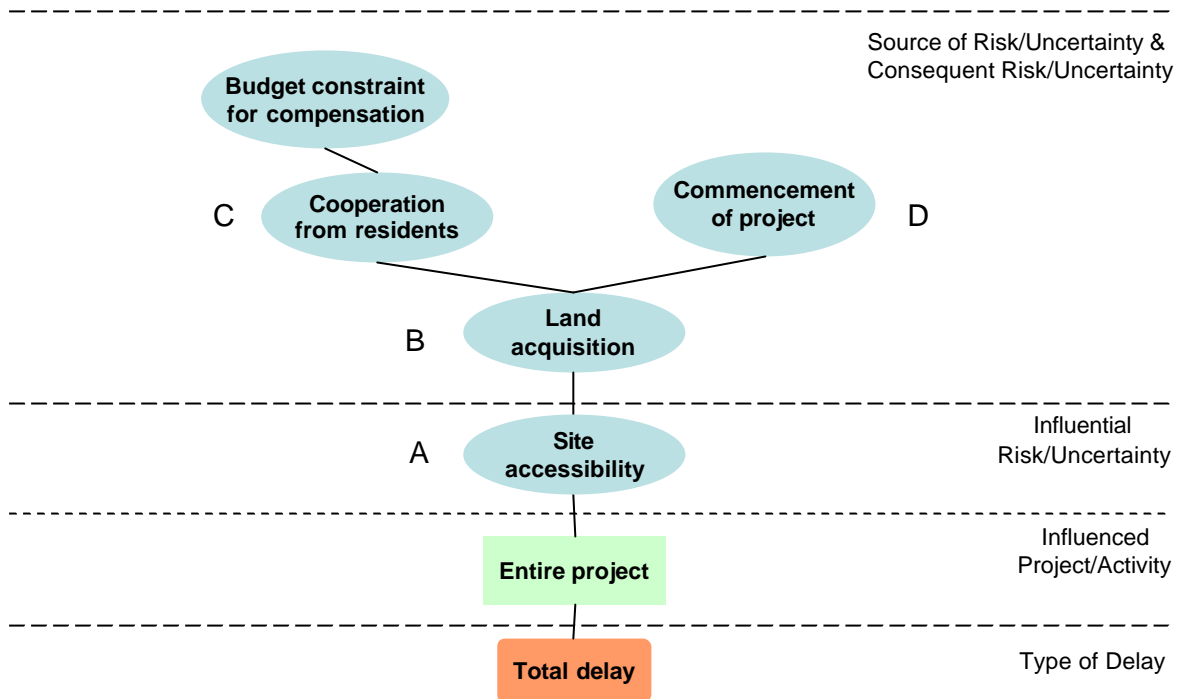


Figure 7.4: Hierarchical structure of risks and uncertainties impacting entire project (contractor)

Table 7.4: Probability and impact assessment of risks and uncertainties impacting entire project based on Figure 7.4(contractor)

Event	Uncertainty	$P(B (C \cap D))$	$P(C)$	$P(D)$	$P(C \cap D)$	$P(C \cap D)$	$P(B \cap (C \cap D))$	Impact
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
B	Land acquisition	0.95	-	-	-	1	0.95	10%
C	Cooperation from residents							
D	Commencement of project							

Note: (8)=(3)\*(7); (9): Impact to project level

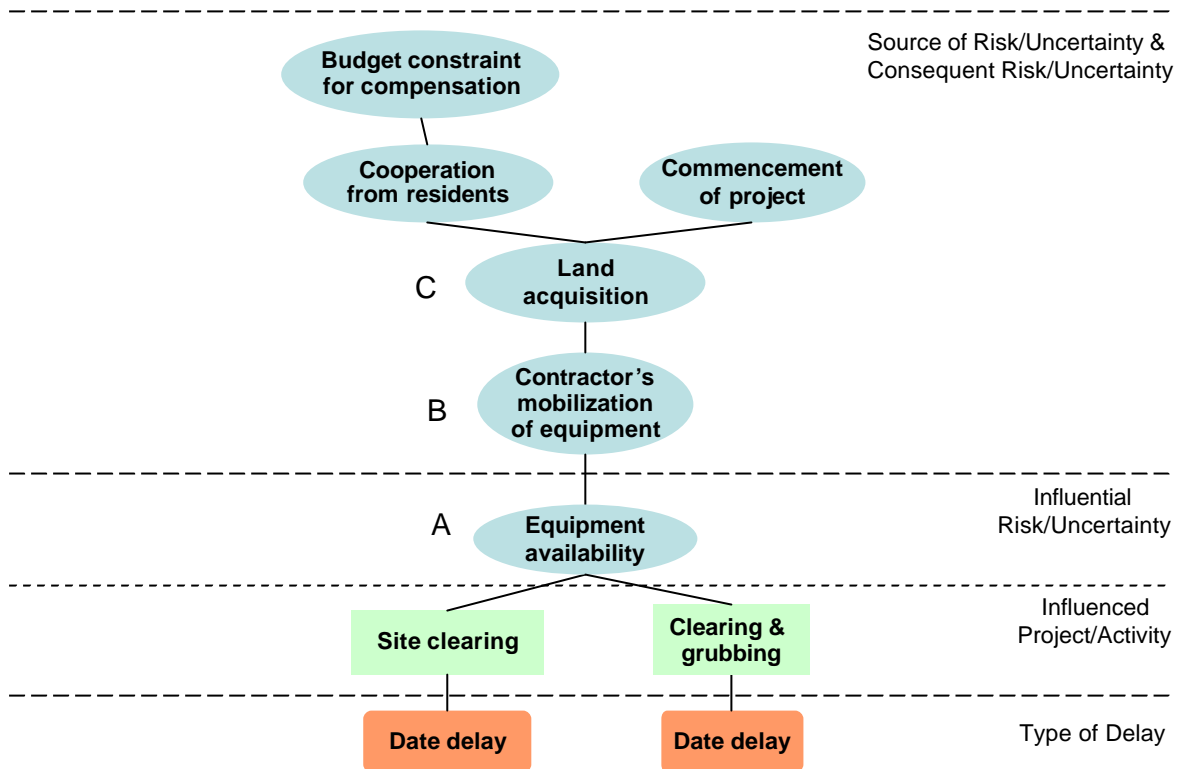


Figure 7.5: Hierarchical structure of risks and uncertainties impacting site clearing and clearing and grubbing activities (contractor)

Table 7.5: Probability and impact assessment of risks and uncertainties impacting site clearing and clearing and grubbing activities based on Figure 7.5 (contractor)

Event	Uncertainty	P(B C)	P(C)	P(BCC)	Impact
(1)	(2)	(3)	(4)	(5)	(6)
B	Contractor's mobilization of subcontractor and equipment (availability)	0.95	1	<b>0.95</b>	<b>100%</b>
C	Land acquisition				

Note: (5)=(3)\*(4); (9): Impact to activity level

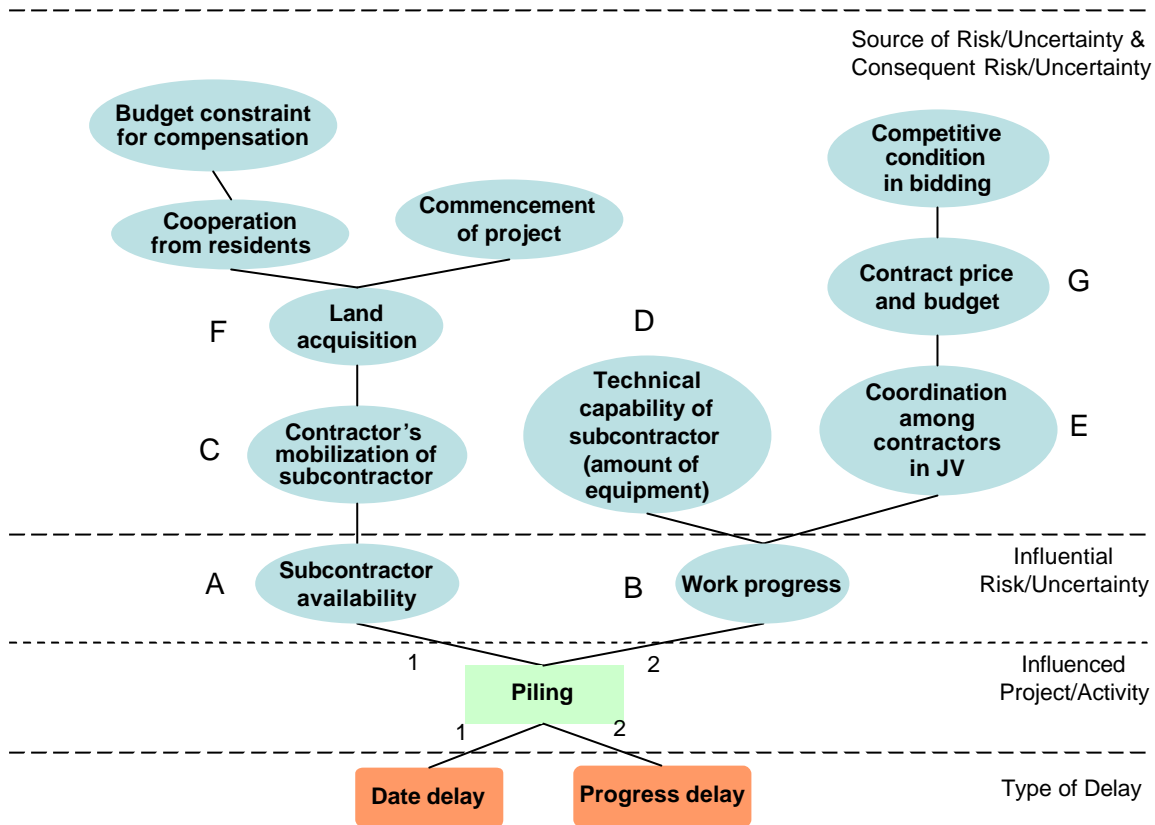


Figure 7.6: Hierarchical structure of risks and uncertainties impacting piling activity (contractor)

Table 7.6: Probability and impact assessment of risks and uncertainties impacting piling activity based on Figure 7.6 (contractor)

Event	Uncertainty	P(B C)	P(C)	P(BCC)	Impact
(1)	(2)	(3)	(4)	(5)	(6)
B	Contractor's mobilization of subcontractor and equipment (availability)	0.95	1	0.95	100%
C	Land acquisition				
Note: (5)=(3)*(4); (9): Impact to activity level					
Event	Uncertainty	P(D)			Impact
(1)	(2)	(3)			(4)
D	Technical capability of subcontractor	0.1			100%
Note: (4): Impact to activity level					
Event	Uncertainty	P(E G)	P(G)	P(EGG)	Impact
(1)	(2)	(3)	(4)	(5)	(6)
E	Coordination among contractors in JV (work progress)	0.95	1.0	0.95	100%
G	Contract price and budget				
Note: (5)=(3)*(4); (6): Impact to activity level					

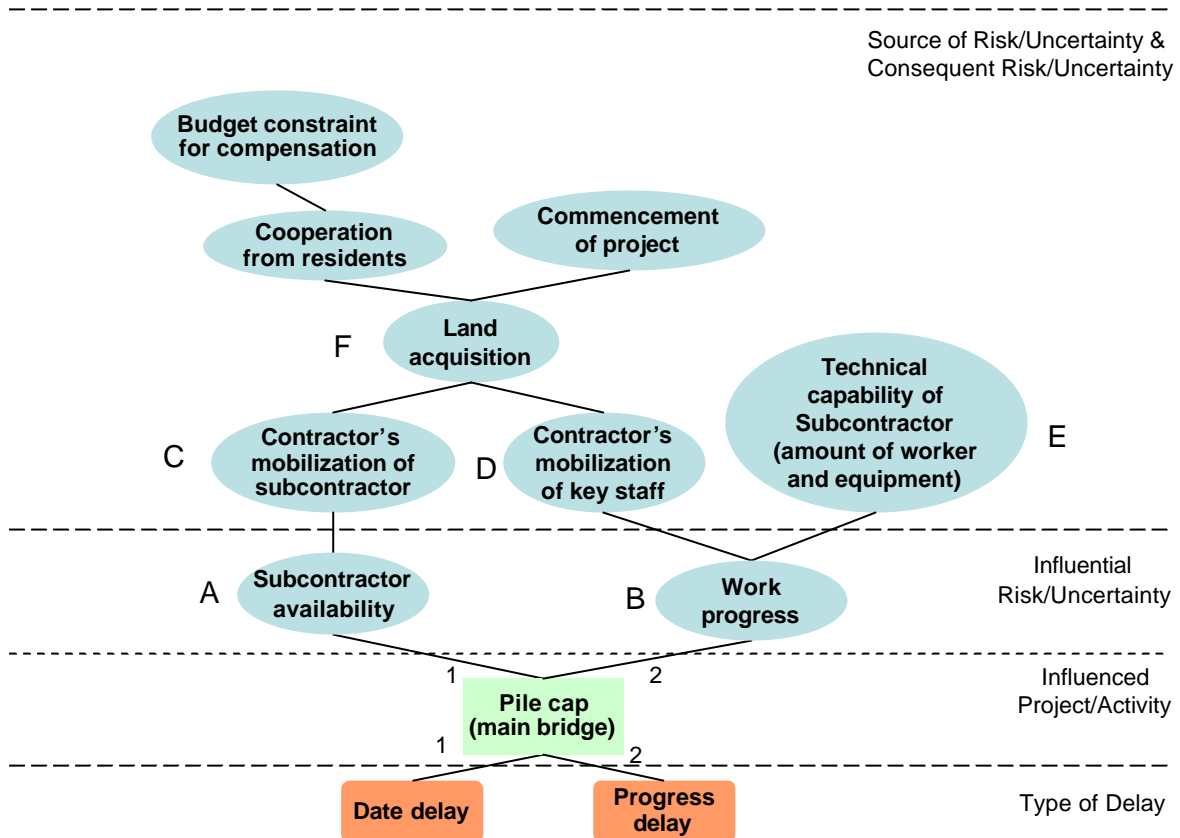


Figure 7.7: Hierarchical structure of risks and uncertainties impacting pile cap activity (contractor)

Table 7.7: Probability and impact assessment of risks and uncertainties impacting pile cap activity based on Figure 7.7 (contractor)

Event	Uncertainty	P(C F)	P(F)	P(CCF)	Impact
(1)	(2)	(3)	(4)	(5)	(6)
C	Contractor's mobilization of subcontractor and equipment (availability)	0.95	1	0.95	100%
F	Land acquisition				
Note: (5)=(3)*(4); (9): Impact to activity level					
Event	Uncertainty	P(D F)	P(F)	P(DCF)	Impact
(1)	(2)	(3)	(4)	(5)	(6)
D	Contractor's mobilization of key staff (work progress)	0.95	1	0.95	10%
F	Land acquisition				
Note: (5)=(3)*(4); (6): Impact to activity level					
Event	Uncertainty	P(E)		Impact	
(1)	(2)	(3)		(4)	
E	Technical capability of subcontractor	0.1		100%	
Note: (4): Impact to activity level					

#### **7.4.3.3 HSRU, Probability and Impact based on Consultant's Perception**

The HSRU presenting relationship among risks/uncertainties and activity or project and probability and impact assessment result based on consultant's perception are shown in following figures and tables.

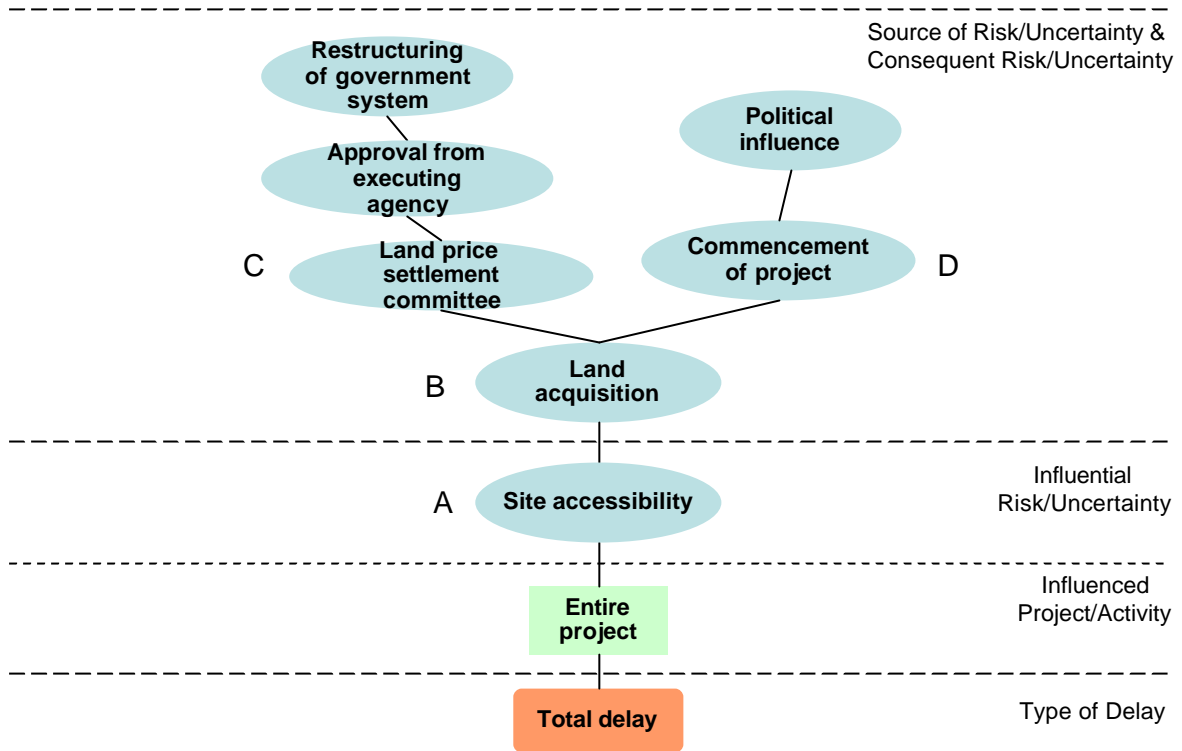


Figure 7.8: Hierarchical structure of risks and uncertainties impacting entire project (consultant)

Table 7.8: Probability and impact assessment of risks and uncertainties impacting entire project based on Figure 7.8 (consultant)

Event	Uncertainty	$P(B (C \cap D))$	$P(C)$	$P(D)$	$P(C \cap D)$	$P(C \cap D)$	$P(B \cap (C \cap D))$	Impact
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
B	Land acquisition	0.95	-	-	-	1	0.95	40%
C	Land price settlement committee							
D	Commencement of project							

Note: (8)=(3)\*(7); (9): Impact to project level

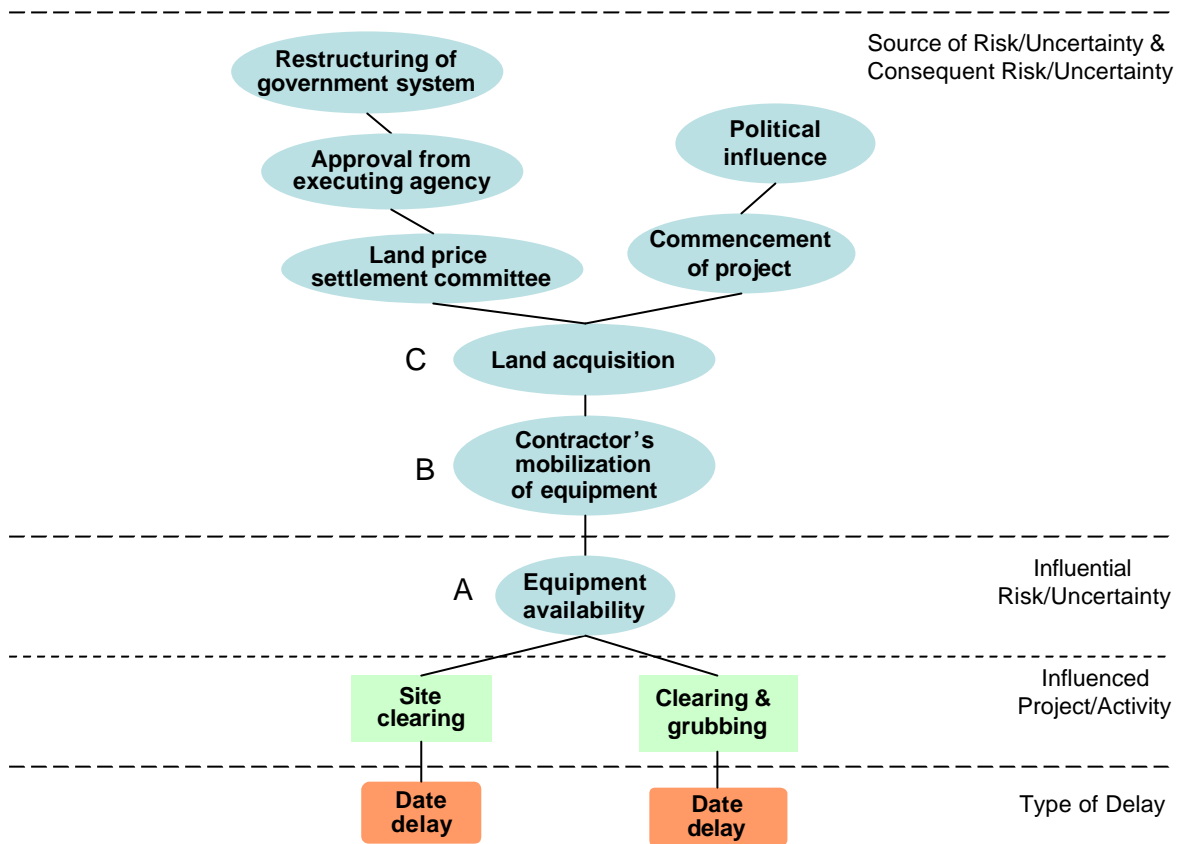


Figure 7.9: Hierarchical structure of risks and uncertainties impacting site clearing and clearing and grubbing activities (consultant)

Table 7.9: Probability and impact assessment of risks and uncertainties impacting site clearing and clearing and grubbing activities based on Figure 7.9 (consultant)

Event	Uncertainty	P(B C)	P(C)	P(B∩C)	Impact
(1)	(2)	(3)	(4)	(5)	(6)
B	Contractor's mobilization of equipment	0.95	0.90	<b>0.855</b>	<b>100%</b>
C	Land acquisition				

Note: (5)=(3)\*(4); (6): Impact to activity level

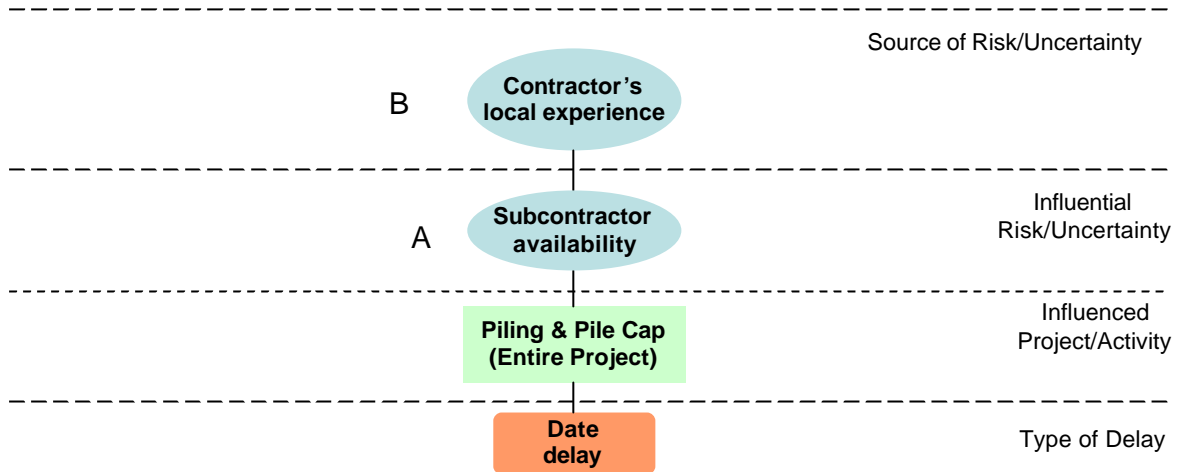


Figure 7.10: Hierarchical structure of risks and uncertainties impacting piling and pile cap activity (impact is expressed in project level) (consultant)

Table 7.10: Probability and impact assessment of risks and uncertainties impacting piling and pile cap activity (impact is expressed in project level) based on Figure 7.10 (consultant)

Event	Uncertainty	P(A B)	P(B)	P(A∩B)	Impact
(1)	(2)	(3)	(4)	(5)	(6)
A	Subcontractors availability	0.05	1.0	0.05	10%
B	Contractor's local experience				

Note: (5)=(3)\*(4); (6): Impact to project level



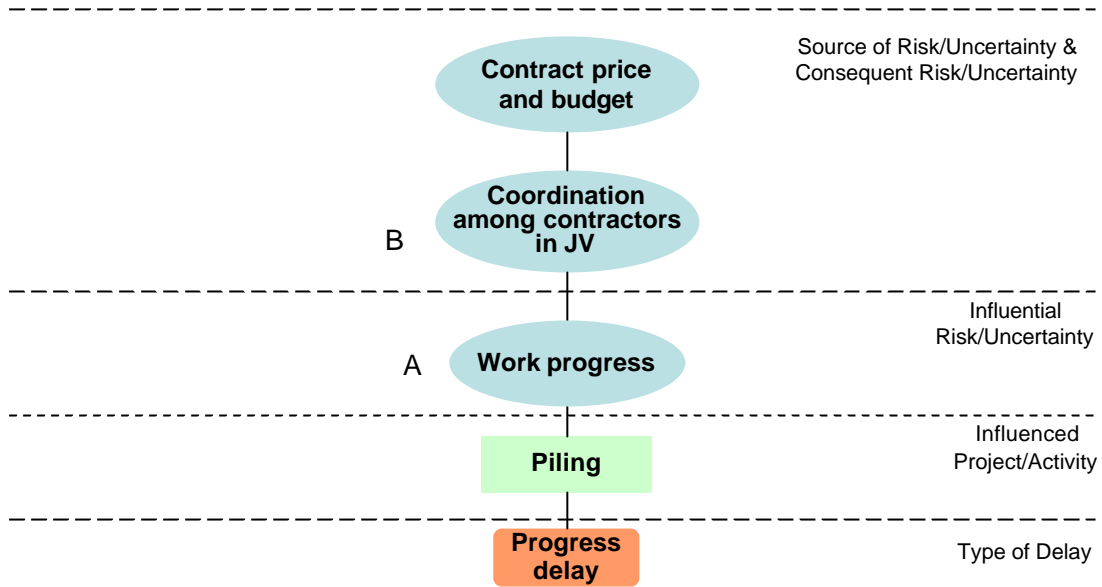


Figure 7.11: Hierarchical structure of risks and uncertainties impacting piling activity (consultant)

Table 7.11: Probability and impact assessment of risks and uncertainties impacting piling activity based on Figure 7.11 (consultant)

Event	Uncertainty	P(A B)	P(B)	P(ACB)	Impact
(1)	(2)	(3)	(4)	(5)	(6)
A	Coordination among contractors in joint venture	0.05	1	<b>0.05</b>	<b>20%</b>
B	Contract price and budget				

Note: (5)=(3)\*(4); (6): Impact to activity level

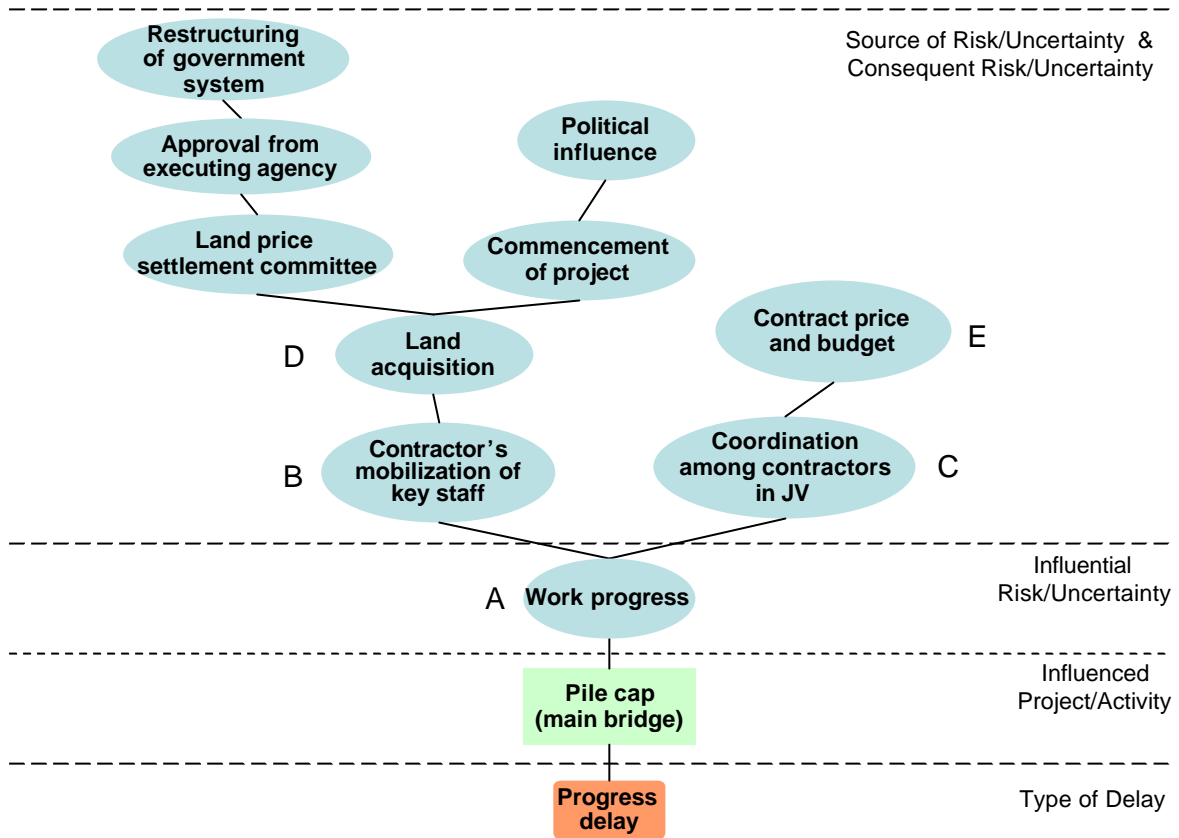


Figure 7.12: Hierarchical structure of risks and uncertainties impacting pile cap (at main bridge) activity (consultant)

Table 7.12: Probability and impact assessment of risks and uncertainties impacting pile cap (at main bridge) activity based on Figure 7.12 (consultant)

Event	Uncertainty	P(B D)	P(D)	P(BCD)	Impact
(1)	(2)	(3)	(4)	(5)	(6)
B	Contractor's mobilization of key staff	0.95	0.95	0.90	100%
D	Land acquisition				
Note: (5)=(3)*(4); (6) Impact to activity level					
Event	Uncertainty	P(C E)	P(E)	P(CCE)	Impact
(1)	(2)	(3)	(4)	(5)	(6)
C	Coordination among contractors in joint	0.05	1	0.05	20%
E	Contract price and budget				
Note: (5)=(3)*(4); (6): Impact to activity level					

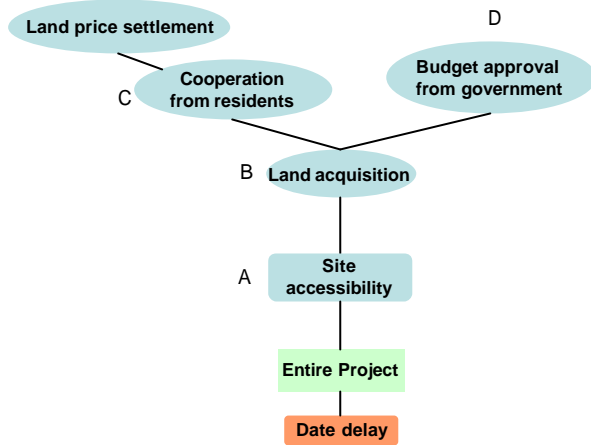
## **7.5 Analyzing Risk and Uncertainty**

After going through the assessment process, each party's perception towards probability and impact of risks and uncertainties impacting project in activity and project level is obtained. In analysis process, by incorporating exposure of risks and uncertainties based on each party's probability and impact assessment, we then obtain the cumulative distribution of project duration as a major output.

In analysis, after we obtained the assessed value of probability and impact towards each consequent risk and uncertainty from each party's perception, first based on conditional probability and the multiplication rule in probability theory, we calculated joint probability in order to find the probability distribution of impact (in term of delay percentage). Then, we transformed the delay percentage to delay duration of each impacted activity (or in project level) and obtained probability distribution of activity duration (or project duration). Joint probability tables, joint impact tables, probability distribution of impact (delay percentage) tables and probability distribution (delay duration) tables of each impacted activity (or project) are provided in Appendix C. An example of analyzing procedure is shown in Figure 7.13.

Subsequently, we assigned obtained probability distribution of activity duration (here activity duration is random variable) in scheduling simulation model based on CPM method in spreadsheet software. The scheduling simulation models presenting dependency and type of delay between activity and uncertainty of each party are shown in Appendix D.

# Probability and Impact Analysis (Executing Agency)



Hierarchical structure of risks and uncertainties impacting entire project

1. Analysis of

C ->	B ->	A
D ->		

$P(B/C \cup D)$	=	0.95
$P(C \cup D)$	=	1
$P(B \cap (C \cup D)) = P(B/C \cup D)P(C \cup D)$	=	0.95
Impact (to project level)	=	20 %

Assumption:

A will occur and provide impact only when B occurs due to either occurrence of C or D.

$$P(A) = P(A \cap (B \cap (C \cup D)))$$

$$P(A/B \cap (C \cup D)) = 1$$

$$P(A'/(B \cap (C \cup D))) = 1$$

Table EA1.1: Joint probability table

	$B \cap (C \cup D)$	$(B \cap (C \cup D))'$
A	0.95	0
A'	0	0.05

Table EA1.2 Impact table

	$B \cap (C \cup D)$	$(B \cap (C \cup D))'$
A	20	0
A'	0	0

Table EA1.3: Summary of probability and cumulative distribution of impact (delay percentage) to entire project (executing agency)

Impact (%)	Probability	Cumulative	E[I]
0	0.05	0.05	0
20	0.95	1	19
	1		19

Table EA1.4: Summary of probability and cumulative distribution of impacted duration of project (executing agency)

Impacted Component	Delay (day)	Impacted Duration (day)	Probability	Cumulative	E[I]	E[D]
Project	0	1020	0.05	0.05	0	51
Original Duration (day)	204	1224	0.95	1	193.8	1162.8
1020			1		193.8	1213.8

Figure 7.13: Example of probability and impact analysis procedure

Next, we conducted the simulation to obtain the simulated project duration. In this simulation process, we employed a simulation software in conducting Monte Carlo simulation. In assigning distribution, in this analysis we used custom distribution function to assign distribution, which we obtained previously, to each assumption cell. The custom distribution function is available in this simulation software. Then, we assigned the forecast cell to cell representing project duration. After that we run the simulation.

Consequently, we obtain the probability and cumulative distribution of project duration and statistics information. The results of simulation of each party are presented in following sections.

### 7.5.1 Simulation Result based on Executing Agency's Assessment

The statistics information of simulation result based on executing agency's assessment is shown in Table 7.13. The probability distribution of project duration is shown in Figure 7.14.

Table 7.13: Statistics information of simulation result based on executing agency's assessment

Items	Value
Trials	10000
Mean	1,213.21
Median	1,224.00
Mode	1,224.00
Standard Deviation	45.66
Variance	2,085.24
Skewness	-3.99
Kurtosis	16.96
Coeff. of Variability	0.04
Range Minimum	1,020.00
Range Maximum	1,224.00
Range Width	204.00
Mean Std. Error	0.46

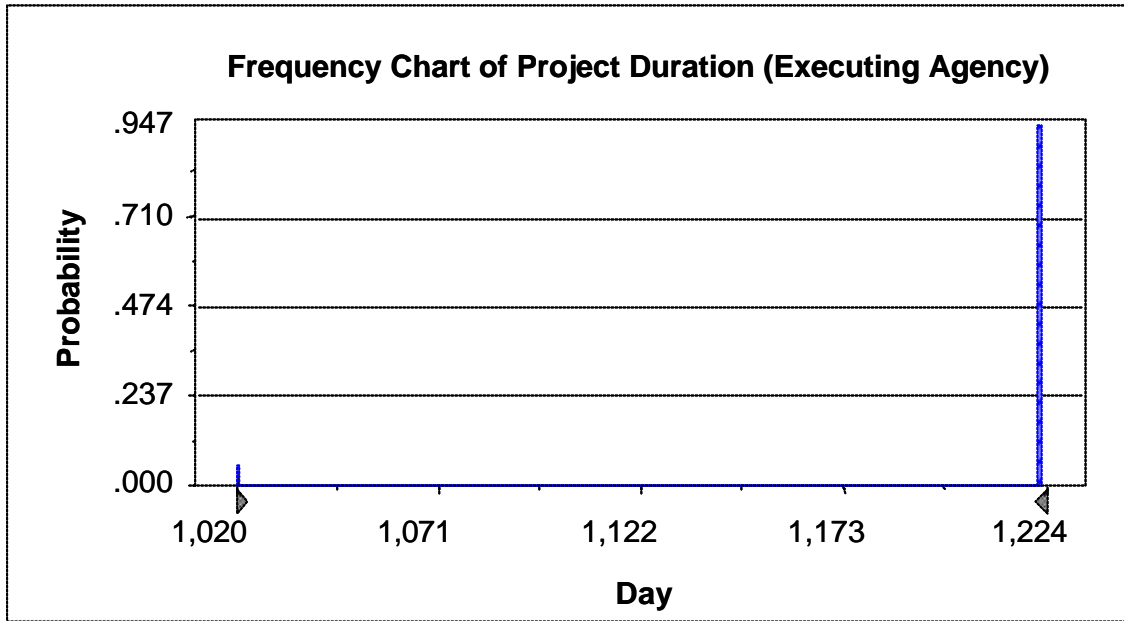


Figure 7.14: Probability distribution of project duration (executing agency)

## 7.5.2 Simulation Result based on Contractor's Assessment

The statistics information of simulation result based on contractor's assessment is shown in Table 7.14. The probability distribution of project duration is shown in Figure 7.15.

Table 7.14: Statistics Information of simulation result based on contractor's assessment

Items	Value
Trials	10000
Mean	1,570.63
Median	1,558.00
Mode	1,558.00
Standard Deviation	69.42
Variance	4,818.88
Skewness	0.70
Kurtosis	3.83
Coeff. of Variability	0.04
Range Minimum	1,312.10
Range Maximum	1,822.00
Range Width	509.90
Mean Std. Error	0.69

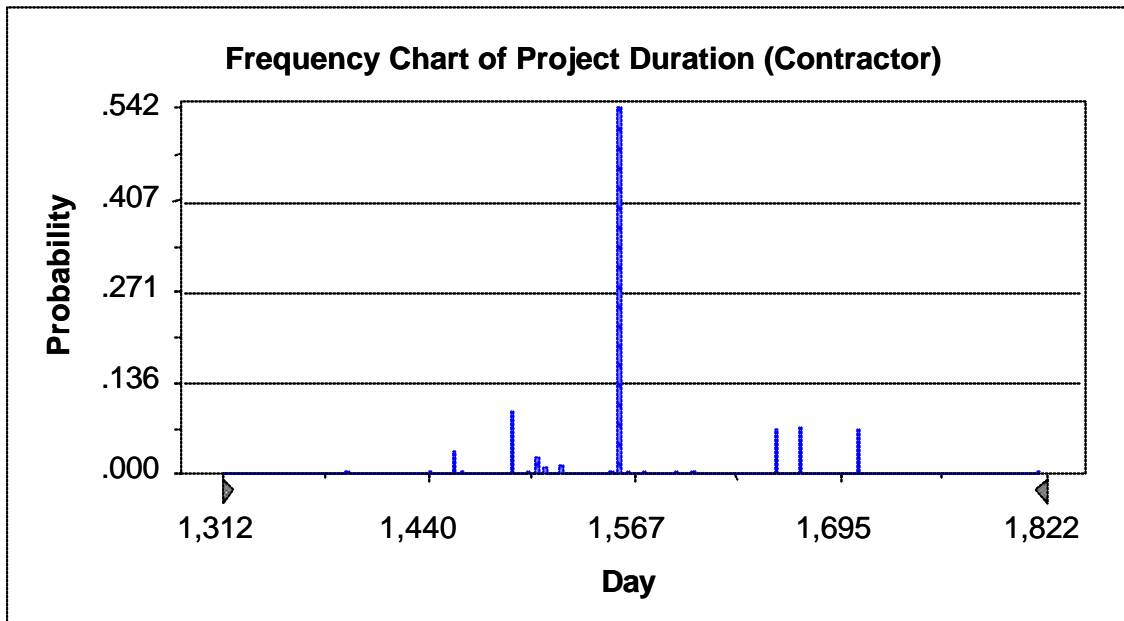


Figure 7.15: Probability distribution of project duration (contractor)

### 7.5.3 Simulation Result based on Consultant's Assessment

The statistics information of simulation result based on consultant's assessment is shown in Table 7.15. The probability distribution of project duration is shown in Figure 7.16.

Table 7.15: Statistics information of simulation result based on consultant's assessment

Items	Value
Trials	10000
Mean	1,530.33
Median	1,560.00
Mode	1,560.00
Standard Deviation	97.38
Variance	9,482.78
Skewness	-3.26
Kurtosis	13.76
Coeff. of Variability	0.06
Range Minimum	1,079.00
Range Maximum	1,684.20
Range Width	605.20
Mean Std. Error	0.97

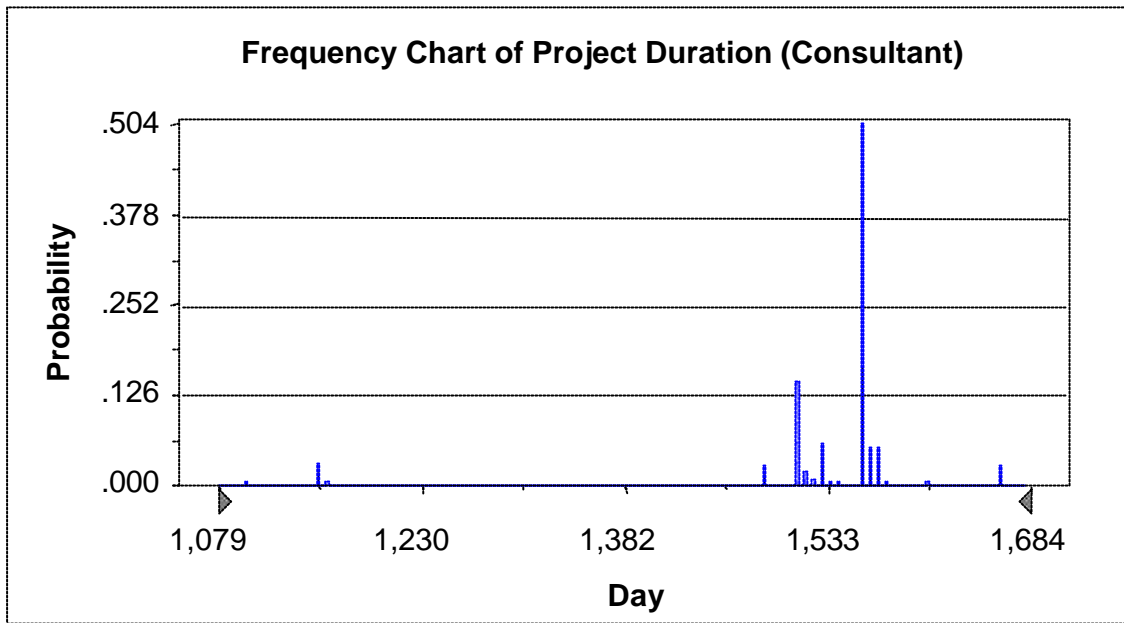


Figure 7.16: Probability distribution of project duration (consultant)

#### 7.5.4 Cumulative Distribution of Project Duration

As the main output of analysis process, we obtain the cumulative distribution of project duration based on all parties' assessment as shown in Figure 7.17. This cumulative distribution of project duration demonstrates how the objective in transforming dimensionless output of RMP to dimensional output is achieved.

From the cumulative distributions plotted in Figure 7.17, it shows that the distribution based on executing agency's assessment is totally located on the left side of ones belong to both contractor and consultant, and its location is quite far from others. The distributions based on contractor's and consultant's assessments are located closely and overlapped in some parts; however, the one belong to consultant mostly locates on the left side of contractor's and has wider range of distribution.



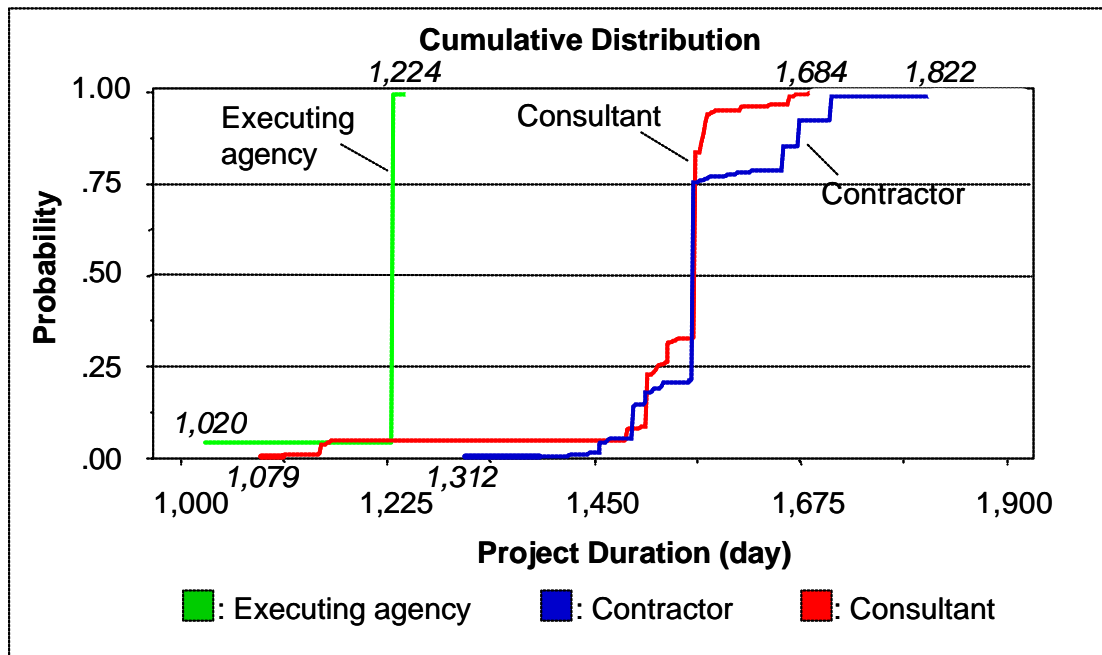


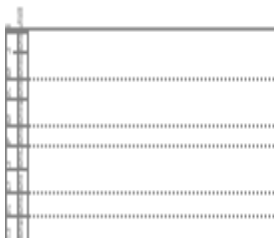
Figure 7.17: Cumulative distribution of project duration (all parties)

### 7.5.5 Integrated HSRU

Moreover, by superimposing all HSRUs perceived by each party, a hierarchical structure called ‘integrated HSRU’ providing holistic view of risks and uncertainties perceived by all parties is obtained as shown in Figure 7.18. Based on the integrated HSRU, all parties are able to visually see the difference of risks and uncertainties perceived by all parties. The integrated HSRU enables all parties to be aware of problem due to difference of each party’s view (problem awareness). After problem is aware, it enables all parties to identify and communicate to find the source of problem (problem identification). By understanding all parties’ views, they are encouraged to integrated their views in cooperatively solving the problem (problem solving).



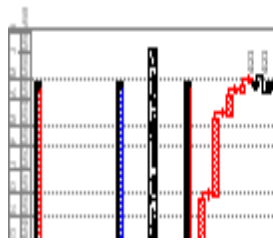
### Baseline Schedule (only critical activities)



### Executing Agency's Risk/Uncertainty Impact Chart (only critical activities)



### Contractor's Risk/Uncertainty Impact Chart (only critical activities)



### Consultant's Risk/Uncertainty Impact Chart (only critical activities)

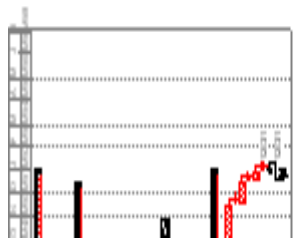


Figure 7.19: Risk/Uncertainty Impact Chart (Only Critical Activities) of all parties

### **7.5.6 Risk/Uncertainty Impact Chart**

Additionally, in order to understand the difference of all parties' perception more comprehensively, the 'risk/uncertainty impact chart' (RUIC) is developed. It aims to present how each party perceived risk/uncertainty that delays the project and by how long. In RUIC, we incorporate impact of risk/uncertainty by assigning expected activity duration to duration of impacted activities. Comparison between baseline schedule (only critical activities) and RUIC (only critical activities) of each party in form of barchart is shown in Figure 7.19. The entire baseline schedule and RUIC of all parties are provided in Appendix E.

### **7.6 Comparing Each Party's Analysis Result**

It is necessary to discuss why the results of each party are different and what are the differences and similarities based on each party's view. In this section, each party's view associated with HSRU, probability, and impact is compared. Then, the discussion on differences and similarities of each party's perception is made.

As a result of all parties' views shown in 'integrated HSRU' (Figure 7.18), we can summarize risks and uncertainties associated with this case study into four categories including:

(1) occurring risks and uncertainties: the risks and uncertainties that have been occurring (such as 'land acquisition' risk/uncertainty in this case study),

(2) subsequent risks and uncertainties: the risks and uncertainties that their occurrence is caused by the occurring risks and uncertainties and they occur during the occurrence of occurring risks and uncertainties (such as 'mobilization of subcontractor and equipment' risk/uncertainty due to 'land acquisition' risk/uncertainty in this case study),

(3) lingering risks and uncertainties: the risks and uncertainties that their occurrence is caused by the occurring risks and uncertainties and they occur after the occurrence of the occurring risks and uncertainties is ended (such as 'mobilization of

key staff' risk/uncertainty due to 'land acquisition' risk/uncertainty in this case study), and

(4) new future risks and uncertainties: the risks and uncertainties that their occurrence is not relevant to risks and uncertainties in other categories.

Furthermore, if we elaborately scrutinize each risk/uncertainty, the characteristic of particular risk/uncertainty is different based on position of each party. The characteristics mentioned here consist of: decision/non-decision, responsibility/non-responsibility, and controllability/uncontrollability. Due to different characteristic of particular risk/uncertainty, uncertainty to one party may be risk to another party, and vice versa.

In addition to the clarification of risk and uncertainty, which has been made in the first chapter, by understanding the characteristics of risk/uncertainty, we can know what is risk or uncertainty to each party, whether that risk or uncertainty can be controlled by that party, whether that party has to be responsible for that risk or uncertainty, and whether that risk or uncertainty is directly related to that party's decision. Therefore, it is desirable for all parties to understand the characteristics of each risk and uncertainty in order to further provide the desirable solutions for all parties. The characteristics of major consequential risks and uncertainties (grouped into four categories described above) associated with each party in this case study are described in Table 7.16.

Moreover, we could grasp categories and characteristics of risk/uncertainty associated with each party as summarized in Table 7.16. Table 7.17 summarizes the result of probability and impact assessment of all parties purposefully for quantitative comparison of each party's perception towards probability and impact. From this table, we also can notice the difference of perception in assessing probability and impact.

Table 7.16: Characteristic of risk/uncertainty associated with each party

Risk/Uncertainty	Executing agency				Contractor				Consultant				Related contractual condition
	D/ND	R/NR	C/NC	Ri/Un	D/ND	R/NR	C/NC	Ri/Un	D/ND	R/NR	C/NC	Ri/Un	
Occuring risk/uncertainty category													
1. Land acquisition	D	R	C	Ri	ND	NR	NC	Un	ND	NR	NC	Un	C18, C19, C20
Subsequent risk/uncertainty category													
1. Mobilization of equipment	ND	NR	C/NC	Un	D	R	C	Ri	ND	NR	C/NC	Un	C5, C21, ITT8
2. Mobilization of subcontractor	ND	NR	C/NC	Un	D	R	C	Ri	ND	NR	C/NC	Un	C5, C21, ITT8
Lingering risk/uncertainty category													
1. Mobilization of key staff	ND	NR	C/NC	Un	D	R	C	Ri	ND	NR	C/NC	Un	C5, C21, ITT8
New future risk/uncertainty category													
1. Technical capability of subcontractor	ND	NR	C/NC	Un	D	R	C/NC	Un	ND	NR	C/NC	Un	C5, C21, ITT8
2. Coordination among contractors in JV	ND	NR	NC	Un	D	R	C	Ri	ND	NR	NC	Un	C21
<b>Note</b> D = Decision, ND = Non-Decision; R = Responsibility, NR = Non-Responsibility; C = Contrallability, NC = Non-Contrallability; Ri = Risk, Un = Uncertainty													
<b>Clause (C)</b> C5: General obligations; C18: Notice to proceed; C19: Commencement time and time of completion; C20: Extension of time for completion; C21: Rate of progress; (Descriptions are provided in Appendix F)													
<b>Instruction to Tenderers (ITT)</b> ITT8: Supplementary documents to accompany the tender; (Descriptions are provided in Appendix F)													

Table 7.17: Summary of probability and impact assessment of all parties

Risk/Uncertainty	Executing Agency		Contractor		Consultant	
	Prob.	Imp.	Prob.	Imp.	Prob.	Imp.
1. Land acquisition	0.95	20% (Project)	0.95	10% (Project)	0.95	40% (Project)
2. Contractor's mobilization of equipment	-	-	0.95	100%	0.855	100%
3. Contractor's mobilization of subcontractor	-	-	0.95	100%	0.05	10% (Project)
4. Contractor's mobilization of key staff	-	-	0.95	10%	0.90	100%
5. Technical capability of subcontractor	-	-	0.1	100%	-	-
6. Coordination among contractors in joint venture	-	-	0.95	100%	0.05	20%
Note: Prob. = Joint probability based on multiplication rule; Imp. = Impact to project or activity (delay percentage of project duration)						

The difference and similarity associated with HSRU, probability and impact are summarized as following:

The executing agency perceived only the land acquisition uncertainty that caused the site accessibility of project. Similar to executing agency, the contractor and consultant also perceived this uncertainty. Furthermore, the contractor and consultant also perceived the subsequent and lingering risks/uncertainties due to land acquisition uncertainty. These subsequent and lingering risks/uncertainties were not perceived by the executing agency.

Based on contractor's perception, these subsequent risks include contractor's mobilization of equipment and subcontractor. Based on consultant's perception, only contractor's mobilization of equipment was perceived. With this difference, the land acquisition is considered as the source of uncertainty to particularly contractor, since contractor has to make decision regarding mobilization of equipment and subcontractor with uncertain condition of amount and sequence of handed over land. On the other hand, the executing agency seemed to lack of understanding of contractor's requirement in mobilizing equipment and subcontractor. Generally, for contractor, not only sufficient amount of land but also sequence of acquired land is significant criterion for making mobilization decision. This source of uncertainty should be addressed in deriving solution by both executing agency and contractor.

For lingering risk/uncertainty, both contractor and consultant perceived the contractor's mobilization of key staff risk/uncertainty as lingering risk/uncertainty due to land acquisition uncertainty. Similar to subsequent risk/uncertainty, the executing agency did not perceive this lingering uncertainty. The contractor and consultant perceived that even though the land can be totally acquired and handed over, contractor may not be immediately transfer or employ new key staffs to project. The executing agency might not understand the staff allocation and recruitment constraint on the part of contractor.

For new future risk/uncertainty category, consultant also pointed out the contractor's local experience that may influence the contractor's mobilization of subcontractor in

piling and pile cap activities. Contractor did not perceive this risk regarding his qualification. Contractor perceived only land acquisition uncertainty influencing his mobilization of subcontractor risk that it might impact the piling and pile cap activities. With this difference, the contractor might overlook self defectiveness (local experience) about difficulty in finding local subcontractor.

Contractor and consultant seemed to have similar concern regarding coordination among contractors in joint venture risk/uncertainty to progress of piling or pile cap activities. Moreover, contractor also perceived the technical capability of subcontractor uncertainty, which was not perceived by consultant. Since consultant did not directly interact with subcontractor, consultant might not know the level of subcontractor's capability.

Next, the probability and impact associated with each risk/uncertainty based on each party's perception are compared. By comparing these two variables, we can understand the difference and similarity of their perception regarding how likely that risk/uncertainty will occur and magnitude of that risk/uncertainty.

As mentioned above, all parties perceived the occurrence of land acquisition risk/uncertainty. They also similarly perceived that this risk/uncertainty will likely to occur. However, their perception towards impact of this risk/uncertainty is different. Among these three parties, the consultant perceived the impact of land acquisition uncertainty was biggest. The impact of this land acquisition risk/uncertainty assessed by executing agency and contractor are one-second ( $1/2$ ) and one-fourth ( $1/4$ ) of consultant's assessment respectively. This difference shows that although all parties perceived the occurrence of the land acquisition risk/uncertainty, the executing agency and contractor did not perceive its huge impact. Experience of past projects, knowledge, and bias associated with each party might make their perception different.

Regarding likelihood of occurrence of others risk/uncertainty, contractor and consultant perceived quite similar level of likelihood of occurrence of contractor's mobilization of equipment and key staff as very high. However, their perceptions are different when



they assessed the likelihood of occurrence of contractor's mobilization of subcontractor risk/uncertainty and coordination among contractors in joint venture risk/uncertainty. The consultant perceived their likelihood as very low. Since this contractor is considered big international company with high reputation, the uncertainties related to contractor's responsibility is not common in practice for consultant. Moreover, consultant might believe in the reputation of contractor.

Regarding the impact of others risk/uncertainty, consultant perceived the impact of contractor's mobilization of subcontractor and coordination among contractors in joint venture uncertainties much lower than contractor's assessment. The reason of this difference may be similar to reason of previous case. The story is different in impact assessment of contractor's mobilization of key staff risk/uncertainty. The contractor did not perceive the big impact of this risk, though consultant perceived its significance. The contractor might be overconfident in their capacity regarding number of key staff, whereas consultant might feel unconfident.

In summary, by quantitatively comparing the probability and impact of risk/uncertainty associated with each party perception, we are aware of the difference in their views. With this observation, we can answer the questions regarding the difference in location and range of cumulative distribution of project duration shown in Figure 7.17. The distribution based on executing agency's perception is totally located on the left side and far from ones belong to contractor and consultant, because the executing agency perceived only land acquisition risk. For contractor and consultant, although they perceived the same set of risks and uncertainties, their perceptions towards probability and impact are different. The consultant perceived big impact of land acquisition uncertainty, whereas the impact of contractor related uncertainties were perceived as low. This is contrary with contractor's perception. This makes the cumulative distribution of project (shown in Figure 7.17) based on consultant's perception is wider than contractor's distribution. One possibility of this difference is that the case of nonoccurrence of land acquisition uncertainty was realized in simulation. The 'risk/uncertainty impact quantification chart' (shown in Figure 7.19 and in Appendix E) illustrates this difference.

With both qualitative and quantitative observations towards all parties' perception of identified risks or uncertainties and their probability and impact, the differences and similarities associated with their perceptions could be aware. By integrating multiple parties' views in scope of application and comparing all parties' perception (using 'overall integrated HSRU' and 'RUIC') following benefits are realized:

- (1) understanding other parties' uncertainties and constraints,
- (2) reducing possibility of ignorance of unperceived risks and uncertainties by realizing subsequent and lingering risks and uncertainties caused by risk/uncertainty as a result of a party's decision (or action) and recognizing risks and uncertainties related to 'third' parties,
- (3) providing consideration of different degree of consequence of risks and uncertainties, and
- (4) providing 'objective' evaluation of one party.

## **7.7 Comparison with Actual Status**

Even though, the analysis result has been derived by using logical and systematic procedure, the discrepancy between estimation and actual status is inevitable in subjective assessment. The comparison between analysis result and actual status is conducted in this section aiming to (1) evaluate the precision of all parties' analysis result and (2) find areas of refinement of the MRUMP and its application.

In order to accomplish the first purpose, the analysis result (expected project duration and cumulative distribution of project duration) based on each party's view is compared with actual status of project (project progress up to 25<sup>th</sup> month). Since we assumed that the assessment has been done at early construction stage of project and period of assessment has been framed from timing of assessment to current status (around 25<sup>th</sup> month of project), we can compare the analysis result based on each party's view with the actual status of project.

In reality, the executing agency provided approximately 490 days for time extension due to late land acquisition. The original schedule of project was then revised.

According to the first revision of schedule, the actual status up to 25<sup>th</sup> month is shown in following table.

Table 7.18: Actual status of project

Items	Description
Original contract period	1020 days
1 <sup>st</sup> time extension	490 days
New contract period	1510 days
Elapsed time	750 days
Cumulative progress	9 %
Schedule (based on 1st revision)	27 %
Actual status (percent)	-18 % (behind 1 <sup>st</sup> revision schedule)
Estimated project delay	184 days (18% of original duration)

Based on observation of analysis result, the precision of analysis result comparing with actual status is different depending on parties' perception. Table 7.19 shows the comparison of assessed expected project duration (means) with actual project duration (including time extension and progress delay up to 25<sup>th</sup> month).

Table 7.19: Comparison of expected project duration with actual project duration

Party	Expected Duration (day)	Error (day)	% Error
Executing agency	1,214	480	28
Contractor	1,571	123	7
Consultant	1,531	163	10
Note: Expected duration is means duration as a result from simulation. Error = Actual project duration (1,694 days) - Expected duration % Error = (Error/Actual project duration)*100			

The level of precision of estimation is considered higher if the difference between estimated and actual values is close to zero. As we can observe from comparison in Table 7.19, the executing agency's assessed expected project duration is mostly deviated from actual project duration and very different from the contractor's and consultant's deviation. On the other hand, the deviation of contractor's estimation from actual status is the smallest one.

Figure 7.20 shows range of cumulative distribution of project duration based on each party's perception compared with actual status. Although the contractor's and consultant's errors are not significantly different, the range of their distributions is different. Only the distribution based on contractor's perception covers the actual project duration. For others' distribution, the actual project duration is located outside the range of their distribution specifically the executing agency's distribution.

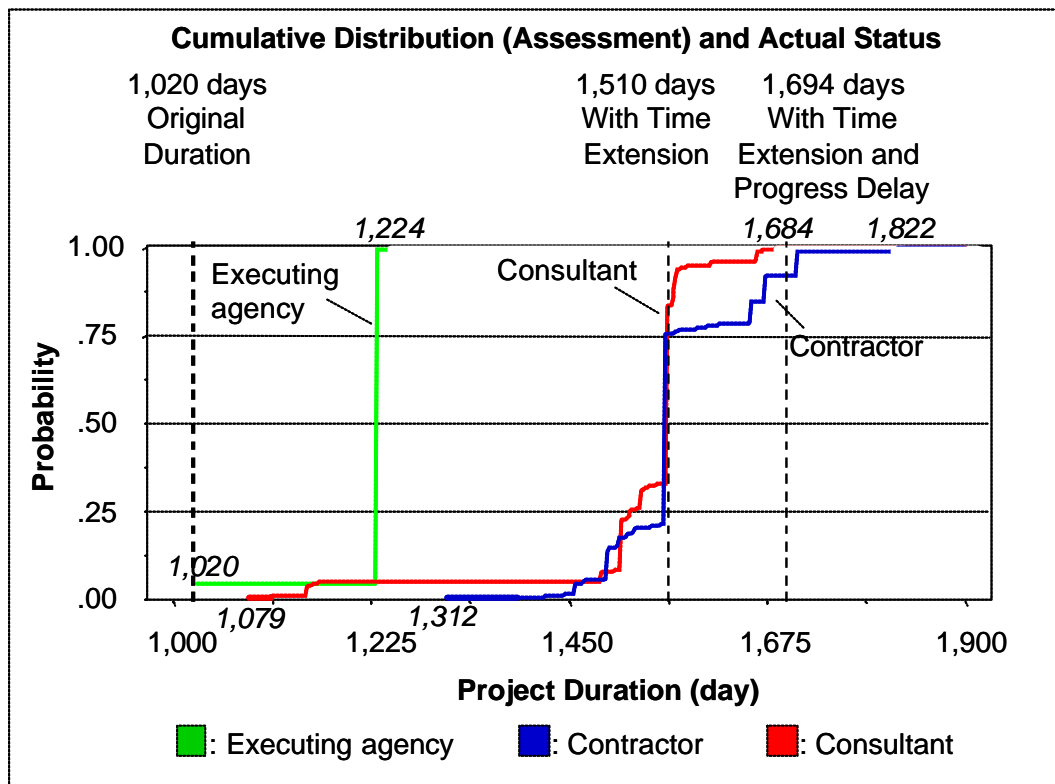


Figure 7.20: Cumulative distribution of project duration (all parties) and actual status

Discussion regarding sources of error, which make the discrepancy between assessor's assessment and actual status, as well as refinement of MRUMP and application are made in next section.

## 7.8 Discussion of Source of Error

Although during the MRUMP application we have attempted to reduce the error by implementing following means: selecting appropriate assessors, explaining probability and impact elicitation procedure, and following up assessment result, the discrepancy associated with subjective judgment is inevitable.

The discrepancy of analysis result and actual status is possibly due to variation of each party's perception associated with three main sources of error i.e., HSRU, probability, and impact of risks and uncertainties. Error analysis is conducted in this section.

For executing agency, lack of experience, inadequate knowledge and opposite position are possible causations of error making ignorance of risks and uncertainties regarding contractor (e.g., mobilization of equipment and subcontractor and inefficient coordination among contractors in joint venture). Based on the executing agency's perception, only the land acquisition uncertainty was perceived as consequent uncertainty, though in reality there were also other risks and uncertainties occurred. Mentioned above the causations of this first source of error may be relevant to experience, knowledge, and position. Since this contractor is considered as international contractor, which has strong financial status, the executing agency might not have experience about the risks and uncertainties related to contractor with high reputation. In practice, the executing agency is mainly responsible for project administration. The consultant is one who performs site supervision for executing agency. With this position, the executing agency might not know contractor's constraint in mobilization of resources. Due to these causations, the executing agency might ignore risks and uncertainties related to contractor.

Moreover, the executing agency seemed to underestimate the impact of land acquisition uncertainty. Even though the executing agency could identify the land acquisition uncertainty, the executing agency seemed not expect the high impact of land acquisition problem. This may be because the executing agency never experienced significant impact of late land acquisition in his past experience.

For contractor, ignorance of risk related to self's defectiveness (lack of local experience), which is possibly caused by position factor, resulted in incomplete HSRU. It is possible that one may overlook in 'objectively' self-evaluation. Regarding deviation of probability, lack of experience and knowledge of local subcontractor possibly is the causation in underestimating probability of technical capability of subcontractor uncertainty. Due to lack of local experience and knowledge of local practice, the contractor seemed to underestimate the impact of land acquisition. Even though, the contractor is the big international contractor, this contractor just enters this country market.

For consultant, with his position the consultant did not directly involve with subcontractor; therefore, the consultant ignored uncertainty related to technical capability of subcontractor. The consultant also seemed to underestimate the probability of contractor's mobilization of subcontractor and coordination among contractors in joint venture uncertainties, since consultant might not expect these uncertainties related to high reputation and well-known contractor. With the same reason, the consultant seemed to underestimate impact of coordination among contractors in joint venture uncertainty.

In addition to above observation, causations of variation of each source of error may be caused by (1) assessor's bias, (2) timing assumption of assessment and (3) inefficient data collection e.g., time limitation of interview.

We can summarize the type and causation of error associated with each source of error according to above observation as following:

- (1) ignorance of risks and uncertainties due to lack of experience, lack of knowledge and different position,
- (2) underestimation of probability of risks and uncertainties due to available past experience, lack of experience and lack of knowledge,
- (3) underestimation of impact of risks and uncertainties due to lack of experience,

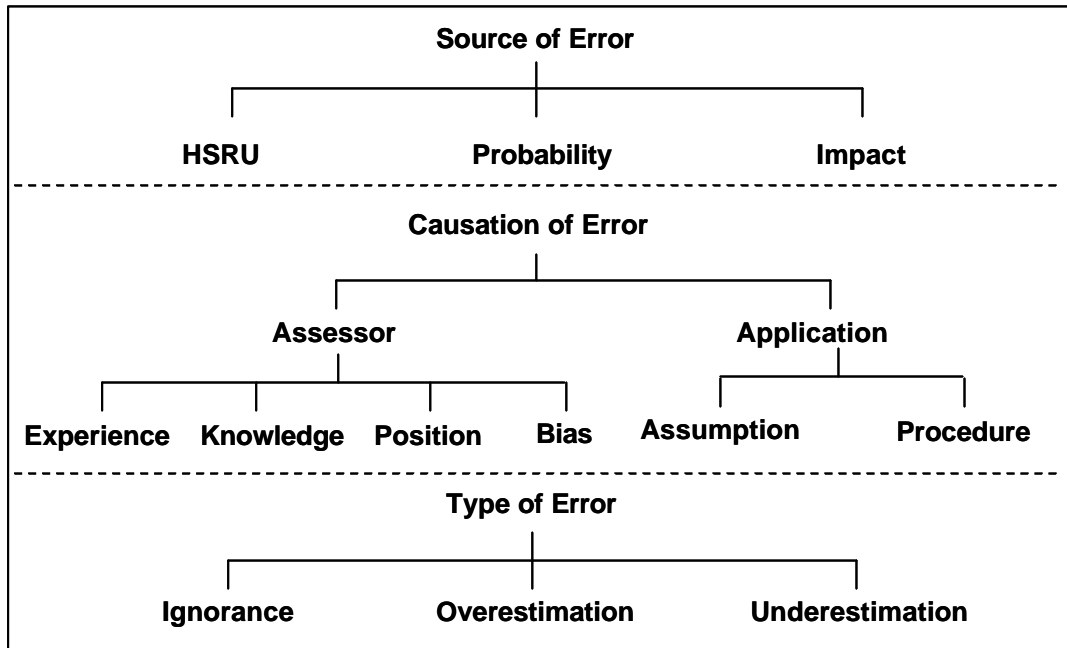


Figure 7.21: Hierarchical structure of source, causation, and type of error

- (4) over and underestimation of probability and impact due to assessor's subjective bias, and
- (5) error due to assumption and procedure in application.

Figure 7.21 shows this summary in hierarchical structure format. By understanding this source, causation, and type of error, we can further refine the MRUMP and improve future application.

Further, this comparison pinpoints the benefit of integration of multiple parties' views. We can observe from the error analysis that error is possibly mitigated by integrating all parties' views, because the comparison shows that one party could provide more realistic assessment of some risks and uncertainties than others and vice versa. By realizing this benefit, the meeting among all parties together with analyst for risk/uncertainty communication and problem solving is simulated to demonstrate how the MRUMP application result can be employed in practice. Next section provides the simulation of meeting.

## 7.9 Interpreting Result

In this section, we aim to make the explanation for two purposes. The first one is to explain the interpretation of the MRUMP application results of this case study. The second one is to demonstrate how the result of the MRUMP application can be used for risk communication among project parties via meeting. This purpose is to challenge the inefficient communication regarding risks in practice. The MRUMP application result from this case study is employed in demonstration.

Based on the timing assumption of assessment in this application previously defined in early part of this chapter, we assumed that the application is implemented during the early stage of construction after project commencement date. Relying on this assumption, for the first purpose, the explanation of result interpretation is also assumed to be made after completion of assessment in early stage of construction.

For the second purpose, we assume the situation that there is a meeting for discussion about the result of the MRUMP application in the case study. The participants who participate in the meeting include analyst and all assessors from executing agency, contractor, and consultant. The analyst is performing the role of facilitator and mediator in the meeting to present the result of application and draw the discussion from all participants.

The result of application, which has been done up to the analysis process i.e., the cumulative distribution of project duration to all parties are focused in this interpretation. In interpreting the result of application, we usually start to look at result of cumulative distribution of project duration, since it tells us about the overview of project based on assessment and analysis of risks and uncertainties. Then, the following questions may come. How can we interpret this distribution? How can it be used? Normally, we can use the cumulative distribution of project duration in answering following two main questions:



Analyst:	In this meeting, I would like to present the result of the MRUMP application and have your discussion towards the result. First, I would like to briefly summarize what we have done in the application. Recently, the project is in the early stage of construction. We are trying to figure out what will happen to the project (in terms of project duration) in the future based on each party's perception. I have assisted all of you in conducting the identification and structuring of risks and uncertainties and assessment of probability and impact of those identified and structured risks and uncertainties. Each party has done these processes separately. In this meeting, everyone will know your own perception and others' perception towards the exposure of risks and uncertainties to the project.
Assessors from executing agency:	Yes, we have gone through the number of steps. Now, I would like to know the result. First, I would like to know <b><i>when will the project finish?</i></b> Could you show me the result?
Analyst:	Initially, I would like to remind and explain pre-specified assumption regarding base project duration used in analysis. As the original contract duration is 1,020 days. In analysis, we used this duration as base duration by assuming that this duration does not incorporate the exposure of newly identified risks and uncertainties. Even though, normally, to estimate this duration in practice, based on past experience, consideration of some risks such as weather condition is already incorporated.
Assessor from contractor:	It means that our estimation of impact of newly identified risks and uncertainties are simply added to this base duration, doesn't it?
Analyst:	Yes, that's right. Then, let me describe the result. According to the statistics information from simulation, the <b><i>most likely project duration</i></b> based on each party's perception are follows: - <b><i>executing agency's perception: = 1,214 days</i></b> - <b><i>contractor's perception: = 1,571 days, and</i></b> - <b><i>consultant's perception: = 1,531 days.</i></b> (see Table 7.13, 7.14, and 7.15)
Assessor from consultant:	Based on each party's perception, project probably seems to suffer from serious delay.
Analyst:	Yes, it seems to be like that. We will discuss why the result is showing like this and what causes delay of project later. Now let us focus on interpretation of this result first.
Assessor from executing agency:	So, I would like to simply know that <b><i>what will be duration of project that we can have high possibility in completion?</i></b>

Analyst:	What is your desired possibility?
Assessor from executing agency:	Let me say 90% chance of completion.
Analyst:	Based on cumulative distribution of project duration in Figure 7.17, <b>at 90% chance of completion, the project duration will be:</b> - <b>executing agency's perception: within 1,224 days</b> - <b>contractor's perception: within 1,672 days, and</b> - <b>consultant's perception: within 1,571 days.</b>
Assessor from consultant:	If I would rather to know that <b>what will be the likelihood that project will be completed within 1,500 days?</b>
Analyst:	Again, based on cumulative distribution of project duration in Figure 7.17, <b>the probability that project will be completed within 1,500 days is:</b> - <b>executing agency's perception: 100% (exceed maximum range)</b> - <b>contractor's perception: about 20%, and</b> - <b>consultant's perception: about 10%.</b>

Figure 7.22: Dialog of interpretation of cumulative distribution discussion

- What will be probability that project will be completed within desired project duration or completion date?
- What will be project duration or project completion date corresponding to desired probability of completion?

Dialog in Figure 7.22 attempts to present how the cumulative distribution of project duration is interpreted. It demonstrates how the result of the MRUMP application particular the interpretation of cumulative distribution of project is utilized. According to the explanation in that dialog, two points are identified.

First, we can notice that the result of estimated project duration of each party is much different from original duration. The reason is relevant to defined assumption that using the original duration as a base duration. Moreover, new risks and uncertainties have been identified and their impacts cause much delay. Regarding this matter, the following question, which should be addressed in meeting, is what are those risks and uncertainties that cause delay of project?

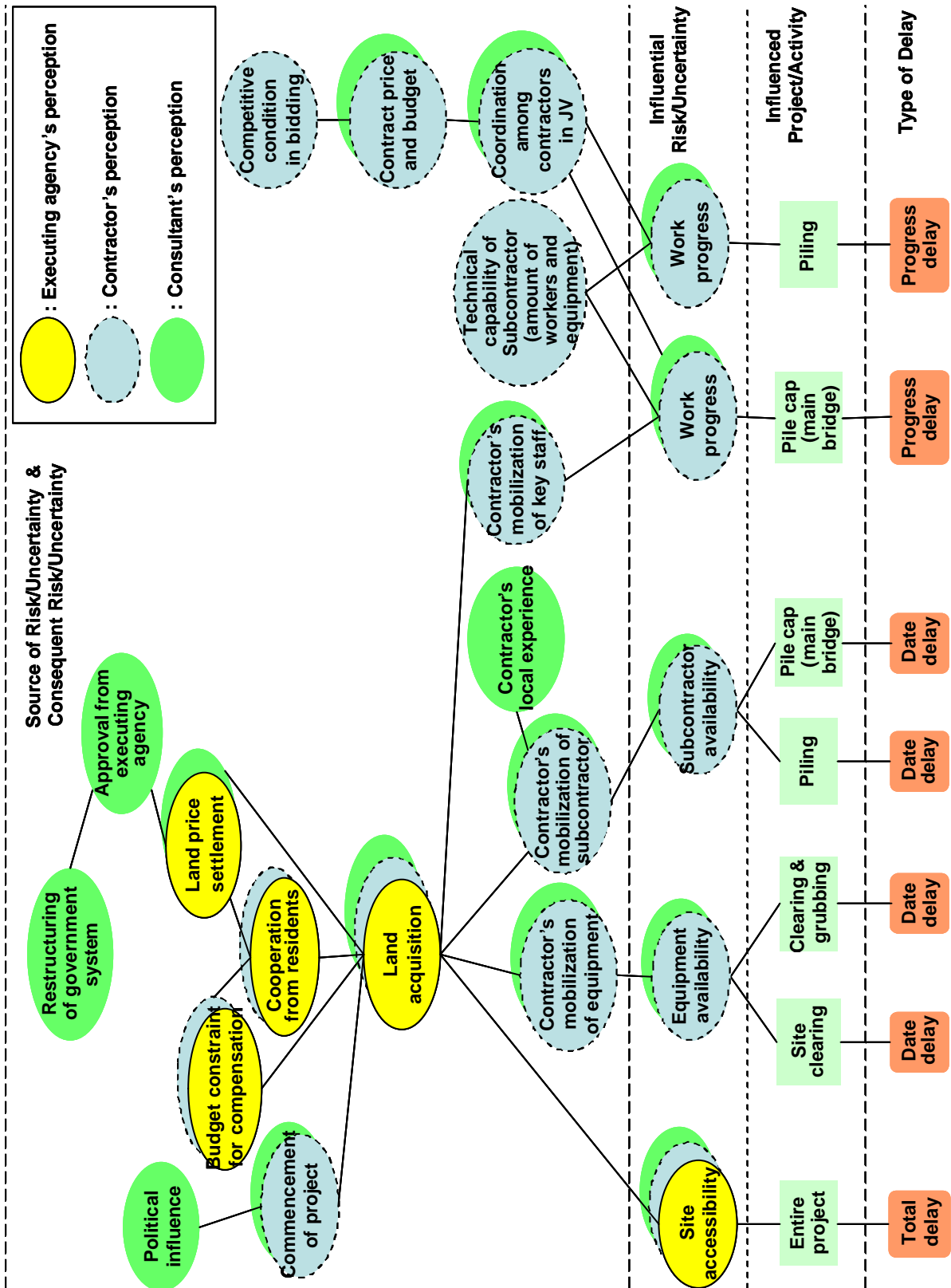


Figure 7.18: Integrated HSRU (again)

Assessor from executing agency:	The project seems to suffer from serious delay. <b><i>What are those risks and uncertainties that cause delay of project?</i></b>
Analyst:	From the application result, I summarize HSRUs of all parties into one structure as shown in Figure 7.18. It is called ‘integrated HSRU.’ From this structure, we can know the impacted activity/project and its type of delay, influential risks/uncertainties causing that delay, and consequent and source of risks and uncertainties. This structure shows you overall picture where delay will occur and what causes delay.
Assessor from consultant:	From this ‘integrated HSRU’, we can understand the holistic view of what will happen to project according to all parties’ perception.
Analyst:	For example, all parties perceive that the <b><i>site accessibility of project is uncertain</i></b> that cause <b><i>project start date delay</i></b> . This is due to risk or uncertainty regarding <b><i>late land acquisition</i></b> that is resulted from several consequent and source risks and uncertainties such as <b><i>inappropriate timing of project commencement, lack of cooperation from residents, constraint of compensation budget and etc.</i></b> Furthermore, the contractor and consultant identified other risks and uncertainties.
Assessor from contractor:	Yes, I similarly identified the land acquisition uncertainty influencing site accessibility of project. Moreover, <b><i>I also perceived the subsequent and lingering effects of land acquisition uncertainty. For subsequent effect, I perceived that due to late land acquisition, I may have to delay in mobilization of equipment and subcontractor. For lingering effect, I may have to delay in mobilization of key staff. Of course these effects may result in date delay and progress delay of some activities.</i></b>
Assessor from consultant:	I also perceived <b><i>the subsequent and lingering effects of late land acquisition that cause delay in contractor’s mobilization of and equipment and key staff, respectively.</i></b>
Assessor from executing agency:	To me, <b><i>I perceived only the site accessibility uncertainty due to late land acquisition.</i></b> Regarding subsequent and lingering effects of late land acquisition, since I understand that it is with contractor’s responsibility to mobilize necessary staff, equipment and subcontractor and these resources should be available when land is handed over.
Analyst:	Another example based on contractor’s perception is that the contractor perceived there may be <b><i>progress delay in piling activity</i></b> due to <b><i>incapable subcontractor</i></b> and <b><i>inefficient coordination among contractors in joint venture.</i></b>

Assessor from consultant:	Yes, I also perceived the work progress of piling activity may be delayed similar to what mentioned by contractor. However, <b><i>I could identify only inefficient coordination among contractors in joint venture as the consequent uncertainty, but not the incapable subcontractor.</i></b>
Analyst:	As you can see from the ‘integrated HSRU’ in Figure 7.18, your structure towards what will cause project delay is in some extent different from party to party. Additionally, based on your ‘risk/uncertainty impact quantification chart’ in Figure 7.19, your perceptions towards impact to activities also are different. This is the first reason explaining difference in the estimated project duration based on each party’s perception. In brief, <b><i>your perception toward risks and uncertainties are different. Then, we can be aware of problem and identify source of problem. Next, we have to integrate each other to propose solution that satisfies all parties as much as possible.</i></b>

Figure 7.23: Dialog of identified risks and uncertainties discussion

The second point is regarding the difference of the result of each party. As we can see from the result described in Figure 7.22, the estimated project duration based on executing agency’s perception is much different from contractor’s and consultant’s estimation. This draws the second question that why the result of each party is different. The dialog in Figure 7.23 discusses these matters.

According to the dialog in Figure 7.23, all parties could be aware of problem and identify the source of problem by employing the ‘integrated HSRU’ (Figure 7.18) and RUIC (Figure.719) based on each party’s perception. Then, in next section, all parties are encouraged to integrate their views together in seeking solution to problem that satisfies all parties as much as possible.

## 7.10 Possible Solution at Early Stage of Construction

Previously, we discuss all parties’ perception regarding their identified risks and uncertainties including land acquisition (occurring risk/uncertainty), mobilization of equipment and subcontractor (subsequent risk/uncertainty), mobilization of key staff (lingering risk/uncertainty), and technical capability of subcontractor and coordination among contractors in joint venture (new future risk/uncertainty). Up to this stage, all

parties suppose to be aware of different viewpoints among them. By gathering all parties' view in problem awareness stage, the 'reference' for problem identification could be obtained. Then, by comparing all parties' perceptions to find difference, in problem identification stage they are encouraged to communicate and identify problem. Finally, the integration of all parties is necessary in problem solving stage, which is demonstrated in this section.

The problem solving stage aims to find solution that satisfies all parties as much as possible. In this stage, all involved parties' views should be integrated. Moreover, they should communicate each other by using reference information such as 'integrated HSRU' and RUIC.

In this case study, based on previous observation and discussion, it could be noted that the future problem to project was related to contractor's mobilization of equipment and subcontractor as subsequent risk/uncertainty due to uncertain condition of land acquisition. As described in Table 7.16, it is executing agency's responsibility to acquire land and it is responsibility of contractor to mobilize the equipment and subcontractor. The problem might not occur or become significant, if there was no influential relation linking these risks/uncertainties. However, practically contractor's decision regarding when equipment and subcontractor should be mobilized mainly depends on amount and sequence of handed over land. Both executing agency and contractor had different views.

Considering contractual condition regarding land acquisition and mobilization, Clause 19.2 stated that: *"... If the Contractor suffers delay or incurs cost from failure on the part of the Employer to give possession, the Employer shall grant an extension of time for the complement of the Works, provided that the Contractor shall not claim any cost for such delay."*

The executing agency also further added following condition to this clause i.e., *"the Employer may require the Contractor to amend the Works Program submitted in accordance with Sub-Clause 5.9, from time to time to suit the precise times after further*

*portions of the Site becomes available, and the Contractor shall modify his program accordingly which shall identify the minimum period required to complete the Works under the new circumstances.”*

It could be interpreted that the executing agency would grant only time extension in corresponding to late land acquisition. The contractor had to consume the incurred cost due to this uncertainty. Furthermore, the contractor had to execute works according to sequence of land handed over by the executing agency (referred to additional clause described above).

Tied with this contractual condition, since contractor might not be able to claim for incurred cost due to late land acquisition, it was not desirable for contractor to mobilize equipment and subcontractor to site when land was still not handed over. As stated above, for contractor, not only amount of land but also sequence of land was important in making decision to start works. It seemed that this governed contract condition might not be compatible with contractor's practice. If the amount and sequence of land handed over to contractor by executing agency was not enough and not in workable order for contractor, the possibility of delay in mobilization of equipment and subcontractor and conflict between the executing agency and contractor might become high.

Therefore, as a possible solution to this problem, both parties should communicate and exchange the information necessary for both parties. They should cooperate together in preparing land acquisition plan and construction schedule. With efficient communication and cooperation, the executing agency might be able to understand the priority of land that should be acquired in order to enable contractor's workability. The contractor also might be able to know when equipment and subcontractor should be mobilized to site. If both parties performed this solution, the impact (delay) of mobilization of equipment and subcontractor uncertainty might be reduced or totally eliminated.

In summary, with this opportunity, from the MRUMP application the risks and uncertainties information were collected and made available as reference to all parties.

And they were encouraged to express their opinion towards each identified risk and uncertainty as well as towards others' perception in matter of difference and similarity in risk perception and matter of characteristics of risk and uncertainty. With this practice, the different views among parties could be aware. Thus, by using gathered risk/uncertainty 'reference,' they were able to communicate and discuss more about the future project situation such as what risks and uncertainties were source of uncertainty and should be put attention in the future. Then the problem could be identified. Significantly, with integration of all parties, this understanding enables all parties to propose solution that is desirable to all parties as much as possible in problem solving stage.

## **7.11 Developing Response Scenario**

As stated at the early part of this chapter, the time frame of second timing of application is assumed to be from current stage to the end of construction. The purpose of the second application is to find the efficient response that satisfies all parties as much as possible. For the assessment point, the assessors were asked to assess risks and uncertainties associated with each response scenario at the current stage.

### **7.11.1 Selected Responded Risk/Uncertainty**

Based on the result of risks/uncertainties identification, structuring, and analysis in previous sections, the potential common causations of project delay perceived by all practitioners are listed up as:

1. Late land acquisition by the executing agency
2. Late mobilization of subcontractor and equipment by contractor
3. Late mobilization of key staffs by contractor
4. Inefficient coordination among contractors in joint venture

These risks/uncertainties are focused in this response process. Following sections explain the application result of response process.



### **7.11.2 Proposed Response Scenarios**

In response process, we try to find the efficient solution for this project and preventive measure for future project. The response alternatives categorized in three categories as (1) accept (do nothing), (2) reactive measure (solution), and (3) proactive measure are summarized as following.

#### **1. Accept (do nothing)**

- 1.1 Do nothing about late land acquisition
- 1.2 Do nothing about late mobilization of subcontractor and equipment
- 1.3 Do nothing about late mobilization of key staffs
- 1.4 Do nothing about inefficient coordination among contractors in joint venture

#### **2. Reactive measure (solution)**

- 2.1 Contractor increases number of subcontractors and equipment, prepares and implements mobilization plan of subcontractors and equipment.
- 2.2 Contractor increases and mobilizes more management and engineering staffs.
- 2.3 Each contractor's management level improve coordination and focus on joint venture's and project's benefit.
- 2.4 Contractor enhances managerial capability of staff.

#### **3. Preventive measure**

- 3.1 Executing agency acquires most or total of land before project commencement date specified in notice to proceed.
- 3.2 Executing agency drafts contract condition related to late land acquisition based on the international standard form of contract (FIDIC) by providing time extension and cost incurred due to late land acquisition.
- 3.3 Executing agency put more importance on contractor's local experience and personnel and equipment performance by adding item to evaluate contractor's local

experience and assigning more weight on personnel and equipment item in prequalification evaluation.

## **7.12 Constructing Response Scenario Diagram and Assessing Probability and Impact**

The response scenario diagram (RSD) presents the consequential relationship between focused risks/uncertainties, proposed response scenario, consequential risks/uncertainty and impact, and outcome associated with the implementation of that response scenario. After response scenarios have been proposed, their RSDs then were developed based on each party's perception. Subsequently, assessors from all parties provided their assessment on probability and impact based on constructed RSD. The RSDs and assessment result of probability and impact associated with each response scenario based on each party's perception are presented in following sections.

### **7.12.1 RSD, Probability, and Impact based on Executing Agency's Perception**

Based on the executing agency's perception, the RSDs and probability and impact assessment result associated with each proposed response scenario are presented in following figures and tables simultaneously.

**Accept Response Scenario : Accept current situation (provide only time extension)**  
**(executing agency)**

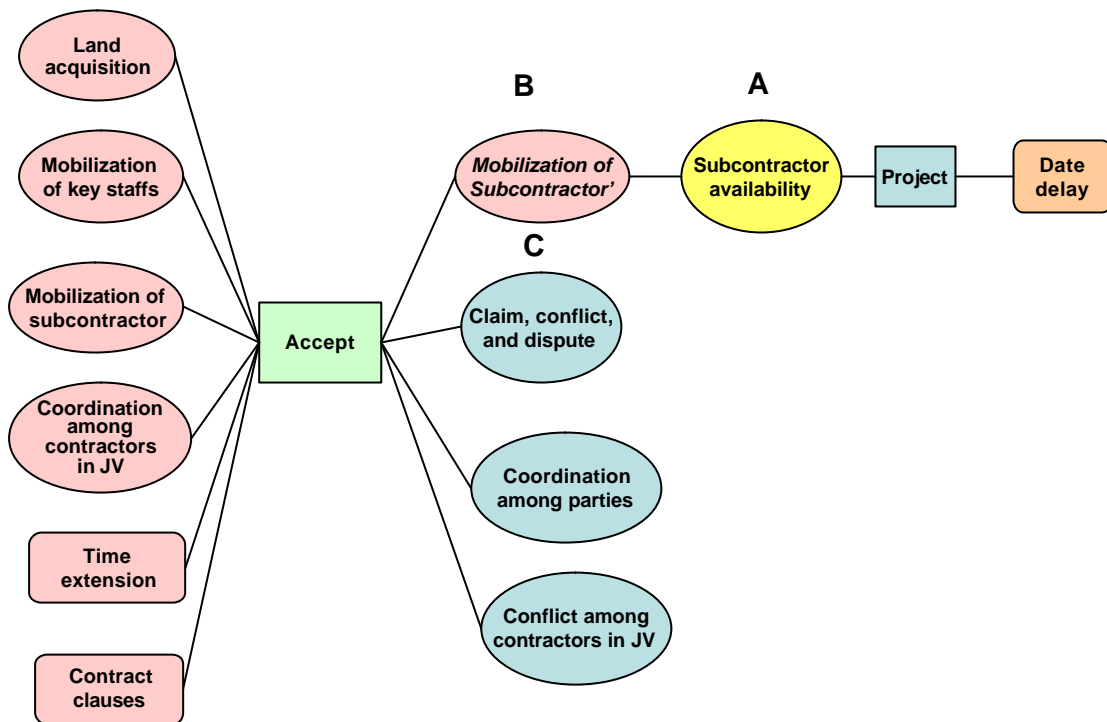


Figure 7.24: Response scenario diagram of accept response perceived by executing agency

Table 7.20: Probability and impact assessment of risks and uncertainties associated with accept response scenario based on Figure 7.24 (executing agency)

<b>Risk/Uncertainty</b>	<b>Probability</b>	<b>Impact</b>
Mobilization of subcontractor' (B)	0.95	100% of remaining duration
Claim, conflict, and dispute (C)	0.2	Approximately 3 years

### Reactive Response Scenario 1: Increasing no. of subcontractors (executing agency)

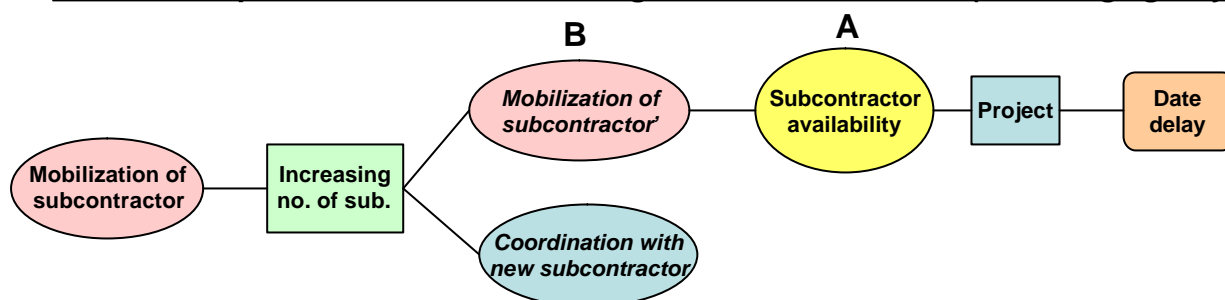


Figure 7.25: Response scenario diagram of reactive response scenario 1 perceived by executing agency

### Reactive Response Scenario 2: Increasing no. of key staffs (executing agency)

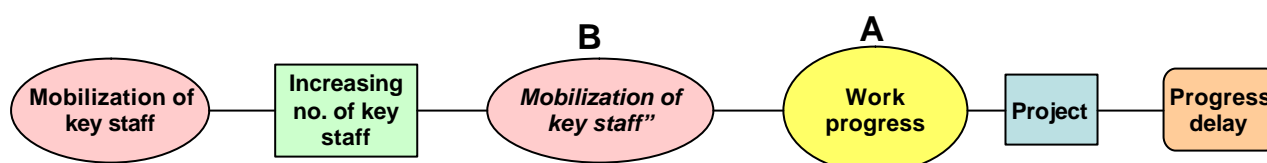


Figure 7.26: Response scenario diagram of reactive response scenario 2 perceived by executing agency

### Reactive Response Scenario 3: Improving contractors' coordination (executing agency)

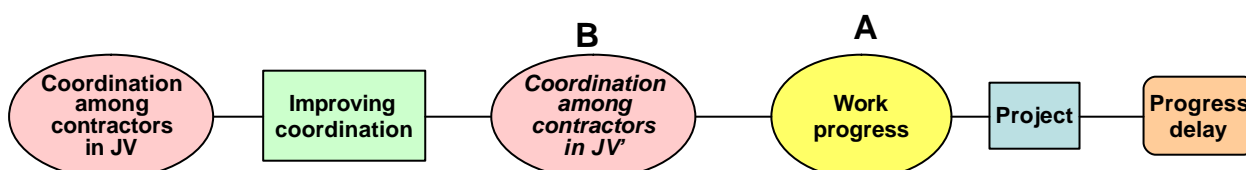


Figure 7.27: Response scenario diagram of reactive response scenario 3 perceived by executing agency

Table 7.21: Probability and impact assessment of risks and uncertainties associated with reactive response scenario 1 based on Figure 7.25 (executing agency)

Risk/Uncertainty	Probability	Impact
Mobilization of subcontractor' (B)	0.95	65% of remaining duration

Table 7.22: Probability and impact assessment of risks and uncertainties associated with reactive response scenario 2 based on Figure 7.26 (executing agency)

Risk/Uncertainty	Probability	Impact
Mobilization of key staff' (B)	0.95	65% of remaining duration

Table 7.23: Probability and impact assessment of risks and uncertainties associated with reactive response scenario 3 based on Figure 7.27 (executing agency)

Risk/Uncertainty	Probability	Impact
Coordination among contractors in JV' (B)	0.95	65% of remaining duration

**Reactive Response Scenario 4: Enhancing managerial capability of contractor's staff  
(executing agency)**

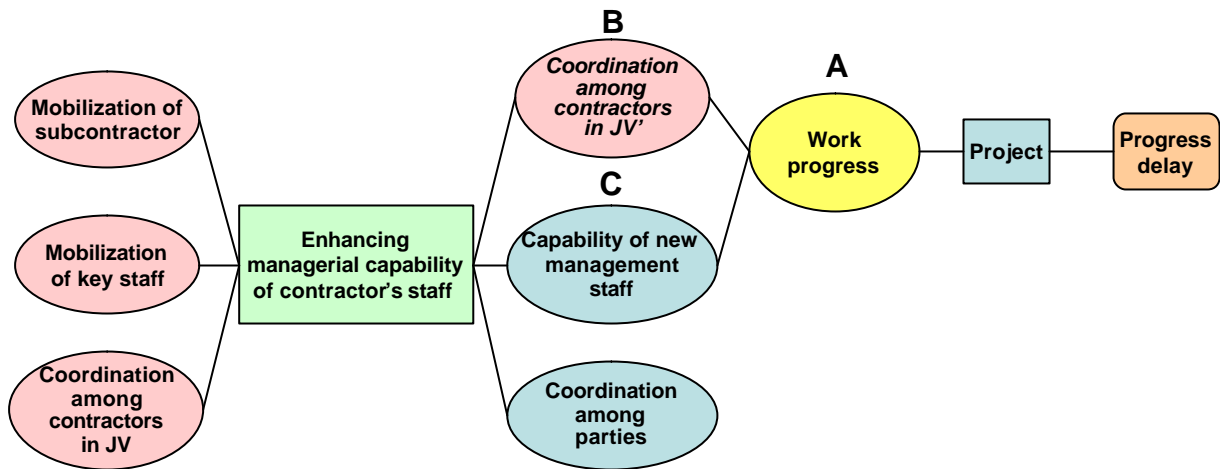


Figure 7.28: Response scenario diagram of reactive response scenario 4 perceived by executing agency

Table 7.24: Probability and impact assessment of risks and uncertainties associated with reactive response scenario 4 based on Figure 7.28 (executing agency)

<b>Risk/Uncertainty</b>	<b>Probability</b>	<b>Impact</b>
Coordination among contractors in JV' (B)	0.5	14% of remaining duration
Capability of new management staff (C)	0.05	5% of remaining duration

**Proactive Response Scenario 1: Acquiring most or total of land before commencement  
(executing agency)**

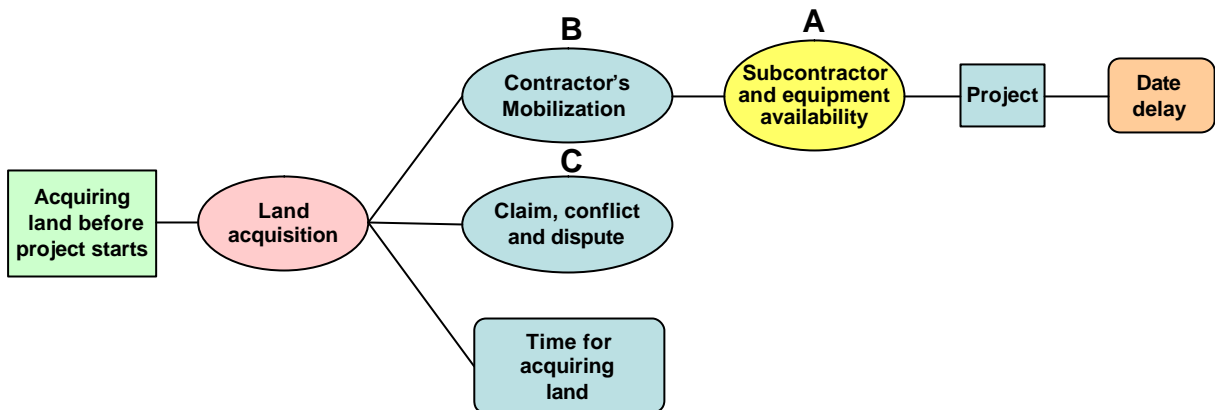


Figure 7.29: Response scenario diagram of proactive response scenario 1 perceived by executing agency

Table 7.25: Probability and impact assessment of risks and uncertainties associated with proactive response scenario 1 based on Figure 7.29 (executing agency)

<b>Risk/Uncertainty</b>	<b>Probability</b>	<b>Impact</b>
Contractor's mobilization (B)	0.5	18% of remaining duration
Claim, conflict, and dispute ©	0.2	Approximately 3 years
Time for land acquisition	-	Approximately 2 years

**Proactive Response Scenario 2: Adopting contract condition of FIDIC (allow time and cost for late land acquisition) (executing agency)**

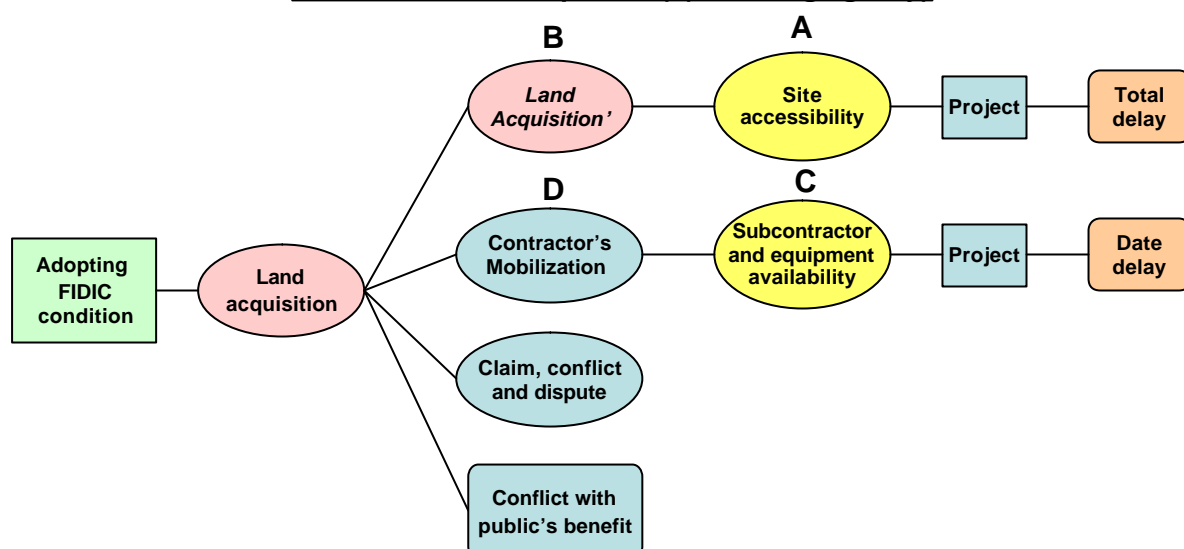


Figure 7.30: Response scenario diagram of proactive response scenario 2 perceived by executing agency

Table 7.26: Probability and impact assessment of risks and uncertainties associated with proactive response scenario 2 based on Figure 7.30 (executing agency)

<b>Risk/Uncertainty</b>	<b>Probability</b>	<b>Impact</b>
Land acquisition (B)	0.95	45% of original duration
Contractor's mobilization (D)	0.5	18% of original duration

For proactive response scenario 3 (improving prequalification criteria regarding contractor's experience and personnel and equipment items), the executing agency did not perceive its applicability. The executing agency perceived financial factor is more important than the criteria regarding local experience and personnel and equipment items.

### **7.12.2 RSD, Probability, and Impact based on Contractor's Perception**

Based on the contractor's perception, the RSDs and probability and impact assessment result associated with each proposed response scenario are presented in following figures and tables simultaneously.

**Accept Response Scenario 1: Accept current situation (provide only time extension)**  
(contractor)

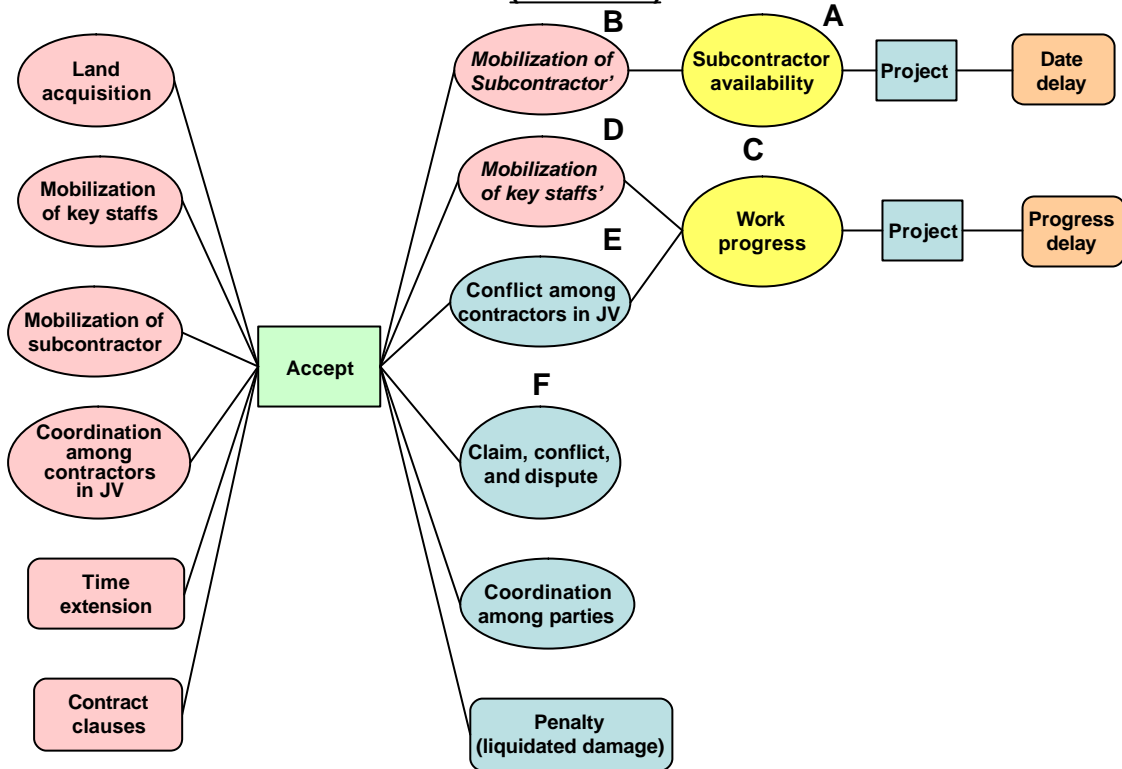


Figure 7.31: Response scenario diagram of accept response scenario perceived by contractor

Table 7.27: Probability and impact assessment of risks and uncertainties associated with accept response scenario based on Figure 7.31 (contractor)

Risk/Uncertainty	Probability	Impact
Mobilization of subcontractor (B)	0.95	100% of original duration
Mobilization of key staffs' (D)	0.95	100% of original duration
Conflict among contractors in JV (E)	0.95	100% of original duration
Claim, conflict and dispute (F)	0.5	Approximately 3 years



**Reactive Response Scenario 1: Increasing no. of subcontractors (contractor)**

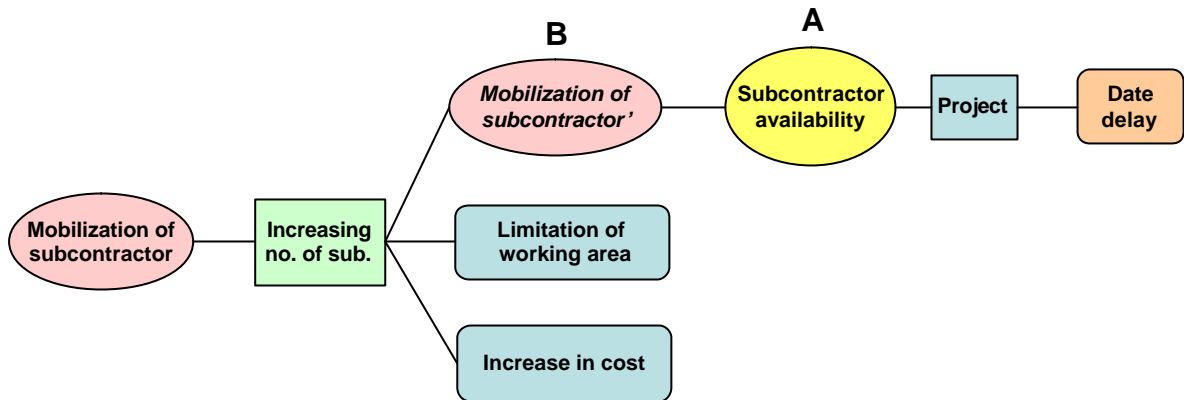


Figure 7.32: Response scenario diagram of reactive response scenario 1 perceived by contractor

**Reactive Response Scenario 2: Increasing no. of key staffs (contractor)**

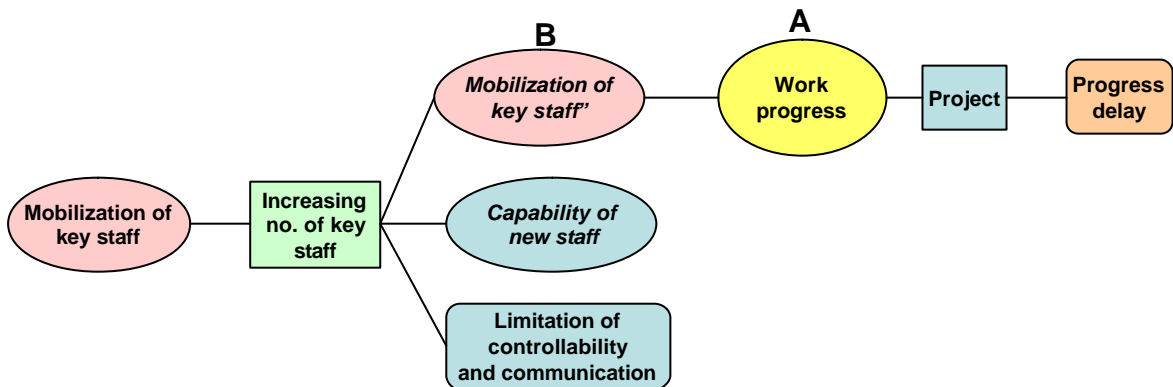


Figure 7.33: Response scenario diagram of reactive response scenario 2 perceived by contractor

Table 7.28: Probability and impact assessment of risks and uncertainties associated with reactive response scenario 1 based on Figure 7.32 (contractor)

Risk/Uncertainty	Probability	Impact
Mobilization of subcontractor (B)	0.05	0.1% of original duration

Table 7.29: Probability and impact assessment of risks and uncertainties associated with reactive response scenario 2 based on Figure 7.33 (contractor)

Risk/Uncertainty	Probability	Impact
Mobilization of key staff' (B)	0.95	50% of original duration

**Reactive Response Scenario 3: Changing contractors' attitude (contractor)**

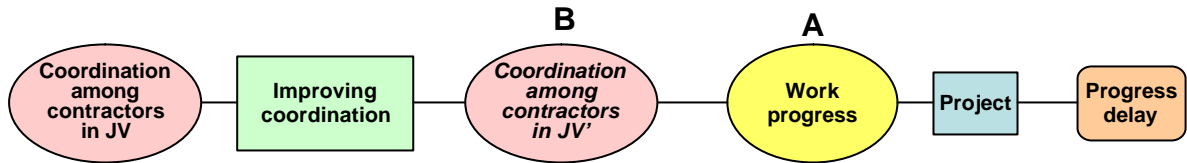


Figure 7.34: Response scenario diagram of reactive response scenario 3 perceived by contractor

Table 7.30: Probability and impact assessment of risks and uncertainties associated with reactive response scenario 3 based on Figure 7.34 (contractor)

<b>Risk/Uncertainty</b>	<b>Probability</b>	<b>Impact</b>
Coordination among contractors in JV' (B)	0.95	50% of original duration

For reactive response scenario 4 (enhancing managerial capability of contractor's staff), contractor did not provide his perception towards this response scenario. However, the contractor added comment regarding the managerial capability of executing agency that if the managerial capability of executing agency's management staff is enhanced by replacement of new staff, there may be coordination and cooperation problem among parties. All parties may face difficulty in working together.

**Proactive Response Scenario 1: Acquiring most or total of land before commencement (contractor)**

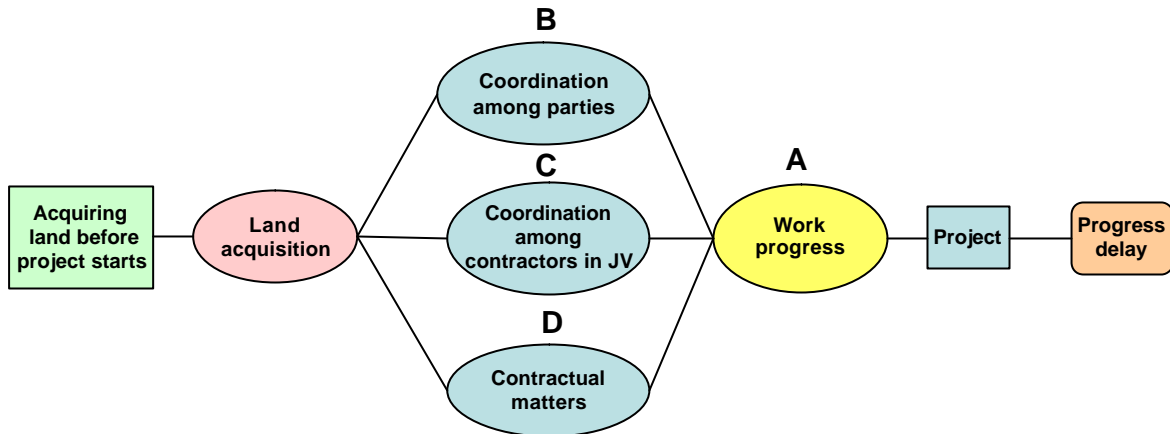


Figure 7.35: Response scenario diagram of proactive response scenario 1 perceived by contractor

**Proactive Response Scenario 2: Adopting contract condition of FIDIC (allow time and incurred cost for late land acquisition) (contractor)**

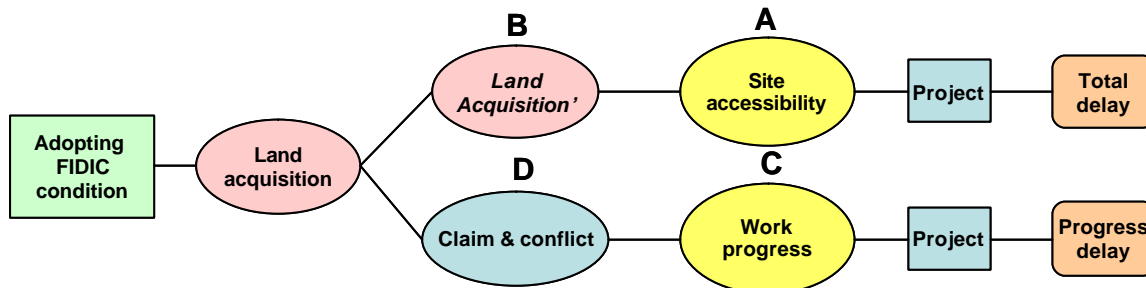


Figure 7.36: Response scenario diagram of proactive response scenario 2 perceived by contractor

Table 7.31: Probability and impact assessment of risks and uncertainties associated with proactive response scenario 1 based on Figure 7.35 (contractor)

Risk/Uncertainty	Probability	Impact
Coordination among parties (B)	0.80 ( $P(B \cap C \cap D)$ )	20% of original duration
Coordination among contractors in JV (C)		
Contractual matters (D)		

Table 7.32: Probability and impact assessment of risks and uncertainties associated with proactive response scenario 2 based on Figure 7.36 (contractor)

Risk/Uncertainty	Probability	Impact
Land acquisition' (B)	0.95	45% of original duration
Claim and conflict (D)	0.95	10% of original duration

For the proactive response scenario 3 (improving prequalification criteria regarding contractor's experience and personnel and equipment items), the contractor perceived the possibility that the contractor may not be qualified.

### **7.12.3 RSD, Probability, and Impact based on Consultant's Perception**

Based on the consultant's perception, the RSDs and probability and impact assessment result associated with each proposed response scenario are presented in following figures and tables simultaneously.

**Accept Response Scenario 1: Accept current situation (provide only time extension)**  
**(consultant)**

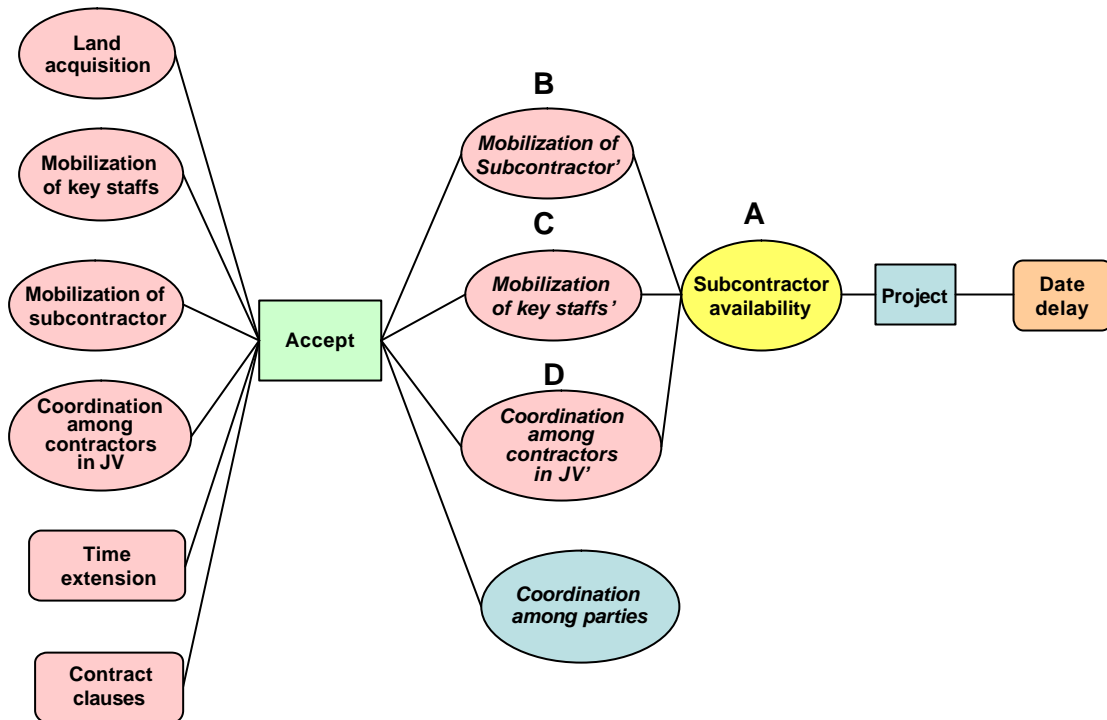


Figure 7.37: Response scenario diagram of accept response scenario perceived by consultant

Table 7.33: Probability and impact assessment of risks and uncertainties associated with accept response scenario based on Figure 7.37 (consultant)

Risk/Uncertainty	Probability	Impact
Mobilization of subcontractor' (B)	0.95 ( $P(B \cap C \cap D)$ )	100% of remaining duration
Mobilization of key staff' (C)		
Coordination among contractors in JV' (D)		

### Reactive Response Scenario 1: Increasing no. of subcontractors (consultant)

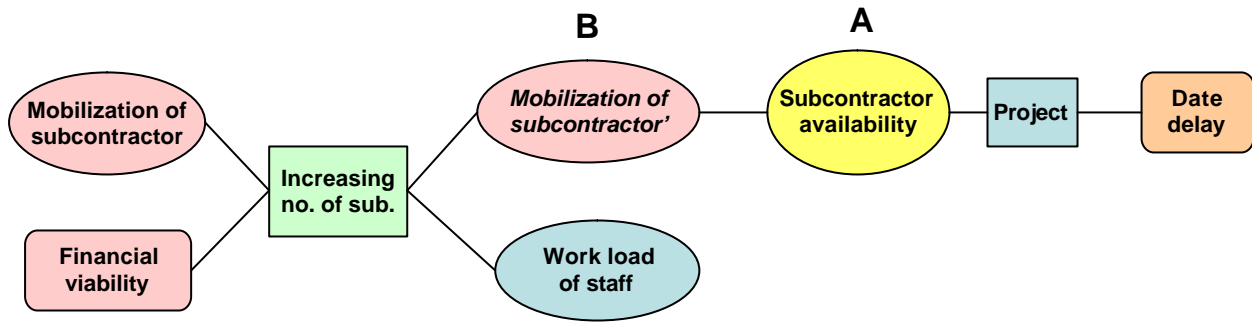


Figure 7.38: Response scenario diagram of reactive response scenario 1 perceived by consultant

### Reactive Response Scenario 2: Increasing no. of key staffs (consultant)

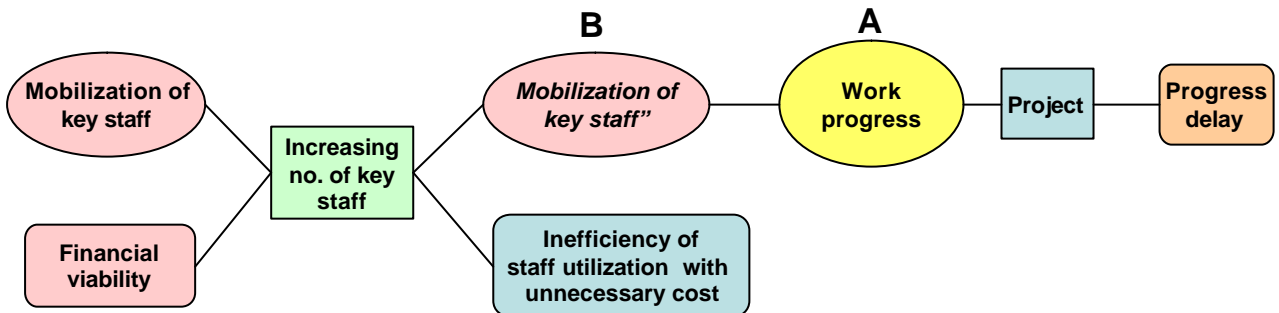


Figure 7.39: Response scenario diagram of reactive response scenario 2 perceived by consultant

Table 7.34: Probability and impact assessment of risks and uncertainties associated with reactive response scenario 1 based on Figure 7.38 (consultant)

Risk/Uncertainty	Probability	Impact
Mobilization of subcontractor' (B)	0.95	50% of remaining duration

Table 7.35: Probability and impact assessment of risks and uncertainties associated with reactive response scenario 1 based on Figure 7.39 (consultant)

Risk/Uncertainty	Probability	Impact
Mobilization of key staff' (B)	0.95	50% of remaining duration

**Reactive Response Scenario 3: Improving contractors' coordination (consultant)**

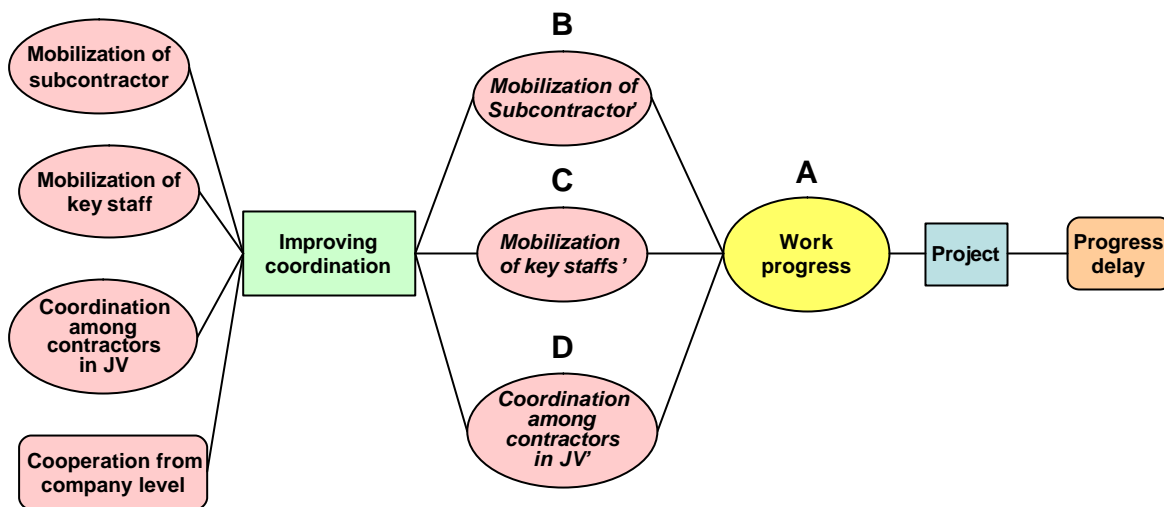


Figure 7.40: Response scenario diagram of reactive response scenario 3 perceived by consultant

Table 7.36: Probability and impact assessment of risks and uncertainties associated with reactive response scenario 3 based on Figure 7.40 (consultant)

Risk/Uncertainty	Probability	Impact
Mobilization of subcontractor' (B)	0.80 ( $P(B \cap C \cap D)$ )	5% of remaining duration
Mobilization of key staff' (C)		
Coordination among contractors in JV' (D)		

**Reactive Response Scenario 4: Enhancing managerial capability of contractor's staff  
(consultant)**

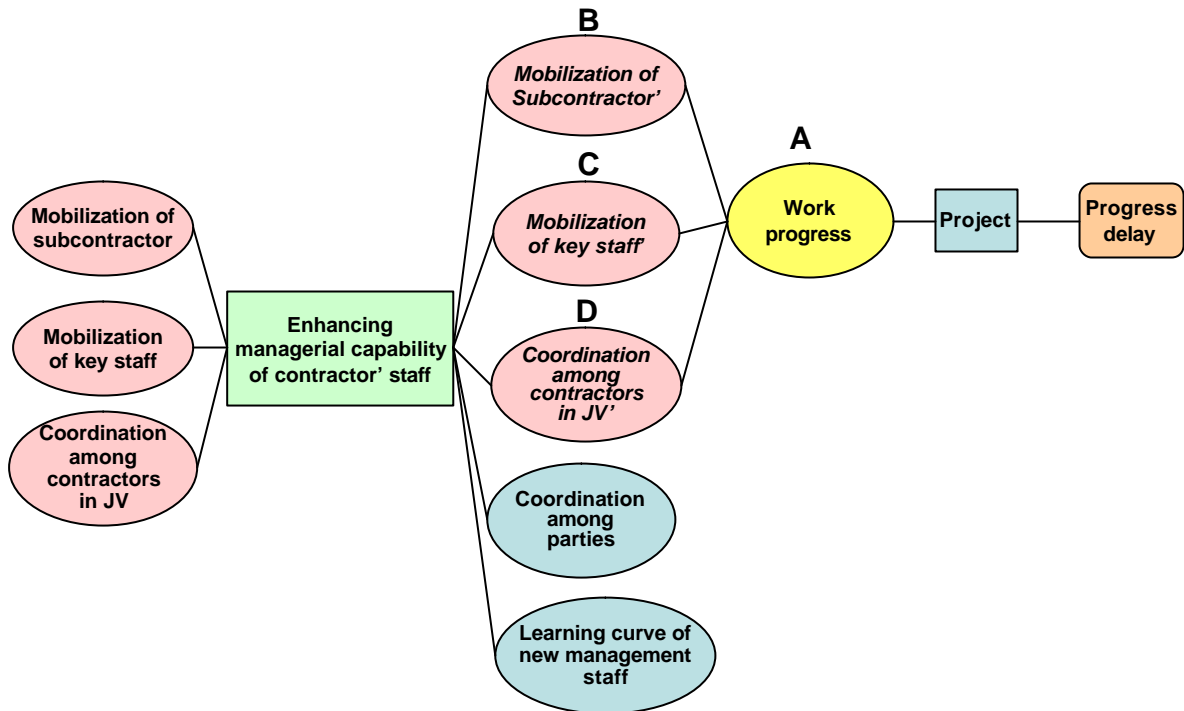


Figure 7.41: Response scenario diagram of reactive response scenario 4 perceived by consultant

Table 7.37: Probability and impact assessment of risks and uncertainties associated with reactive response scenario 4 based on Figure 7.41 (consultant)

Risk/Uncertainty	Probability	Impact
Mobilization of subcontractor' (B)	0.80 ( $P(B \cap C \cap D)$ )	30% of remaining duration
Mobilization of key staff' (C)		
Coordination among contractors in JV' (D)		



**Reactive Response Scenario 5: Increasing no. of subcontractors and staff (consultant)**

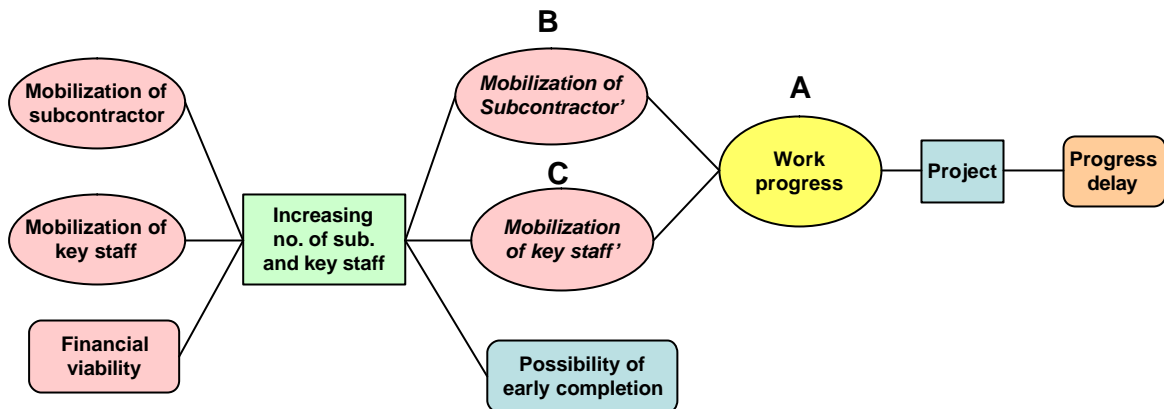


Figure 7.42: Response scenario diagram of reactive response scenario 5 perceived by consultant

**Proactive Response Scenario 1: Acquiring most or total of land before commencement (consultant)**

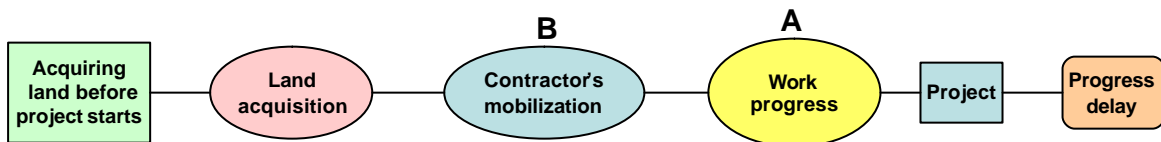


Figure 7.43: Response scenario diagram of proactive response scenario 1 perceived by consultant

Table 7.38: Probability and impact assessment of risks and uncertainties associated with reactive response scenario 5 based on Figure 7.42 (consultant)

Risk/Uncertainty	Probability	Impact
Mobilization of subcontractor' (B)	0.05 $P(B \cap C)$	0.1% of remaining duration
Mobilization of key staff' (C)		

Table 7.39: Probability and impact assessment of risks and uncertainties associated with proactive response scenario 1 based on Figure 7.43 (consultant)

Risk/Uncertainty	Probability	Impact
Contractor's mobilization (B)	0.05	5% of original duration

Regarding proactive response scenario 2 (adopting FIDIC contract conditions for land acquisition), the consultant commented that this response may not be applicable because the condition does not conform with local regulation.

For proactive response scenario 3 (improving prequalification criteria regarding contractor's local experience and personnel and equipment items), the consultant also perceived that this response may not be applicable.

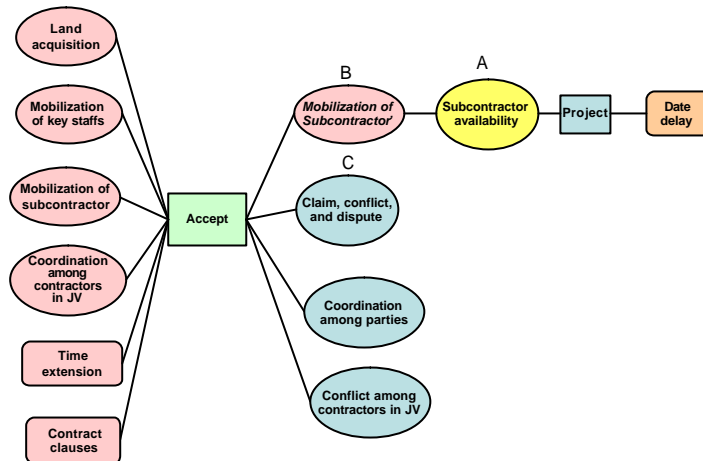
### **7.13 Analyzing Response Scenario**

The next step is to conduct the analysis of risks and uncertainties associated with each response scenario based on each party's perception. The analysis is conducted based on constructed RSDs and assessed probability and impact. The analysis procedure is grounded on similar basis of probability theory and simulation employed in risk/uncertainty analysis process. The joint probability tables, joint impact tables, probability distribution of impact (delay percentage) tables and probability distribution (delay duration) tables of each response scenario are provided in Appendix F. An example of response scenario analysis procedure is provided in Figure 7.44.

As similar to analysis process, we assigned the obtained probability distribution to project duration. In the simulation model, the project duration is characterized from three main types of duration i.e., elapsed time, impacted duration due to risk/uncertainty, and preparation time or other nominal impact. The simulation models of each response scenario are shown in Appendix G.

The simulation results associated with each response scenario of all parties are provided in next sections.

Accept Response Scenario: Accept current situation (provide only time extension)  
(Executing Agency)



Risk response diagram of 'Accept' response scenario

1. Analysis of influential uncertainty



$P(B) = 0.95$   
 Impact = 100% of remaining duration  
 Note: The progress is reduced around 50%. Or it equals to 100% delay of project duration.  
 Assumption  
 $P(A/B) = 1$   
 $P(A'/B') = 1$

Table EA Ac-1.1: Joint probability table

	B	B'
A	0.95	0
A'	0	0.05

Table EA Ac-1.2: Impact table

	B	B'
A	100	0
A'	0	0

Table EA Ac-1.3: Summary of probability and cumulative distribution of impact (delay percentage) to entire project (executing agency)

Impact (%)	Probability	Cumulative	E[I]
0	0.05	0.05	0
100	0.95	1	95
	1		95

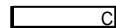
Table EA Ac-1.4: Summary of probability and cumulative distribution of impacted duration of project (executing agency)

Impacted Component	Delay (day)	Impacted Duration (day)	Probability	Cumulative	E[I]	E[D]
Project	0	270	0.05	0.05	0	13.5
Remaining Duration (day)	270	540	0.95	1	256.5	513
270			1		256.5	526.5

Note: the remaining duration is 270 days (1020 - (25mth\*30days))

2. Analysis of consequential uncertainty

1. Claim, conflict and dispute



$P(C) = 0.2$   
 Impact = 1095 days (3 years)  
 Note: It depends on project manager of each party. It may consume many years for dispute resolution.

Table EA Ac-1.5: Probability and impact table

	Prob.	Impact (day)	E[D]
C	0.2	1095	219
C'	0.8	0	0
			219

2. Coordination among parties

The productivity of work may be reduced due to inefficient coordination among parties.

3. Conflict among contractors in JV

Conflict due to coordination problem among contractors in joint venture may occur. However, the impact may be very

Figure 7.44: Example of response scenario analysis procedure

### **7.13.1 Simulation Result of Response Scenario of All Parties**

As the results from simulation, the statistics information and cumulative distribution of project duration associated with each response scenario could be obtained.

Based on the executing agency's perception, the statistics information of each response scenario is shown in Table 7.40 and the cumulative distribution of project duration is shown in Figure 7.45. Based on the contractor's perception, the statistics information of each response scenario is shown in Table 7.41 and the cumulative distribution of project duration is shown in Figure 7.46. Based on the consultant's perception, the statistics information of each response scenario is shown in Table 7.42 and the cumulative distribution of project duration is shown in Figure 7.47.

### **7.13.2 Duration-Risk Map**

After statistics information associated with each response scenario could be obtained from simulation, then the risk-duration map is developed. The duration-risk map presents the tradeoff between project duration (in terms of means duration) and risk (in terms of standard deviation). The means of project duration is plotted in X axis and standard deviation is plotted in Y axis. The characteristic of response scenario can be understood by using duration-risk map.

The duration-risk map associated with each response scenario of executing agency, contractor, and consultant are provided in Figure 7.48, Figure 7.49, and Figure 7.50, respectively.

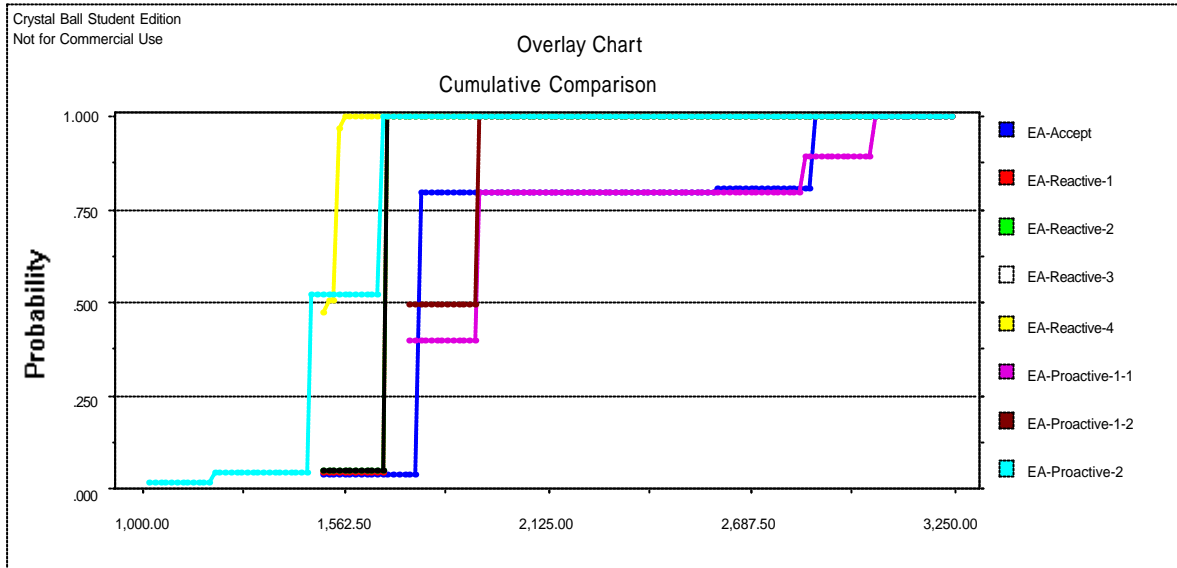


Figure 7.45: Cumulative distribution of project duration of each response scenario based on executing agency's perception

Table 7.40: Statistics information of all response scenarios based on executing agency's perception

Statistics Value	Accept	Reactive 1	Reactive 2	Reactive 3	Reactive 4	Proactive 1-1	Proactive 1-2	Proactive 2
Trials	10000	10000	10000	10000	10000	10000	10000	10000
Mean	1,988.82	1,676.88	1,676.58	1,676.64	1,529.42	2,065.51	1,842.68	1,549.74
Median	1,780.00	1,685.50	1,685.50	1,685.50	1,523.50	1,933.60	1,933.60	1,479.00
Mode	1,780.00	1,685.50	1,685.50	1,685.50	1,510.00	1,750.00	1,933.60	1,662.60
Standard Deviation	445.39	37.92	38.54	38.43	19.16	451.82	91.80	133.46
Variance	198,374.44	1,438.18	1,485.32	1,477.01	367.27	204,145.32	8,427.31	17,811.70
Skewness	1.42	-4.17	-4.09	-4.10	0.04	1.37	-0.02	-1.64
Kurtosis	3.16	18.41	17.74	17.85	1.11	3.13	1.00	7.11
Coeff. of Variability	0.22	0.02	0.02	0.02	0.01	0.22	0.05	0.09
Range Minimum	1,510.00	1,510.00	1,510.00	1,510.00	1,510.00	1,750.00	1,750.00	1,020.00
Range Maximum	2,875.00	1,685.50	1,685.50	1,685.50	1,561.30	3,028.60	1,933.60	1,662.60
Range Width	1,365.00	175.50	175.50	175.50	51.30	1,278.60	183.60	642.60
Mean Std. Error	4.45	0.38	0.39	0.38	0.19	4.52	0.92	1.33

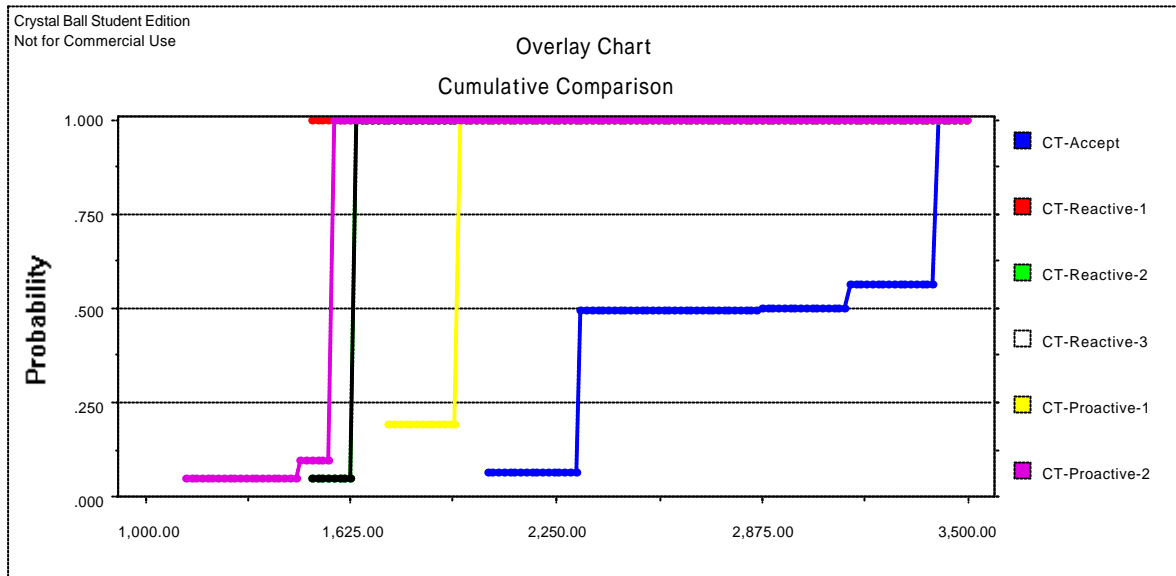


Figure 7.46: Cumulative distribution of project duration of each response scenario based on contractor's perception

Table 7.41: Statistics information of all response scenarios based on contractor's perception

Statistics Value	Accept	Reactive 1	Reactive 2	Reactive 3	Proactive 1-1	Proactive 2
Trials	10000	10000	10000	10000	10000	10000
Mean	2,830.27	1,510.01	1,638.17	1,638.14	1,914.61	1,552.78
Median	2,875.00	1,510.00	1,645.00	1,645.00	1,954.00	1,581.00
Mode	3,415.00	1,510.00	1,645.00	1,645.00	1,954.00	1,581.00
Standard Deviation	556.52	0.06	29.59	29.65	80.53	102.86
Variance	309,709.08	0.00	875.61	878.89	6,484.94	10,580.75
Skewness	-0.02	3.99	-4.10	-4.09	-1.55	-3.86
Kurtosis	1.13	-0.57	17.81	17.74	3.42	16.49
Coeff. of Variability	0.20	0.00	0.02	0.02	0.04	0.07
Range Minimum	1,780.00	1,510.00	1,510.00	1,510.00	1,750.00	1,020.00
Range Maximum	3,415.00	1,510.27	1,645.00	1,645.00	1,954.00	1,581.00
Range Width	1,635.00	0.27	135.00	135.00	204.00	561.00
Mean Std. Error	5.57	0.00	0.30	0.30	0.81	1.03

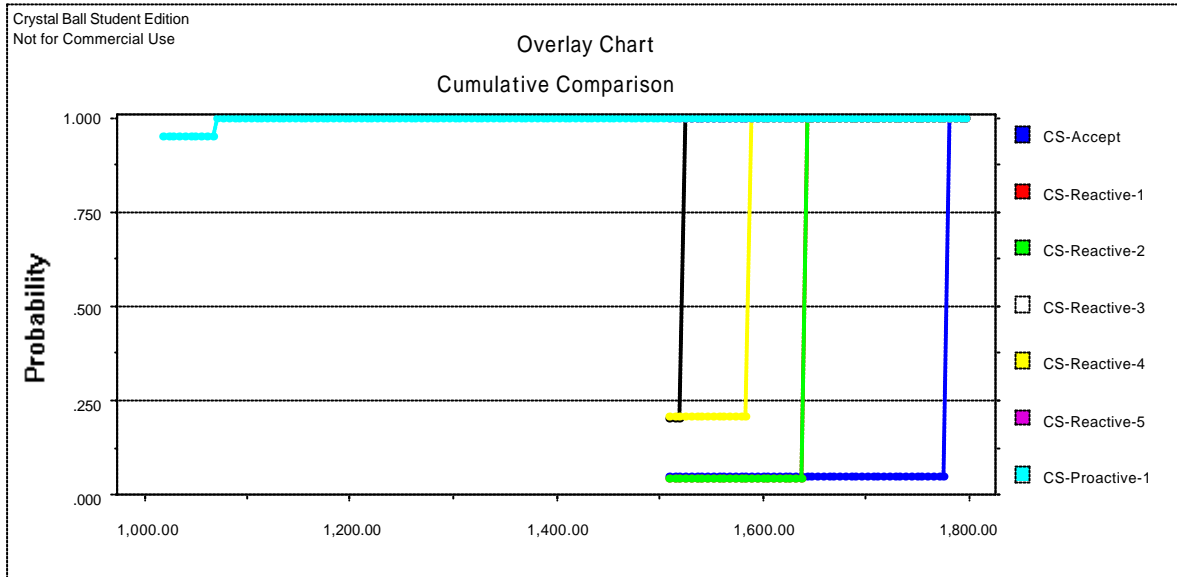


Figure 7.47: Cumulative distribution of project duration of each response scenario based on consultant's perception

Table 7.42: Statistics information of all response scenarios based on consultant's perception

Statistics Value	Accept	Reactive 1	Reactive 2	Reactive 3	Reactive 4	Reactive 5	Proactive 1
Trials	10000	10000	10000	10000	10000	10000	10000
Mean	1,766.34	1,638.45	1,638.26	1,520.79	1,574.14	1,510.01	1,022.33
Median	1,780.00	1,645.00	1,645.00	1,523.50	1,591.00	1,510.00	1,020.00
Mode	1,780.00	1,645.00	1,645.00	1,523.50	1,591.00	1,510.00	1,020.00
Standard Deviation	59.18	29.00	29.40	5.41	32.88	0.06	10.65
Variance	3,502.44	841.13	864.13	29.23	1,081.32	0.00	113.44
Skewness	-4.10	-4.20	-4.13	-1.50	-1.44	4.12	4.35
Kurtosis	17.81	18.67	18.09	3.24	3.07	-3.55	19.93
Coeff. of Variability	0.03	0.02	0.02	0.00	0.02	0.00	0.01
Range Minimum	1,510.00	1,510.00	1,510.00	1,510.00	1,510.00	1,510.00	1,020.00
Range Maximum	1,780.00	1,645.00	1,645.00	1,523.50	1,591.00	1,510.27	1,071.00
Range Width	270.00	135.00	135.00	13.50	81.00	0.27	51.00
Mean Std. Error	0.59	0.29	0.29	0.05	0.33	0.00	0.11

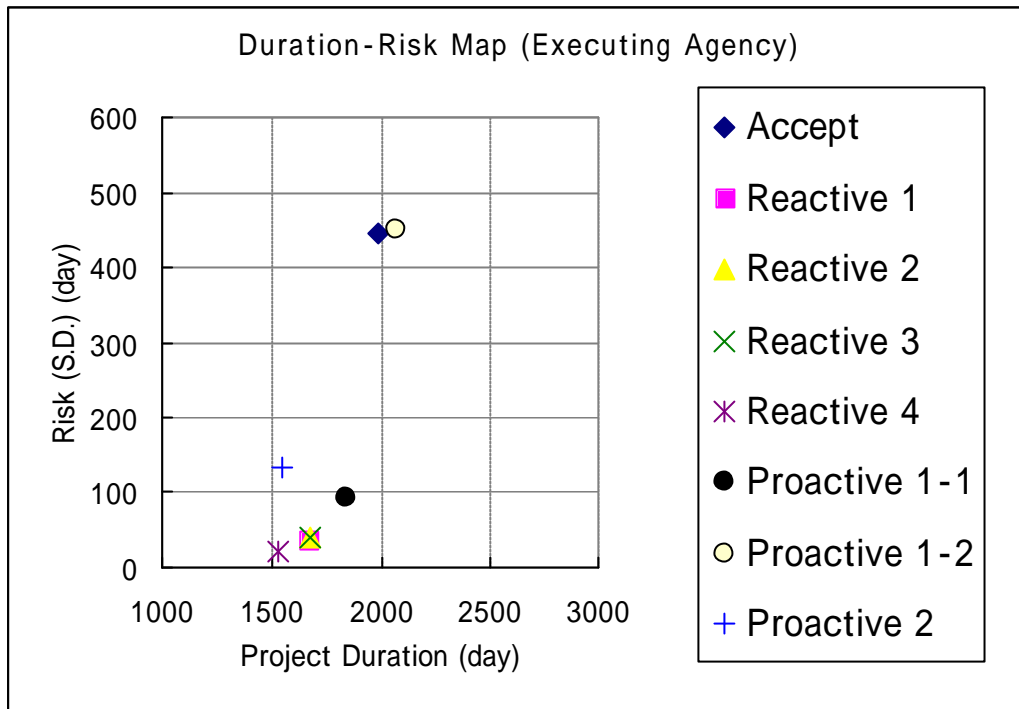


Figure 7.48: Duration-risk map based on executing agency's perception

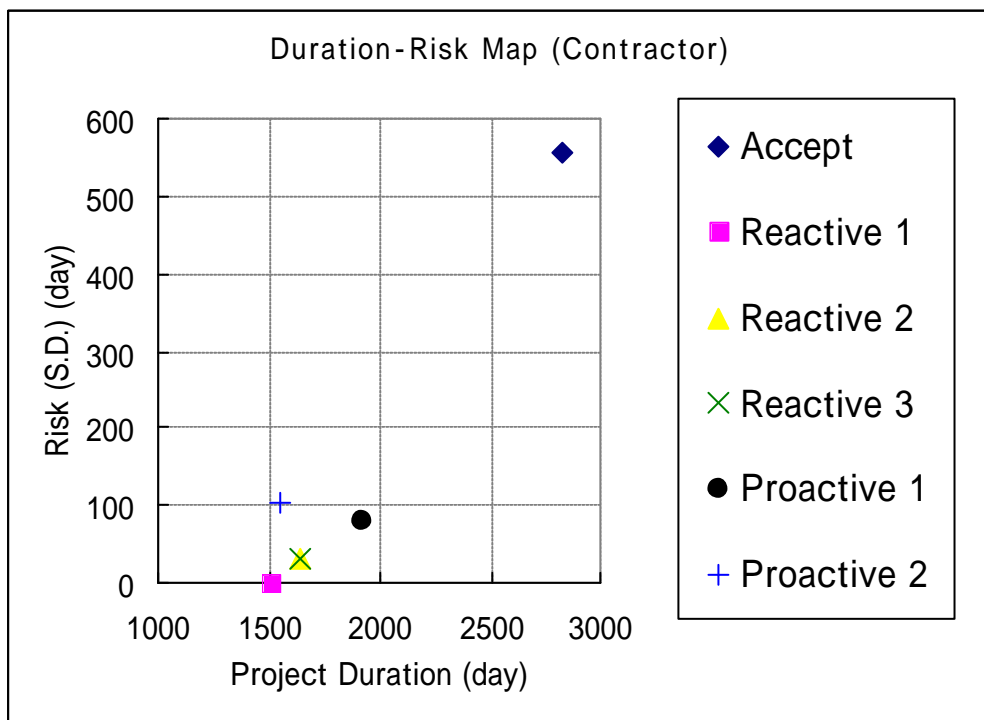


Figure 7.49: Duration-risk map based on contractor's perception



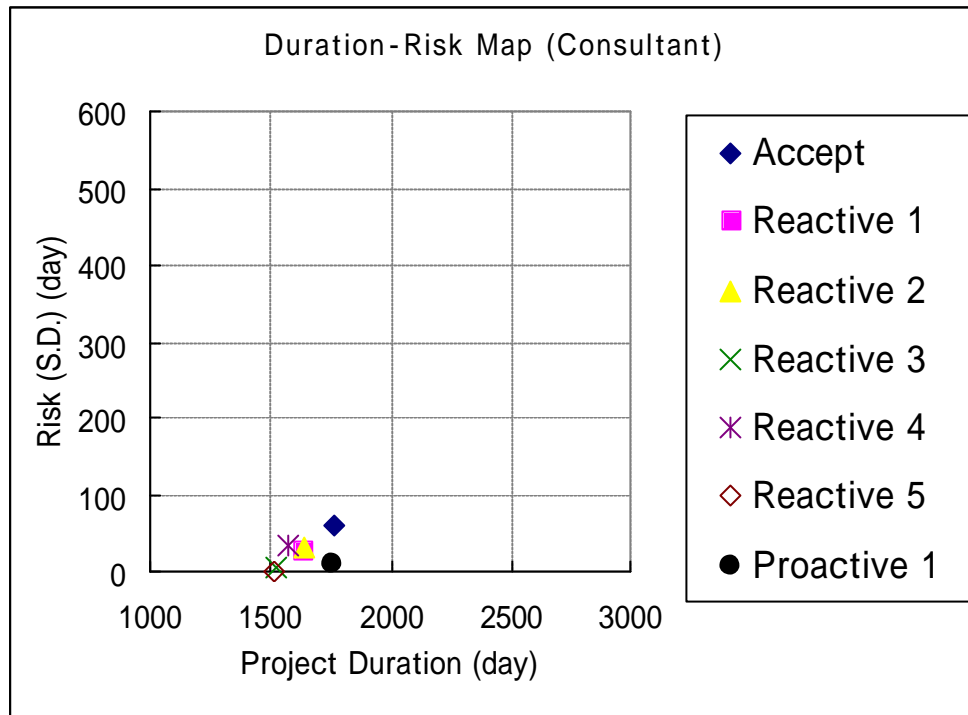


Figure 7.50: Duration-risk map based on consultant's perception

### 7.13.3 Integrated Response Scenario Diagram

The development purpose of integrated response scenario diagram (RSD) is similar to the development purpose of integrated HSRU. All parties' views associated with each response scenario are integrated. Their RSD of each response scenario are superimposed. Based on all parties' views, the integrated RSD provides us what are different in each response scenario. The integrated RSD of each response scenario are shown in following figures.

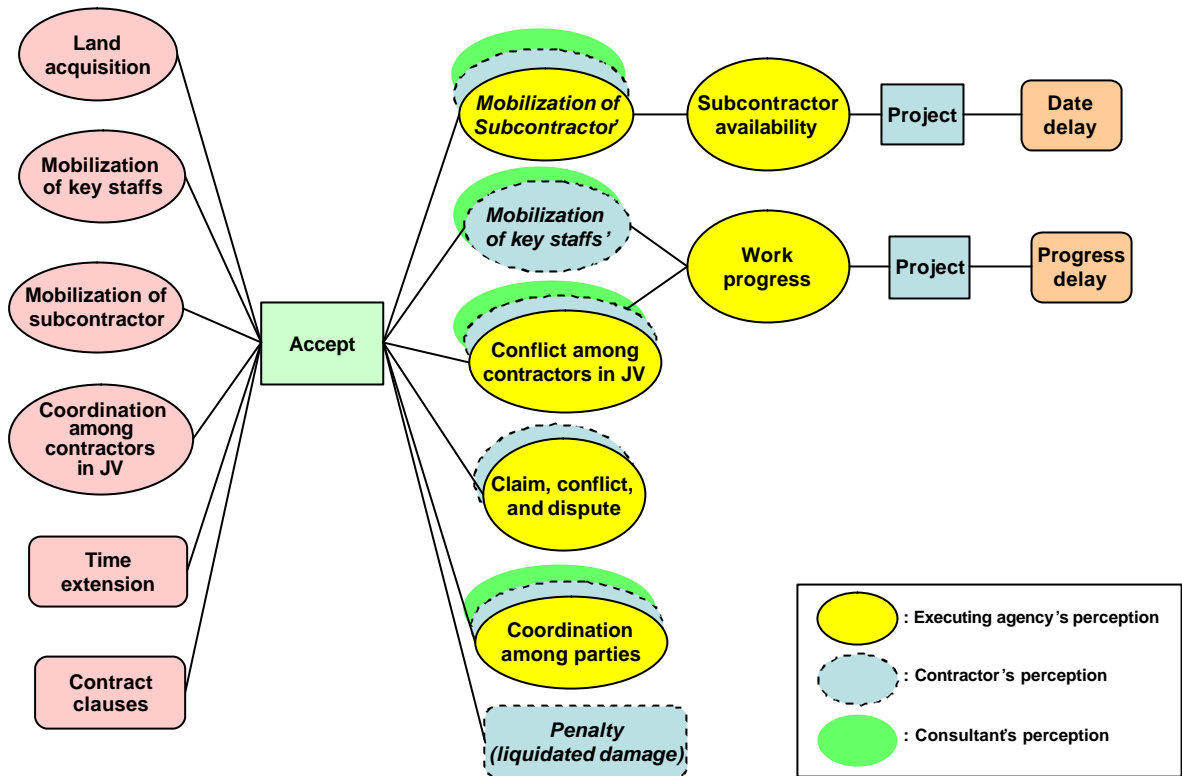


Figure 7.51: Integrated RSD of accept response scenario

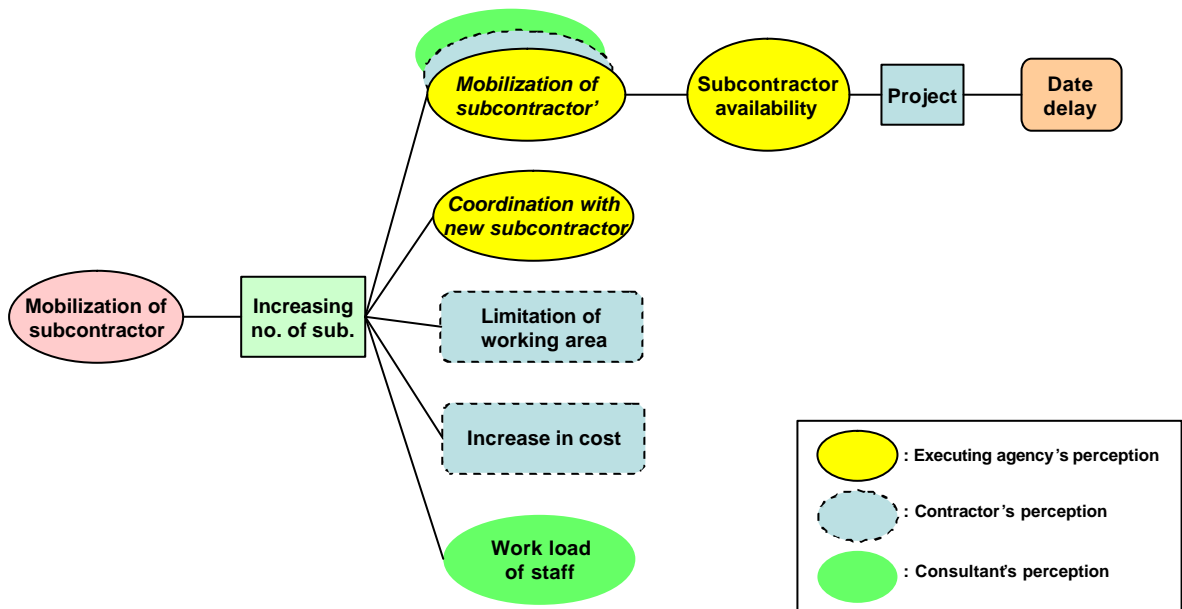


Figure 7.52: Integrated RSD of reactive response scenario 1

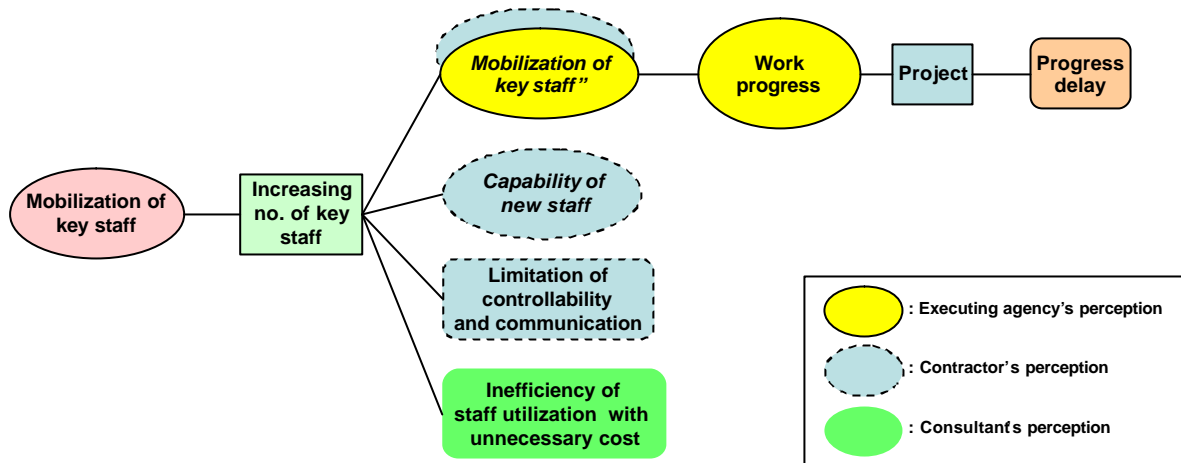


Figure 7.53: Integrated RSD of reactive response scenario 2

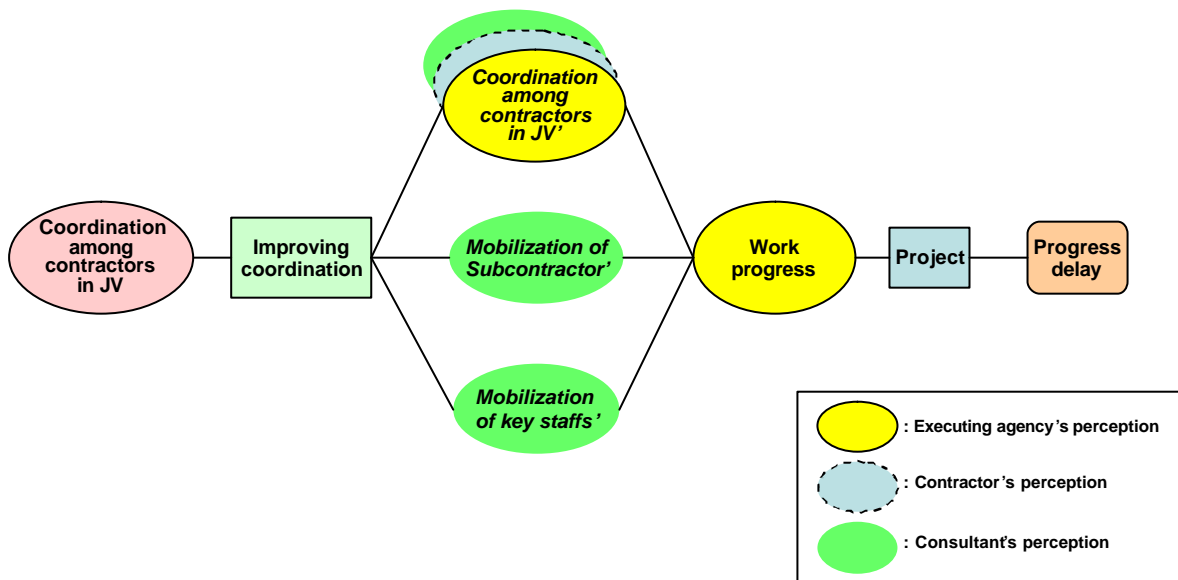


Figure 7.54: Integrated RSD of reactive response scenario 3

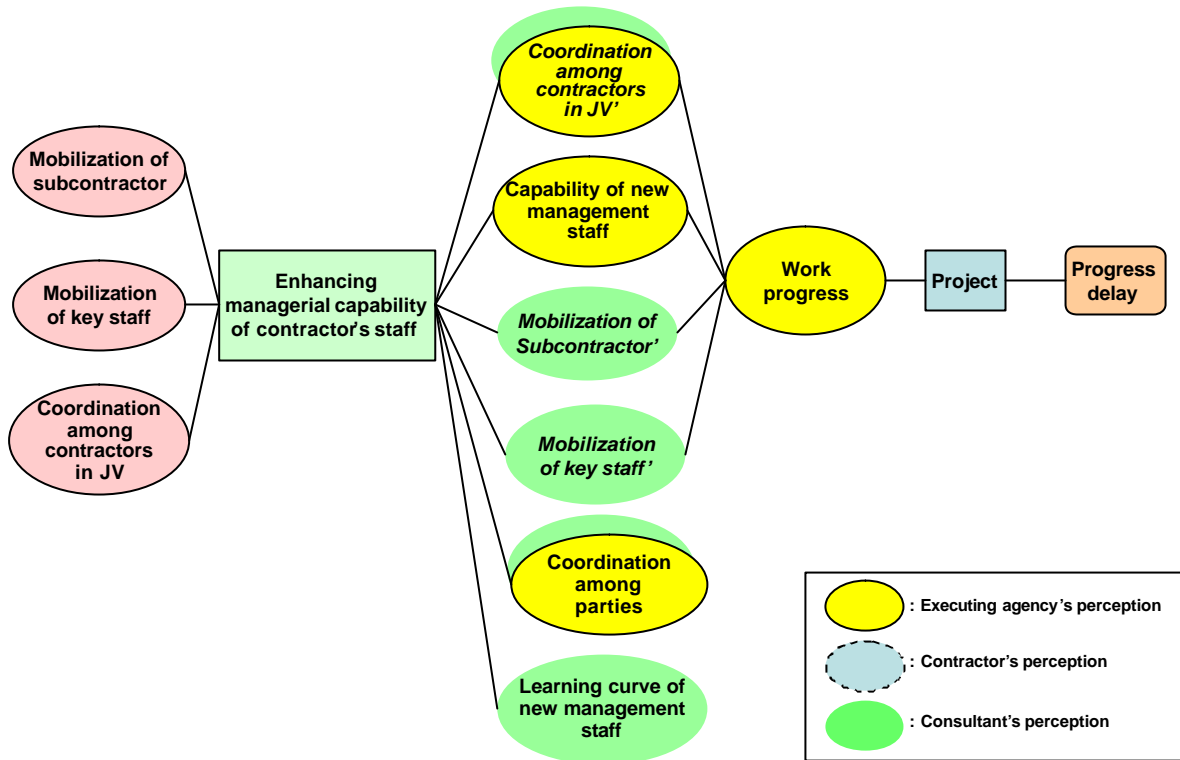


Figure 7.55: Integrated RSD of reactive response scenario 4

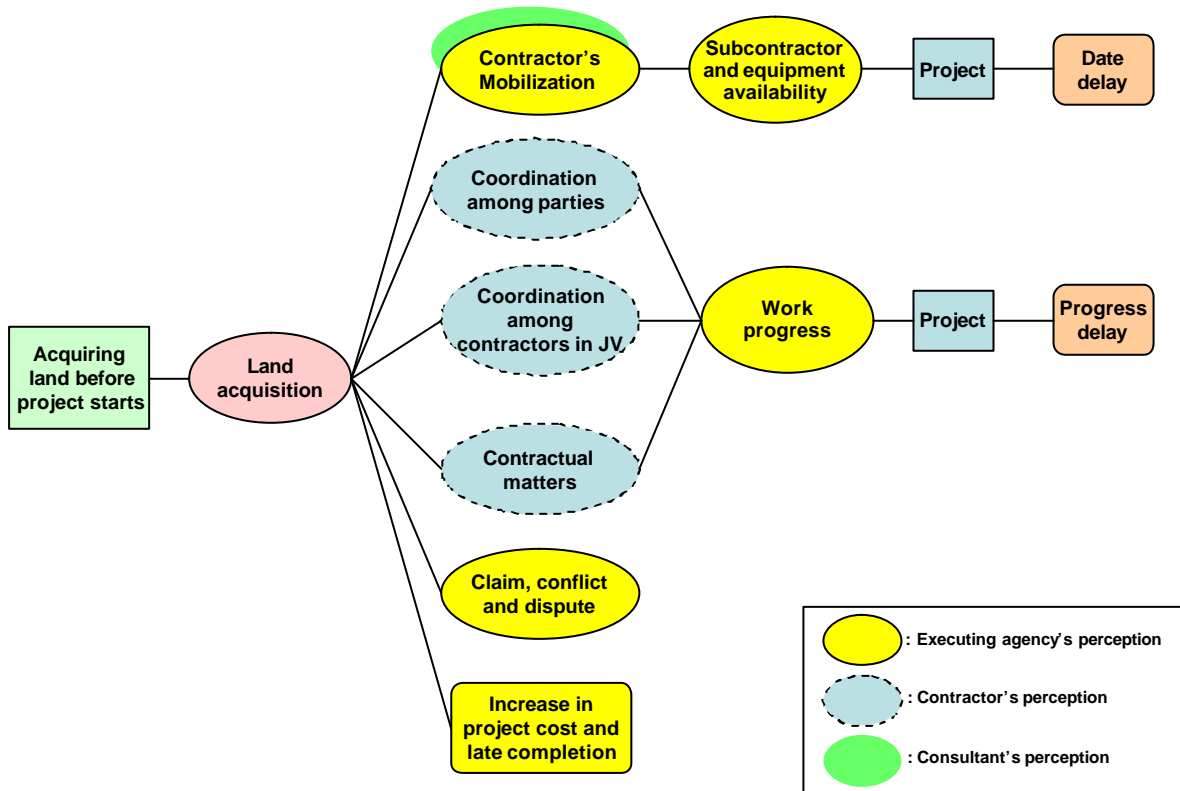


Figure 7.56: Integrated RSD of proactive response scenario 1

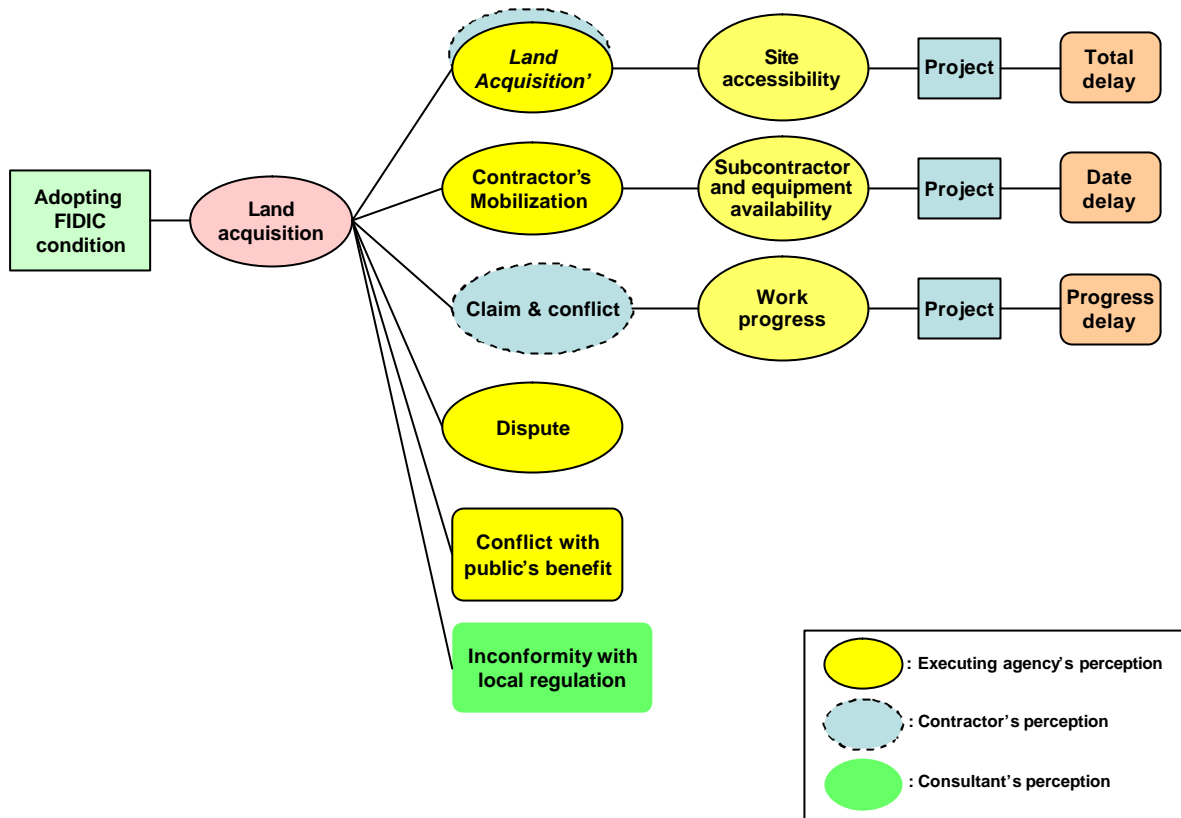


Figure 7.57: Integrated RSD of proactive response scenario 2

#### 7.13.4 RUIC of Response Scenario

Employing the same basis of risk/uncertainty impact chart (RUIQC), the RUICs of each response scenario are developed. The RUIC of response scenario shows how each party perceived the risk/uncertainty associated with implementation of each response scenario. The RUICs of response scenario of executing agency, contractor, and consultant are provided in Figure 7.58, Figure 7.59, and Figure 7.60, respectively.

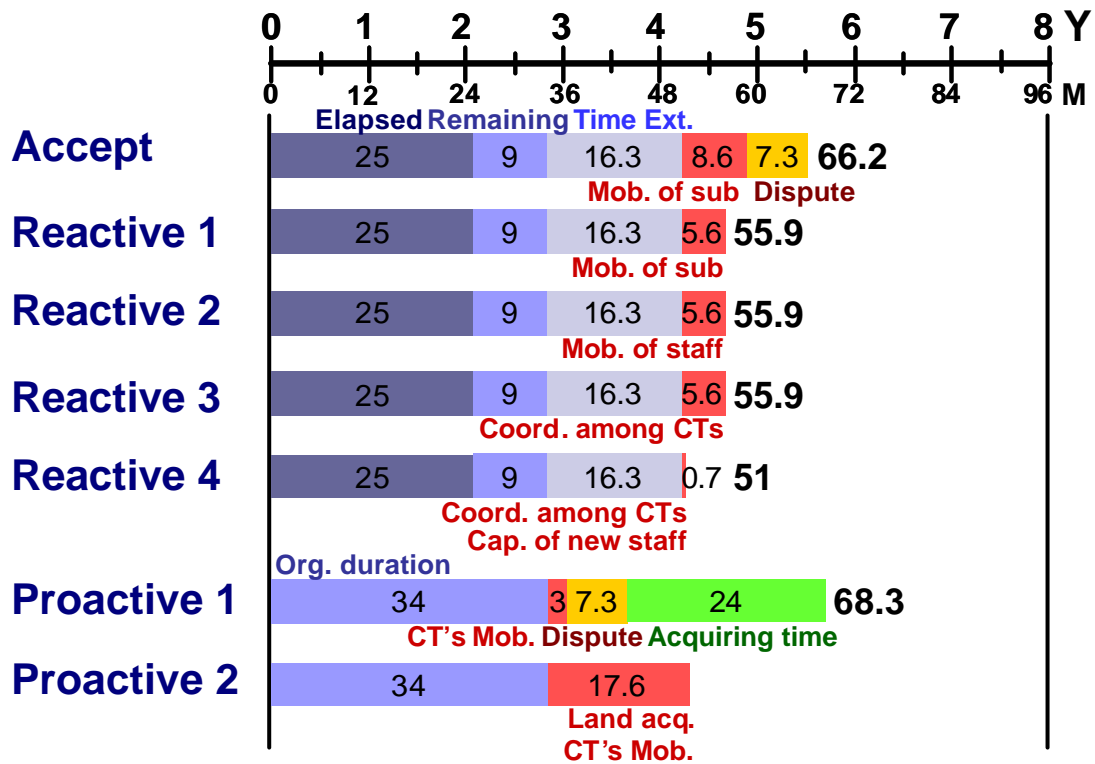


Figure 7.58: RUIC of response scenario based on executing agency's perception

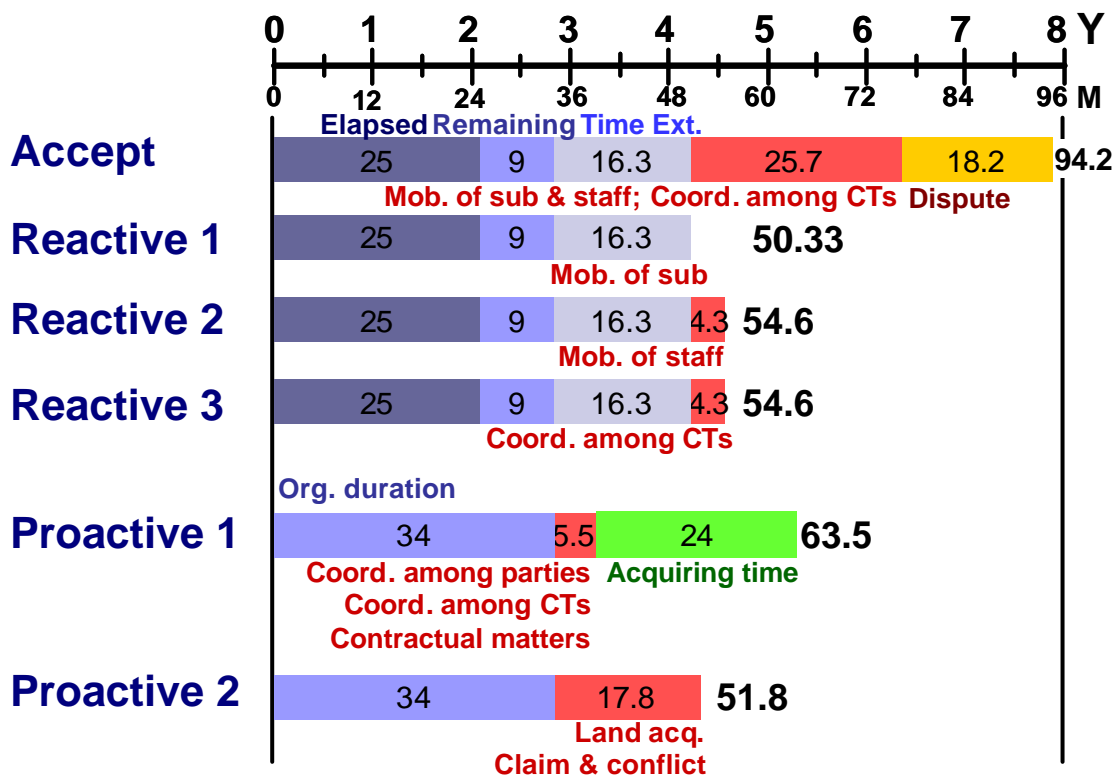


Figure 7.59: RUIC of response scenario based on contractor's perception

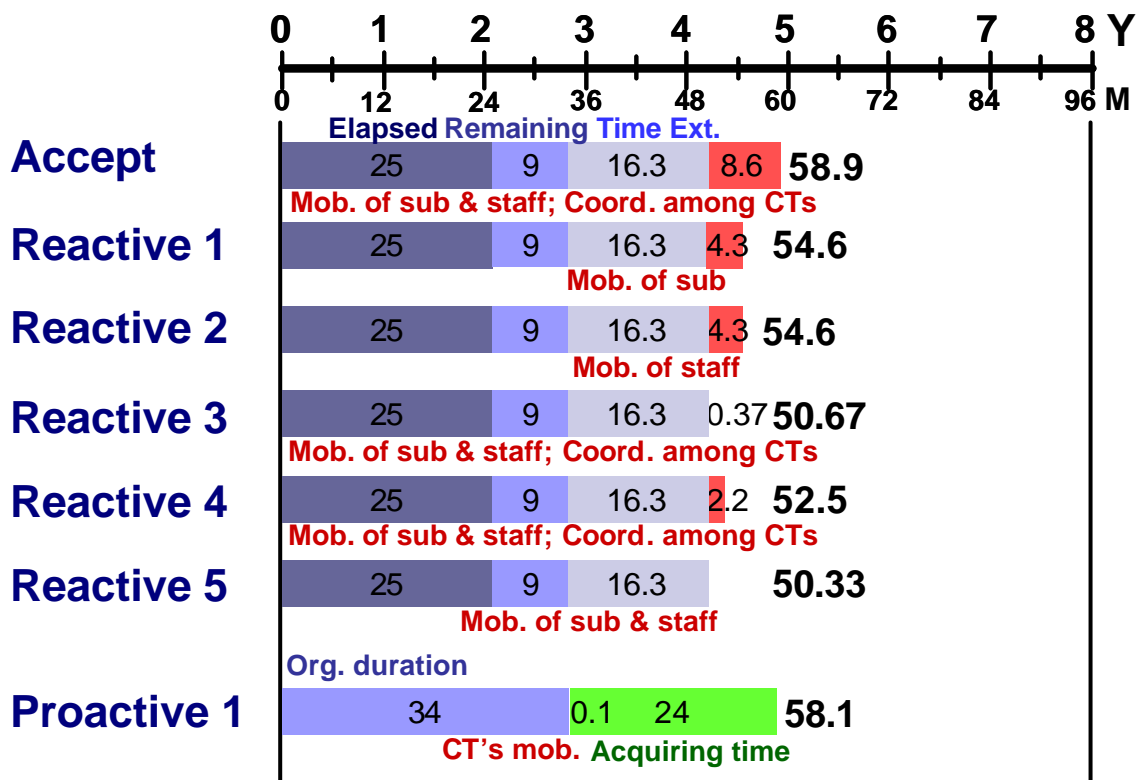


Figure 7.60: RUIC of response scenario based on consultant's perception

## 7.14 Summary

This chapter provides the explanation of MRUMP application. From the comparison of all parties' views with actual status of case study in the first application, it was found that: consultant's view was considered to be the most realistic, overall assessment covered most of major risks and uncertainties actually occurred, and all parties' views should be integrated in problem solving process. Risk/uncertainty meeting is proposed as a means in integrating multiple parties' views. In this meeting, assessors from all parties and analyst will participate. Analyst will show assessment result and facilitate all assessors in awareness of difference, identification of difference, and solving the difference. From the simulation of meeting in the first application, all parties were enabled to propose possible solution. Based on result of the first application, to proactively solve problem at early stage of construction, executing agency and contractor should cooperatively prepare land acquisition plan and construction schedule.

Moreover, the analyst should further conduct analysis of risks and uncertainties associated with this response.

From the second application, it was found that all parties were thinking about possibility of dispute. With this situation, the problem seemed to evolve to uncontrollable and unmanageable stage. Therefore, based on this application, the MRUMP should be applied in preventing the problem as early as possible before the problem become more serious and uncontrollable.



## Chapter 8

# Conclusions and Recommendations

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### 8.1 Summary and Deliverables of Research

The background of this research starts with the attention on poor project goal achievement such as severe delay of real infrastructure projects due to many problematic and potential risks and uncertainties. Several risk management processes (RMPs) have been introduced to deal with the risks impacting the project objectives. Author also proposed a RMP called multi-party risk management process (MRMP) (Pipattanapiwong and Watanabe 2000) to overcome a limitation of other conventional RMPs. However, associated with those conventional RMPs and MRMP, there are still fundamental and technical limitations including:

- 1) inattention on catastrophic event (which is ‘uncertainty’ event),
- 2) little established risk structuring and analysis procedure,
- 3) interpretation difficulty of dimensionless output, and
- 4) insufficient involvement of multiple parties.

As the ultimate goal, this research aims to overcome these limitations associated with conventional RMPs and MRMP. To achieve this goal, a series of objectives have been set. Following major deliverables have been developed to accomplish these objectives including:

- 1) risk/uncertainty map,
- 2) hierarchical structure of risk and uncertainty (HSRU) framework,
- 3) duration valuation process (DVP), and
- 4) multi-party risk and uncertainty management process (MRUMP).

The risk/uncertainty map for infrastructure project financed by international lender has been developed to overcome the first fundamental limitation by providing accumulated experience of risks and uncertainties as ‘knowledge base.’ Then, we can reduce the error

due to ‘ignorance’ of risks and uncertainties and deal with risks and uncertainties better. The ‘unnecessary and insufficient’ risk identification process and inefficient risk structuring process of (M)RMP as technical limitations are improved by development of HSRU framework. HSRU framework is a “standard” and “organized” risk structuring diagram aiming to assist practitioners in better assessment and analysis of probability and impact of risks and uncertainties. The cause and effect events are hierarchically separated in HSRU along with the flow of source of risk/uncertainty, consequent risk/uncertainty, influential risk/uncertainty, activity, and type of delay.

Second, to overcome the constraint in interpreting dimensionless output of (M)RMP, the DVP has been developed. DVP aims to provide logical and systematic assessment procedure of probability and impact and to offer dimensional presentation of output in form of cumulative distribution of project duration. The developed DVP consists of four main processes consisting of:

- 1) development of HSRU,
- 2) assessment and transformation of probability,
- 3) assessment and transformation of impact, and
- 4) simulation by using Monte Carlo simulation.

To assess probability, DVP designs assessing questions based on basic probability theory such as conditional probability and multiplication rule. Productivity concept, work breakdown structure and scheduling concept, and classification of delay (total delay, date delay and progress delay) are basis in quantification of impact in terms of delay. Based on the HSRU framework and probability and impact assessment procedures in DVP, the illogical and unsystematic probability and impact assessment procedure as a technical limitation of (M)RMP can be improved resulting in higher precision of output. By employing simulation method, the dimensional output in form of cumulative distribution is obtained. With this information, we can know not only expected value (means value) but also minimum and maximum range of project duration. Chapter 5 provides explanation of DVP and its demonstration.

To overcome the limitation regarding inattention on involvement of multiple parties, this research improves the previously proposed MRMP with integration of multiple parties’ views. From the MRMP application, each party’s view for mutual ‘reference’ could be obtained. However, to obtain ‘reference’ is just the first step to manage risk in a project. To complete risk management, it is necessary to go through following processes: problem awareness from knowing reference, problem identification through

communication among parties, and problem solving by integration of multiple parties' views. Therefore, this research develops a prototype tool called multi-party risk and uncertainty management process (MRUMP) aiming to assist all parties in systematically and efficiently managing risks and uncertainties and encourage all parties to communicate each other, identify problem, and cooperatively solve the problem.

The HSRU framework, DVP and other processes i.e., response process, application planning process, and application control process are assembled together to form the MRUMP. The MRUMP consists of five main processes including:

- 1) risk and uncertainty management planning,
- 2) risk and uncertainty identification and structuring,
- 3) risk and uncertainty assessment and analysis,
- 4) risk and uncertainty response, and
- 5) risk and uncertainty management control.

A number of systematic procedures and tools such as risk/uncertainty breakdown structure (RUBS) and risk/uncertainty checklist are also provided in the MRUMP. The MRUMP is presented in form of implementing manual for hands-on application purpose. Chapter 6 provides explanation of the MRUMP manual.

## **8.2 Application of MRUMP**

The MRUMP has been applied to an infrastructure project financed by an international lender as a case study located in a Southeast Asian country as the accomplishment of the last research objective. There are at least two major benefits for conducting the application. First, we could discuss its applicability and draw lesson for further refinement from application study. Second, by applying the MRUMP, we could reveal how the project has been being practiced that is beneficial for both practitioners currently working on site and prospective practitioners for future project.

Based on framework of application, the application of this case study was scoped to two periods i.e., early stage of construction and during construction of project. The executing agency, contractor, and consultant involved in the project have been focused

as main players in application. The top managements in project level of each party have been selected as assessors and their perceptions have been investigated in the application.

### **1. At early stage of construction**

For the application at early stage of construction period, the assessors were asked to identify the risks and uncertainties, which may occur from early stage to current stage of construction, and assess probability and impact of identified risks and uncertainties at the early stage of construction. The reason of this assumption is because we aim to conduct the error analysis by comparing their analysis results with known actual status of project up to current stage.

From the application at the early stage of construction, we could obtain all parties' perceptions towards HSRU presenting source of risk/uncertainty, consequential risk/uncertainty, and influential risk/uncertainty associated with activities and project and type of delay. In addition, we could know their perceptions towards probability and impact of risks/uncertainties. Then, by conducting the analysis and simulation, the cumulative distribution of project based on all parties' perception could be obtained.

By developing 'integrated HSRU' based on all parties' perception, occurring, subsequent, lingering, and future risks and uncertainties could be identified. All parties could compare their perceptions towards the impact of risks/uncertainties to activities by using 'risk/uncertainty impact chart' (RUIC). This chart presents how much project is delayed and how critical path is changed. With this information, the difference of each party's view could be aware.

Moreover, in error analysis, difference is also realized when we compare analysis result of each party with actual status of case study. Assessor's experience, knowledge, position and biases resulting in ignorance of risks/uncertainties, and over- and under-estimation of probability and impact could be identified as causations and types

of error associated with each source of error. By understanding these sources, causations, and types of error, we can further refine the MRUMP and improve future application.

Additionally, we could observe from the error analysis that we might be able to mitigate error by integrating all parties' views, because the comparison shows that one party could provide more realistic assessment of some risks and uncertainties than others and vice versa. By realizing this benefit, the meeting among all parties together with analyst for risk/uncertainty communication and problem solving is simulated to demonstrate how the MRUMP application result can be made use in practice.

From the simulation of meeting, after each party could understand and be aware of others' views then, with this 'reference,' it enables all parties to communicate and identify the future 'problem,' which may occur due to different in their views. The 'integrated HSRU' and RUIC can be used for assisting this purpose. Finally, with integration of all parties' views, they were enabled to derive the possible and constructive solution that satisfied them as much as possible.

## **2. During construction**

The second timing period of application is from current stage to the end of construction. The purpose of this application is to discuss the reactive and proactive response scenarios for problems currently occurring in the project. The assessors were asked to provide their perceptions towards created response scenarios and possible future risks/uncertainties based on current situation and contractual condition. Then, response scenario diagrams, which present consequential relationship between created response scenario and risks/uncertainties, have been developed based on their perceptions. With this qualitative analysis, the preferable reactive and proactive responses perceived by each party could be derived.

Furthermore, based on the application result of this case study, we could categorize proposed reactive and proactive response scenarios into two categories i.e., 1) unique response, which was applicable for this specific case study and 2) common response,

which was applicable for entire implementation system. By understanding these unique response scenarios, it enabled practitioners to make decision regarding solution to problem more efficient. The common responses as lesson learnt from this project also could be used for further improvement of implementation system.

Based on this application, the MRUMP is considered useful and applicable for problem preventing and solving in construction stage. According to practitioners' comment on the MRUMP, they perceived its usefulness in using as communication and problem preventing and solving tool among relevant parties during construction stage. In addition to this comment, the lesson learnt from current project could be used as post evaluation information that is beneficial for project implementation reform, policy making and project planning for future projects as well as for inexperienced practitioners.

### **8.3 Contributions of Research**

Based on the development and application of MRUMP, this research provides a number of contributions, which constitute its originality and uniqueness. The provided contributions are categorized into four main categories comprising of 1) integration of multiple parties' views, 2) attention on uncertainty, 3) valuation of probability and impact, and 4) management measure for uncertainty. The contributions associated with each category are explained as follows.

#### **1. Integration of multiple parties' views**

The importance of multiple parties' involvement and contractual role is put into consideration in this research. This research explicitly integrates the multiple parties into the scope and processes. With this integration, a number of benefits can be obtained.

First, by integrating multiple parties' views in the scope of MRUMP and simulating meeting for risk/uncertainty communication, understanding among parties toward

others' views and efficiency of problem solving tend to be enhanced. The MRUMP enables all parties to know each party's view regarding risks and uncertainties. Afterward, it increases the opportunity to communicate each other towards perceived risks and uncertainties and to identify the 'problem' occurring due to difference in their views. Consequently, by integrating all parties, it enables all parties to prepare proactive and reactive measures in responding those prospective risks and uncertainties. This encourages the creation of 'harmony' among project parties that builds cooperative atmosphere and enhance project performance.

Second, by knowing integrated views of all parties, unperceived risks and uncertainties during identification process can be revealed. The 'integrated HSRU' demonstrates this function. Its presentation shows the risks/uncertainties, which may occur and are identified by one party due to the 'ignorance,' but it is identified by other parties. From application of MRUMP, new future risks/uncertainties, subsequent and lingering risks/uncertainties caused by one party's decision and action, and indirect third party related risk/uncertainty were ignored by one party, but they could be identified by other parties.

Third, with RUIC, all parties are able to understand the difference of each party's perception towards the magnitude and characteristic of impact of risks and uncertainties. It provides understanding of how much project is delayed and how critical path of schedule is changed. With this integration, it enables all parties to elaborate the outcome of risks and uncertainties to activities and project more realistically.

Fourth, with due consideration of totally exhaustive issue in development of RUBS and risk/uncertainty checklist, risk/uncertainty categories related to all parties are also included in RUBS and risk/uncertainty checklist. By incorporating all parties in risk and uncertainty identification process, the MRUMP provides 'objective' self evaluation of one party when all parties' perceptions are integrated. The application result also illustrates this feature.

## **2. Attention on uncertainty**

First, the MRUMP does not neglect the importance of low probability but high impact event, which is called ‘uncertainty’ here. On the other hand, to prioritize risks, the conventional RMPs normally rely on concept of expected impact that may overlook the importance of this type of event. From application, consultant assessed the mobilization of subcontractor uncertainty as low probability but high impact. With the attention on this type of event in MRUMP, it was not discarded during the analysis. In reality, this event actually occurred.

Second, the possibility of ‘ignorance’ of risks/uncertainties can be reduced by using the risk/uncertainty map in identifying and structuring risks/uncertainties. From time to time, we are encouraged to accumulate risks/uncertainties from experience and periodically update its structure in order to build structure as ‘complete’ as possible. We can use it as ‘knowledge base’ for both experienced and inexperienced practitioners in better dealing with risk/uncertainty in future project, respectively.

Third, the DVP provides cumulative distribution of project objective e.g., duration as information for practitioners in better dealing with uncertainty. By adopting the advantage of simulation, we can know the minimum and maximum range of distribution, which enables us to recognize the worst case scenario (maximum value). Since conventional RMPs normally center the attention on expected value, the worst case scenario is often overlooked.

## **3. Valuation of probability and impact**

With DVP, the probability and impact of risks and uncertainties to project objective can be derived logically and systematically. The DVP provides a logical and systematic procedure to assess the probability and impact of risk/uncertainty, which can enhance the reliability of assessment and analysis. For probability, the questions are designed based on basic probability theory such as conditional probability and multiplication rule. The conditional probability is assessed based on developed HSRU. For impact, it is



based on classification of delay in assessing variation of duration, work quantity and productivity rate associated with project or activity. The dependency between risk/uncertainty and activity are specified based on developed HSRU.

#### **4. Management measure of uncertainty**

First, the MRUMP enables practitioners to sufficiently prepare for proactive and reactive management measures to prospective risks and uncertainties with consideration of contractual condition among parties. Here, risk and uncertainty management is viewed as both problem preventing and solving tools. Therefore, the managerial response scenarios are created based on timing of implementation and divided into two categories i.e., 1) proactive managerial response scenario and 2) reactive managerial response scenario. For proactive managerial response scenario, it is related to planning and monitoring functions in management. For reactive managerial response, it is related to controlling function in management. In developing response scenario, the contractual issue is also considered as decision variable or nominal value depending on the stage of project.

Second, since this research realizes the necessity of lesson learnt and feedback system for future project, the initiated managerial responses scenario are grouped into 1) common response, which is applicable for entire implementation system or several projects and 2) unique response, which is particular to the problem in that focused project. With this way of categorization, it can facilitate the practitioners in understanding areas of improvement of implementation system and cautions for particular project. The derived response scenarios from application illustrate this benefit.

Conclusively, based on holistic view, overall contributions attempt to assist all parties in better dealing with risks and uncertainties. Moreover, all parties are encouraged to identify and solve the problem due to possible and potential risks and uncertainties before it eventually becomes unmanageable to all parties and threat to project performance. With this consideration, the MRUMP is considered as proactive more than

reactive tool in problem solving process, though it can be used as both purposes.

## **8.4 Recommendations for Further Research**

With due consideration of theoretical and practical improvement and refinement of the MRUMP, areas for further research are described as follows.

The first recommendation for further research is related to refinement of probability and impact assessment procedure in the DVP. According to application of the MRUMP in this research, one of source of error is associated with the bias of assessors. More study may be done by incorporating more other techniques in eliciting probability. Additionally, to refine this procedure, the scope of study should be extended to cover the psychological issues.

Second, to overcome the interpretation difficulty of dimensionless output of (M)RMP, this research firstly focuses on project duration by trying to transform subjectively assessed impact to impact in terms of project delay. By employing simulation technique, the DVP can produce cumulative distribution of project duration as a main output. By focusing on only 'time' objective may not be necessary sufficient to have the complete view of impact of risks and uncertainties. Next, this research recommends that 'cost' objective should be focused. Based on the framework of DVP development, cost valuation process (CVP) should be developed. Afterward, both DVP and CVP should be used jointly in transforming dimensionless impact in order to enhance our understanding of magnitude of impact associated with risks and uncertainties.

Third, for the application purpose, this research presents the MRUMP in form of implementing manual. Since this is the first prototype, various standardized forms and examples of inputs and outputs are not completely provided. Further study may improve and refine explanation and presentation of inputs, processes and outputs described in MRUMP implementing manual. Moreover, with consideration of benefit of information technology, the software based on the framework of MRUMP may be developed in order to enhance the efficiency in application of MRUMP.

In this research, the scope of MRUMP application has been framed only in the construction stage for problem preventing and solving purposes. Expectedly, the practitioners may employ the MRUMP in other application purposes such as policy making and planning, negotiation in contract formation, alternative dispute solution (e.g., mediation and dispute review board) in both pre- and during construction stages of project. Further research may be conducted to apply the MRUMP for other application purposes. Then, its applicability in these areas should be discussed.

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