APPLICABILITY OF MULTI-PARTY RISK AND UNCERTAINTY MANAGEMENT PROCESS: BENEFITS FROM ITS APPLICATON ON AN INFRASTRUCTURE PROJECT

Jirapong PIPATTANAPIWONG*, Tsunemi WATANABE**
Team Consulting Engineering and Management*
Kochi University of Technology **

ABSTRACT**:** This paper demonstrates application of the multi-party risk and uncertainty management process (MRUMP) to a real infrastructure project located in a Southeast Asian country as a case study. There are two objectives for its application. The first objective is to discuss applicability of the MRUMP for further refinement and improvement. The second objective is to reveal lessons learnt resulting from outputs of the MRUMP as benefits for both practitioners currently working on site and prospective practitioners of future projects. The MRUMP is designed for proactively solving problem through problem awareness, problem identification and problem solving. From the application, it could illustrate the MRUMP's benefits at least in the following aspects, i.e., 1) facilitating problem solving by integration of multiple parties' views, 2) increasing attention on uncertainty, 3) enhancing assessment by valuation of probability and impact and 4) realizing efficient management measures of uncertainty. Moreover, the MRUMP can be used as a post-evaluation study to draw lessons learnt for similar projects in future. It is further expected that the MRUMP is applicable for contract evaluation, assistance in policy making, planning, and problem avoidance at early stage of project and problem solving at later stage of project.

KEYWORDS: risk and uncertainty, risk management process, application of risk management process in infrastructure project

1. INTRODUCTION

As previously introduced and intensively described in a preceding paper, the multi-party risk and uncertainty management process (MRUMP) associated with other complimentary systematic deliverables have been developed as an effective risk and uncertainty management process for but not limited to infrastructure projects (Pipattanapiwong 2004). Motivation of such development lies in improvement of fundamental and technical limitations of conventional risk management processes. Such limitations associated with previously proposed RMPs include: 1) inattention on low-probability and high-impact event (which is often called 'uncertainty' event), 2) little established risk structuring and analysis procedure, 3) little established risk impact quantification procedure and interpretation difficulty of dimensionless output, and 4) insufficient involvement of multiple parties. Resulting from these limitations, conventional RMPs may not fully provide efficient way in managing risks and uncertainties successfully in real world projects.

The MRUMP combining other developed deliverables i.e. prototype of risk/uncertainty map, hierarchical structure of risk and uncertainty (HSRU) framework, duration valuation process (DVP), and systematic procedures have been developed to be used as a logical and systematic tool assisting all parties. It aims to systematically and efficiently manage risk and uncertainty inherent in projects. The MRUMP is provided in the form of guideline and implementation manual for the sake of hands-on application purpose.

Better treatment of low-probability and high-impact event, higher precision of output, representation of output in terms of days, and facilitation of problem solving by integrating multiple parties' views are key essences in development of the MRUMP (Watanabe and Pipattanapiwong 2004).

The MRUMP was applied to a real infrastructure project located in a Southeast Asian country as a case study. Following sections demonstrate application of the MRUMP process by process.

2. OBJECTIVES OF APPLICATION AND CASE STUDY

Objectives of application

There are two objectives in this paper. The first objective is to discuss applicability of the MRUMP for further refinement and improvement. The second objective is to reveal lessons learnt resulting from outputs from the MRUMP application as benefits for both practitioners currently working on site and prospective practitioners of future projects.

Overview of a cast study

The case study project was a bridge and road construction project partly financed by an international lender. This project provided a new road and bridge network linking a major port with the existing roads and industrial areas. The main components of works consist of main cable stayed bridge, approach bridge, and at-grade road. Total length was approximately three kilometers. The contract value was approximately 70 million U.S. dollars. The original contract duration of this project was 34 months.

Timing of application

At the time of conducting the MRUMP application study, the case study project was on going in construction stage at 25^{th} month of contract duration.

The application of the MRUMP to this case study was then scoped to two periods, i.e., early stage of construction and during construction of project. In order to discuss applicability of the MRUMP, it was assumed that the MRUMP had been applied at the very beginning of the construction stage. The assessors were asked to "go back" to the beginning stage of construction. Then, they were asked to identify the project risks and uncertainties which could occur from the early stage. For probability and impact assessment of project risks and uncertainties, the assessors were asked to do so with "fresh" mind by freeing their minds from the current project status as much as possible.

The second timing of application is 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. The assessors were asked to assess risks and uncertainties associated with each response scenario at the current stage.

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 first and second applications of the MRUMP are described in the following sections.

3. FIRST APPLICATION: PLANNING, IDENTIFYING, STRUCTURING, AND ANALYZING

3.1 Risk and uncertainty management planning

The first process in MRUMP is related to planning activities of how the MRUMP is going to be implemented. The risk and uncertainty management planning process aims to set and define framework of application including the 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.

Roles in application

Since the MRUMP pays attention to involvement of multiple parties in the process, all top managements in project level of each involved party in this case study, i.e., owner, consultant, and contractor, were selected as assessors. The author performed role of an evaluation analyst by conducting following tasks: educating assessors regarding introduction, objective and overview of the MRUMP processes, preparing documents and presentation for facilitating assessors during interview, arranging appointment and conducting interviews, summarizing assessment, analyzing data, and providing analysis result to all assessors.

Educating MRUMP

At the very beginning of application, the analyst provided explanation of overall procedures to all assessors by conducting presentation together with supplementary documents. At this step, the analyst attempted to enhance understanding of practitioners regarding overview of process and data collection procedure.

3.2 Risk and uncertainty identification and structuring

The next process is risk and uncertainty identification and structuring process aiming to identify risks and uncertainties, which influence project goals, and to construct hierarchical structure representing influential relationship between risk and uncertainty factors and achievement of project goals based on each party's view. The identification and structuring of risks and uncertainties is a significant task, which is crucial to successive processes and accuracy of final outputs. In this case study, the project duration was focused for identifying risks and uncertainties associated with this goal.

Collecting project information

The first task of this process was to collect project information including general project description, contract information, and scheduling information. Much of this information was available in contract documents, e.g., contract, contract conditions, supplementary conditions, specification, addendum, bill of quantity, submitted schedule, and drawing. Status of project was tracked from project progress report, minutes of meeting, and schedule information (e.g. work breakdown structure, base line construction schedule, and actual schedule). By studying these documents, we could understand the background of project, current status, and preliminary identification of risks and uncertainties.

Identifying risks and uncertainties

The next step was to identify risks and uncertainties based on each party's perception. Assessors play a main role in this step with analyst's assistance. The facilitating tool used in this step includes risk and uncertainty breakdown structure, risk and uncertainty check list and hierarchical structure of risk and uncertainty framework. After analyst conducted the in-dept interview with assessors, the identified project risks and uncertainties perceived by assessors from top management level of owner, consultant, and contractor could be obtained.

Constructing hierarchical structure risk and uncertainty

After risks and uncertainties were identified by each party, they were structured by specifying the cause and effect relationship associated with each identified risk and uncertainty. Moreover, the assessors were asked to specify the influential impact relationship to project activities. This task of structuring is based on the framework of hierarchical structure of risk and uncertainty (HSRU).

After obtaining the HSRUs perceived by all assessors, the analyst then elaborates the identified risks and uncertainties and constructed the integrated HSRU according to all parties' views by superimposing HSRU of each party into one. As a result, the integrated HSRU from this application is presented in Figure 1.

Based on the integrated HSRU, all parties were 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 in 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 integrate their views in cooperatively solving the problem (problem solving).

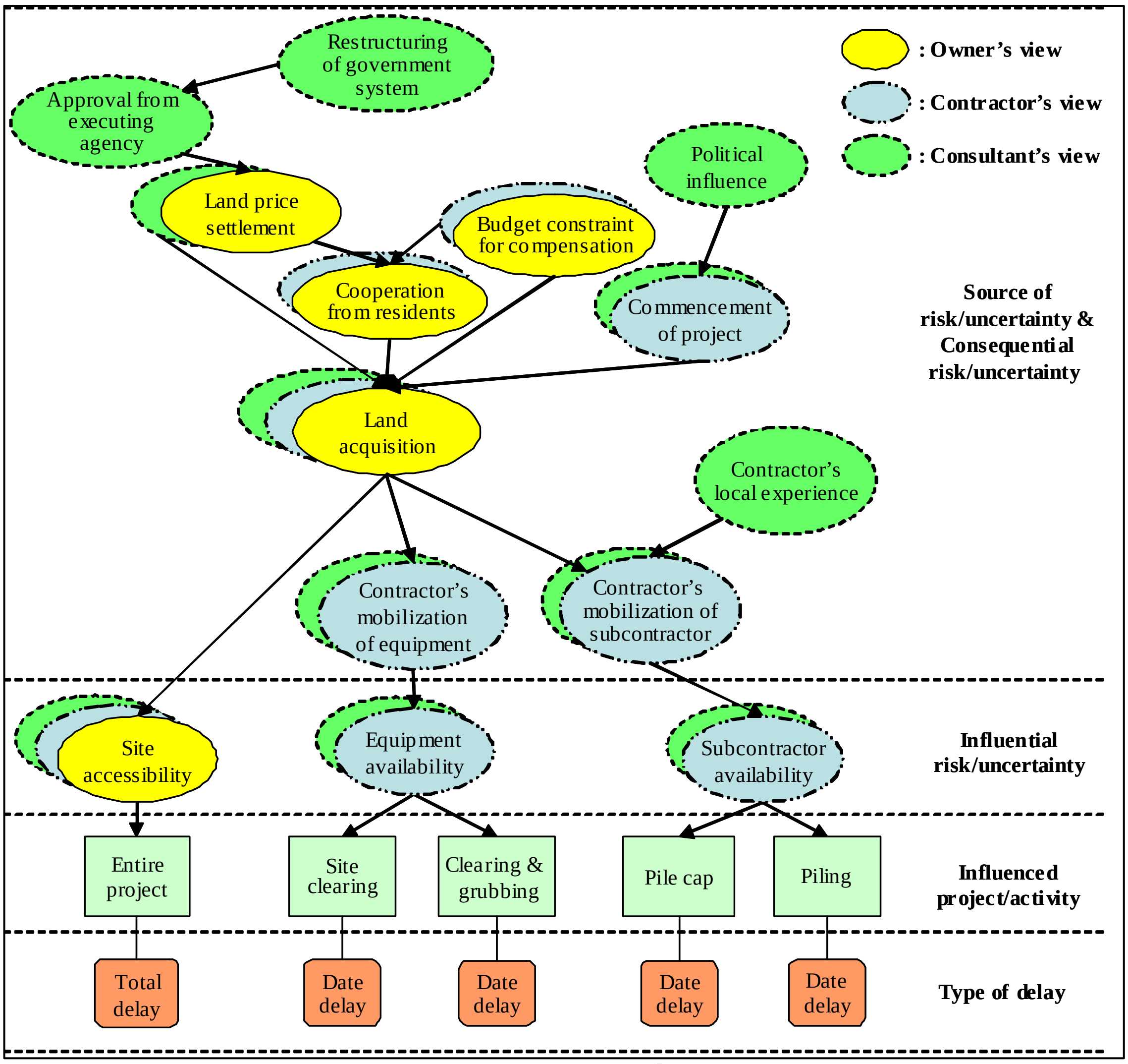


Figure 1 Integrated HSRU

3.3 Risk and uncertainty assessment and analysis

The risk and uncertainty assessment and analysis process is the successive process after risks and uncertainties are identified and their hierarchical influential relationships are structured. The 'probability' and 'impact' are two main components characterizing risk and uncertainty events. This process aims to assess and analyze these two main components of risk and uncertainty based on their hierarchical structure.

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 are inevitably represented in dimensionless values. In order to easily interpret results, therefore, it is desirable to further transform these dimensionless values to those with dimension such as time and to present them in terms of the cumulative distribution function (CDF) of project duration. This is the motivation for developing the duration valuation process (DVP) as a major component in the MRUMP.

By going through this process in this case study, the following steps were conducted:

- educating probability and impact assessment procedure to assessors,
- calibrating probability and impact assessment scale,
- assessing probability of risk and uncertainty based on perceived HSRU,
- assessing impact of risk and uncertainty based on perceived HSRU and type of delay,
- transforming assessed probability and impact to dimensional value, and
- building analysis model and conducting simulation.

Assessing probability and impact

Before starting the assessment process, the procedures of assessment, example of probability and impact scale, and example of questions were explained to assessors. Followings are example of questions in probability assessment (Figure 2) and impact assessment procedure (Figure 3).

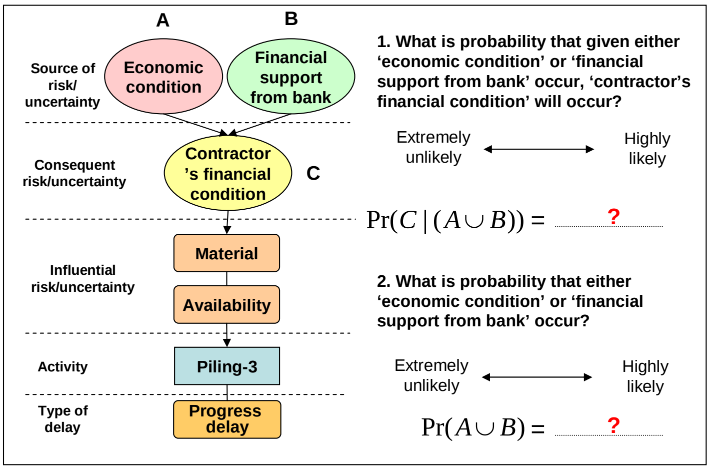


Figure 2 Questions in probability assessment

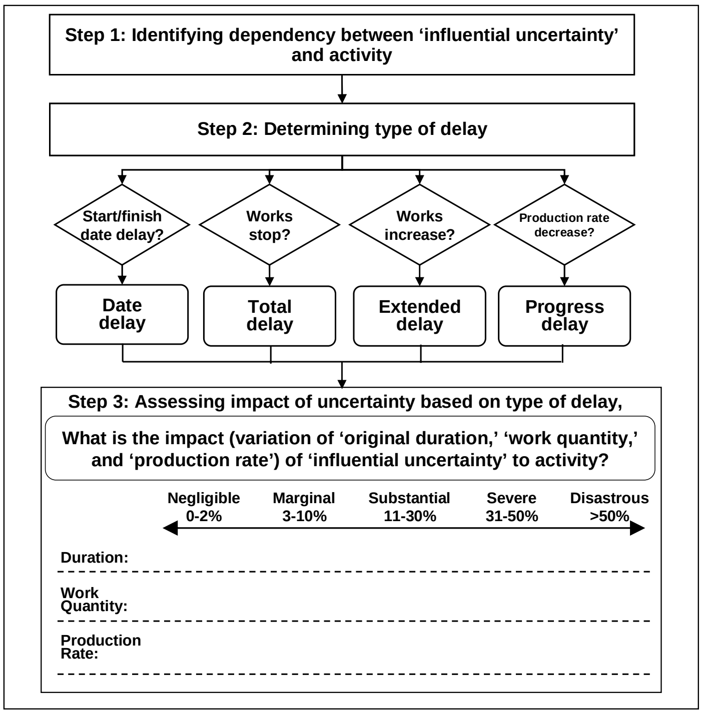


Figure 3 Impact assessment procedure

After we educated assessors and calibrated probability assessment scale, the assessors from each party assessed the probability and impact of risks and uncertainties based on their developed HSRUs.

Analyzing risks and uncertainties

In analysis process, based on conditional probability and the multiplication rule in probability theory, joint probabilities were calculated in order to find the probability distribution of impact (in terms of delay percentage). Then, the delay percentages associated with each impacted activity were transformed to delay duration. The probability distributions of activity durations were obtained. Joint probability, joint impact, probability distribution of impact (delay percentage) and probability distribution of delay duration of each impacted activity were calculated in tabulated spreadsheet software.

Subsequently, based on the DVP process, the probabilistic approach by using the Monte Carlo simulation technique was adopted in conducting simulation. The random variable was activity duration. The simulation model was developed in spreadsheet software based on the critical path method (CPM) presenting dependency and type of delay between activity and risks/uncertainties of each party. Then, distribution function was assigned, and the scheduling model was simulated by using simulation software.

Consequently, the statistics information (such as mean, minimum range, maximum range, standard deviation, and variance) and cumulative distribution of project duration associated with each party's view were obtained. These outputs were presented in unit of 'day', not dimensionless value. The result of cumulative distribution of project duration is shown in Figure 4.

Additionally, in order to understand the difference of all parties' perception more comprehensively, the 'risk/uncertainty impact chart' (RUIC) was developed. Additionally, in order to understand the difference in all parties' perception more comprehensively, the 'risk/uncertainty impact chart' (RUIC) was developed. It aims to present how each party perceived risk/uncertainty that delays the project and by how much extent. 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 was presented in form of scheduling bar chart developed by scheduling software.

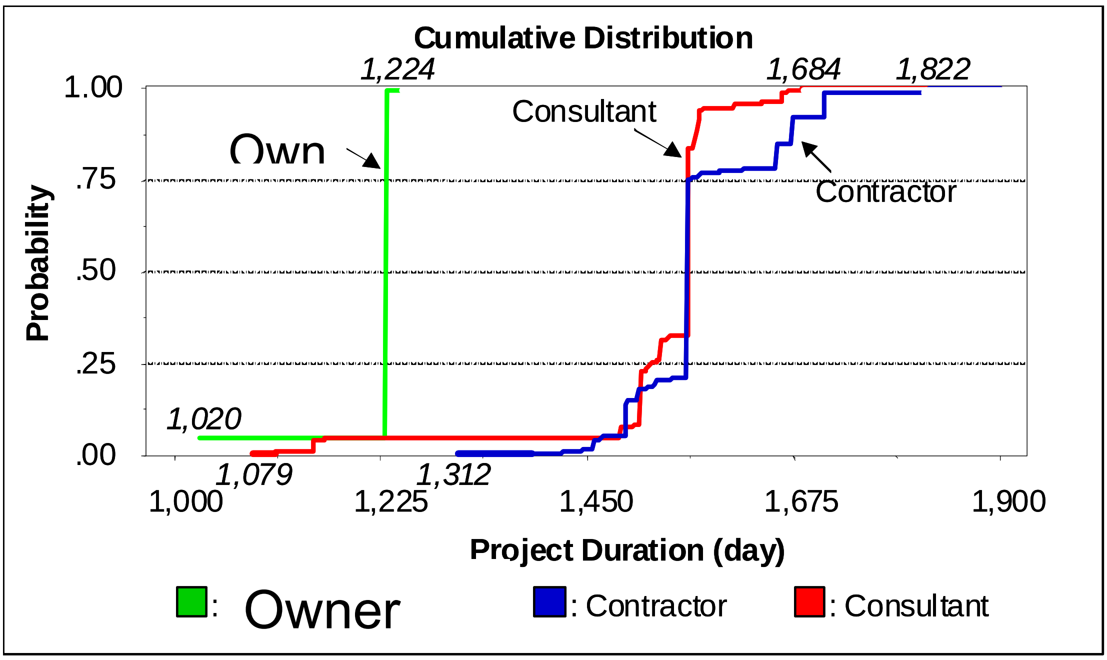


Figure 4 Cumulative distribution of project based on each party's view

Here for the sake of simplicity, it is shown in following chart (Figure 5).

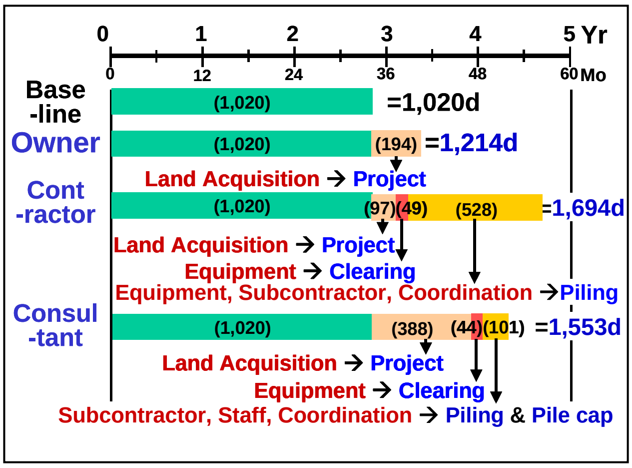


Figure 5 Risk/Uncertainty Impact Chart (RUIC)

3.4 Discussion of first application

Interpreting result

Discussing the result of cumulative distribution shown in Figure 4, the distribution based on owner's assessment is totally located on the left side to the distributions based on contractor's and consultant's assessments. That is, the owner was more optimistic than the both contractor and consultant. It is worthwhile investigating reasons for this difference in duration estimations by the three parties.

A first reason for this estimation difference can be difference in a risk and uncertainty structuring diagram perceived by each party. In the integrated HSRU as shown in Figure 1, "occurring risk/uncertainty" was "land acquisition" risk/uncertainty. "Subsequent risks/uncertainties" were "mobilization of equipment and subcontractor risks/uncertainties.

The owner only identified the land acquisition uncertainty that caused the site accessibility of the project. The contractor and consultant not only identified this occurring risk/uncertainty of land acquisition but also subsequent risks/uncertainties of contractor's mobilization of equipment and subcontractor.

Awareness of these subsequent risks/uncertainties, which arise from the land acquisition uncertainty, characterizes contractor's perception from that of the owner. Generally, a significant criterion for the contractor to make a decision on whether subcontractors and equipment should be mobilized or not is not only availability of sufficient land but also appropriate sequence of land handed over. The owner did not seem to take into consideration the mobilization decision criterion for the contractor.

A second reason for the difference in the duration estimation can be different assessment of occurrence probability and impact of each risk and uncertainty by each party. The RUIC represents all parties' views towards the impact of risks/uncertainties to activities, that is, the all parties' perceptions about how long the project would be delayed and why.

The RUIC contains three types of information: a) source or consequential risk/uncertainty or influential uncertainty, b) influenced project/activity, and c) expected days of delay associated with each influenced project/activity. One of the largest perception differences by the three parties was found in the land acquisition risk/uncertainty. Although assessment of occurrence probability of this risk/uncertainty by the all parties was similar, their assessment of its impact was different. The impact of this land acquisition risk/uncertainty assessed by the executing agency and the contractor are one-second (1/2) and one-fourth (1/4) of consultant's assessment, respectively. The consultant's assessment was the closest to the actual impact of late land acquisition. Experience of similar projects in the past, knowledge, and bias with each party seems a reason for this assessment difference.

Other large perception differences were subsequent risks/uncertainties of contractor's mobilization of equipment and subcontractors. As already mentioned, these risks/uncertainties were not identified by the owner. Assessment of impact of these risks/uncertainties was different by the consultant and the contractor.

Comparison with actual status

In order to evaluate the precision of all parties, their analysis results were compared with actual status. The first application was assumed to be conducted at early stage of construction, and the period of assessment was framed from beginning to the current status of project (project progress up to 25th month). In actual status, approximately 16 months was provided for time extension due to late land acquisition. Then, the original project duration was then revised.

Comparison among the all parties' views and actual status of project demonstrates that consultant's view was considered to be most "realistic." The owner did not seem aware of contractor's difficulty, and the contractor seemed to know little governmental and political constraints, which delayed commencement of the project. To the contrary, the consultant could identify most of major risks/uncertainties actually occurred and assess their impacts most closely to the actual impact.

These results imply that in this case study project setting up risk management meetings at early stage of construction could have been beneficiary for the three parties to be aware of and to identify problems. Such meetings could have promoted mutual understanding especially between the owner and the contractor and generated a constructive solution. In these meetings a party who is considered to have a best understanding of the other parties' views, the consultant in this case, would play a significant role in making the meetings efficient and effective. It should also be noted that one more party would play key roles: the party who listens to all parties' discussions and represents each party's view at the real time using the MRUMP also would play roles of not only analyst but also facilitator.

In summary of the first application, the risks and uncertainties information were collected and made available as reference to all parties. Then, they were encouraged to express their opinions towards each identified risks and uncertainties 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 application, different views among parties could be aware. Thus, by using collected risk/uncertainty 'reference,' the involved parties were able to communicate and discuss more the future project situation such as what risks and uncertainties were source of uncertainties 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.

4. SECOND APPLICATION: RESPONDING AND ANALYZING SCENARIOS

The second application was assumed to start from current stage to the end of construction. The purpose of this application is to discuss proactive and reactive 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 situations and contractual conditions.

4.1) Risk and uncertainty response process

In response process, we aim to find the efficient solution for this project and preventive measure for future projects. Furthermore, we rely on the concept of scenario analysis and put in consideration on type and category of response and contractual issues.

By adopting scenario analysis, the MRUMP provides 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.

There are three types of response i.e., proactive, accept, and reactive responses defined based on timing of implementation (before, current, or after occurrence of risks/uncertainties). There are four categories including avoidance, mitigation, transfer, and retention. To define category of response directly depends on who is the decision maker.

The contractual issue is also put in consideration when analyzing response scenarios. Basically, 'how to draft contract clause' is defined as decision variable to owner during planning stage. Otherwise, after the contract clauses are already prepared, the 'contract clause' is defined as nominal variable. In the second application, related contract clauses associated with each response scenario were identified.

The response process consists of following steps:

- initiating response scenarios
- identifying contract clauses related to response scenarios
- identifying 'consequential uncertainties' and 'consequential impact'
- developing response scenario diagram
- assessing probability and impact of risks/uncertainties associated with each response scenario
- conducting simulation of project duration in each response scenario

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:

causation from owner:

- late land acquisition,

causations from contractor:

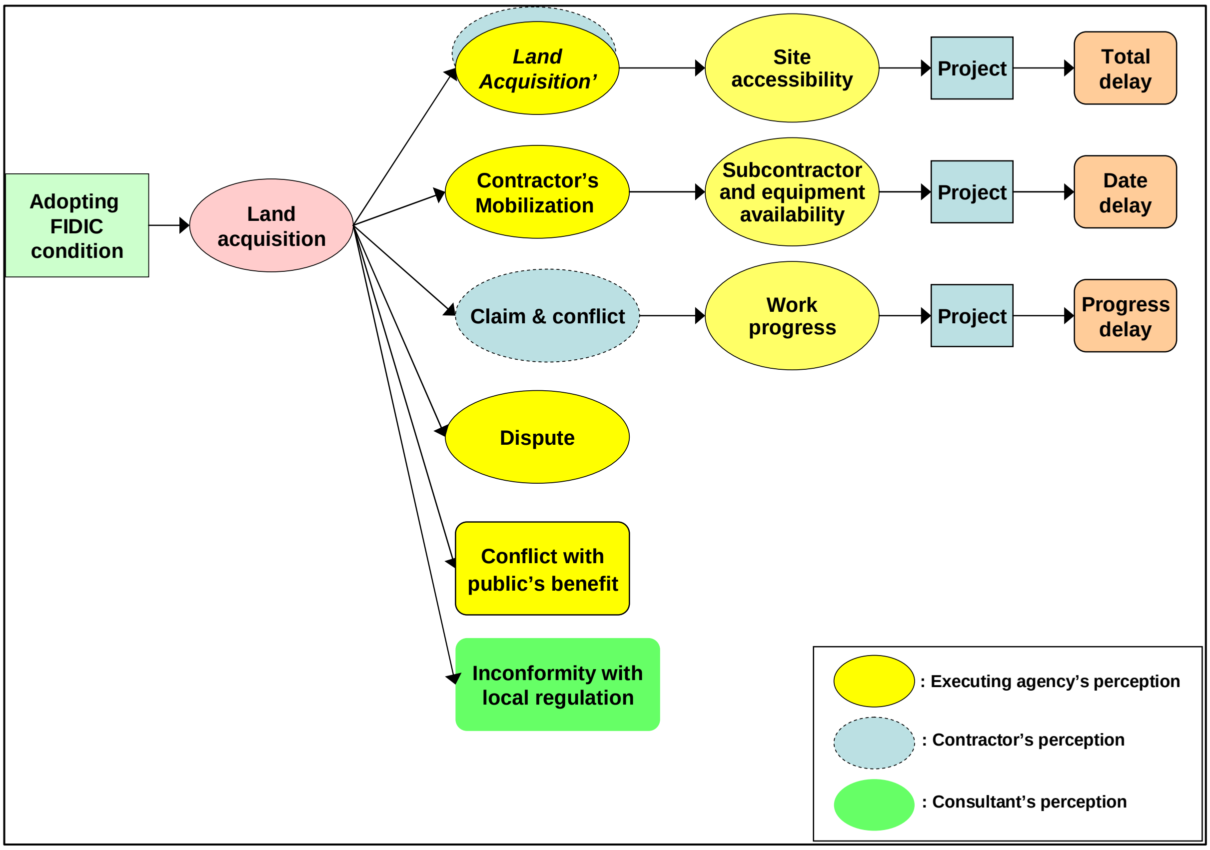
- late mobilization of subcontractor and equipment,
- late mobilization of key staffs**,** and
- inefficient coordination among contractors in joint venture**.**

Responses to risks/uncertainties related to causation from owner

In real practice only time extension was provided to contractor as compensation due to late land acquisition caused by the owner. However, there was discussion that the contractor also suffered from cost incurred due to late land acquisition. For further consideration of contract clauses evaluation in future projects, to respond this risk, preventive measures related to contractual condition were analyzed by comparing two responses:

1) accepting current contract condition: providing only time extension not cost incurred, and
2) adopting international standard form of contract of FIDIC: providing time extension and cost incurred.

After response scenarios were proposed, then, response scenario diagrams (RSD) were developed. The RSD presents the consequential relationship among focused risks/uncertainties, proposed



response scenario, consequential risks/uncertainty and impact, and outcome associated with the implementation of that response scenario. The integrated RSD based on each party's perception of 'adopting FIDIC condition' is shown in Figure 6.

Afterward, assessors from all parties provided their assessment on probability and impact based on constructed RSD. The next step was to conduct the analysis of risks and uncertainties associated with each response scenario. The analysis was conducted based on constructed RSD and assessed probability and impact. This procedure was grounded on similar basis of probability theory and simulation employed in risk/uncertainty analysis process. As the results from simulation, the statistics information and cumulative distribution of project duration associated with each response scenario was obtained.

Then, the duration-risk map is developed for evaluating efficiency of response scenarios based on the concept of risk efficiency (Chapman and Ward 1997).

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 duration-risk map associated with responses of 'late land acquisition' is shown in Figure 7.

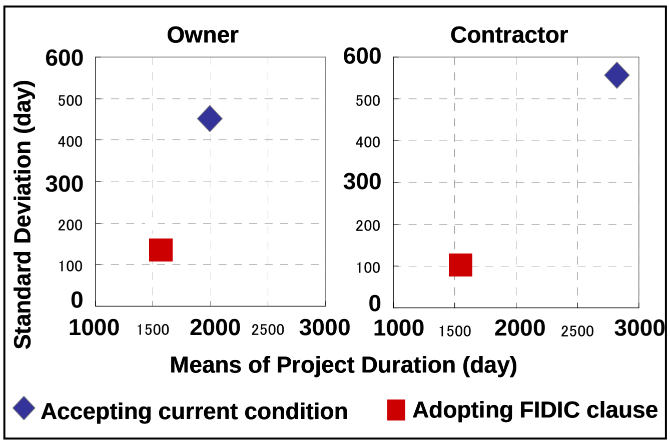


Figure 7 Duration-risk map associated with responses to 'late land acquisition'

Responses to risks/uncertainties related to causation from contractor

For risks/uncertainties caused by contractor, they are related to contractor's resources and capability. Following reactive measures were proposed by all parties to deal with these prospective risks/uncertainties:

1) increasing number of subcontractors,
2) increasing number of key staffs,
3) improving internal coordination, and
4) enhancing management capability

By considering all these reactive responses, they seemed to be appropriate responses that the contractor should implement.

However, there were questions regarding which response should be deserved high priority or would there be subsequent problems occurring after implementing such response. Therefore, the analysis of responses for contractor aims to find priority of reactive responses based on efficiency condition perceived by each party.

The steps of analysis are similar to analysis of responses to risks/uncertainties associated with owner in the previous section.

The duration-risk map showing the efficiency condition of analyzed responses based on each party' view is presented in Figure 8.

4.2) Discussion of second application

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

Based on the risk efficient concept, the lower means and standard deviation of project duration is, the more efficient response is (shown in Figure 8)). For example, contractor perceived that 'increasing number of subcontractors' is the most efficient. According to all parties' perception, different parties have different views towards efficient response. Then, in order to find a desirable solution, each parties' efficient response was scrutinized in more detail by concurrently considering the result of duration-risk map with integrated RSDs of each response scenarios perceived by each party.

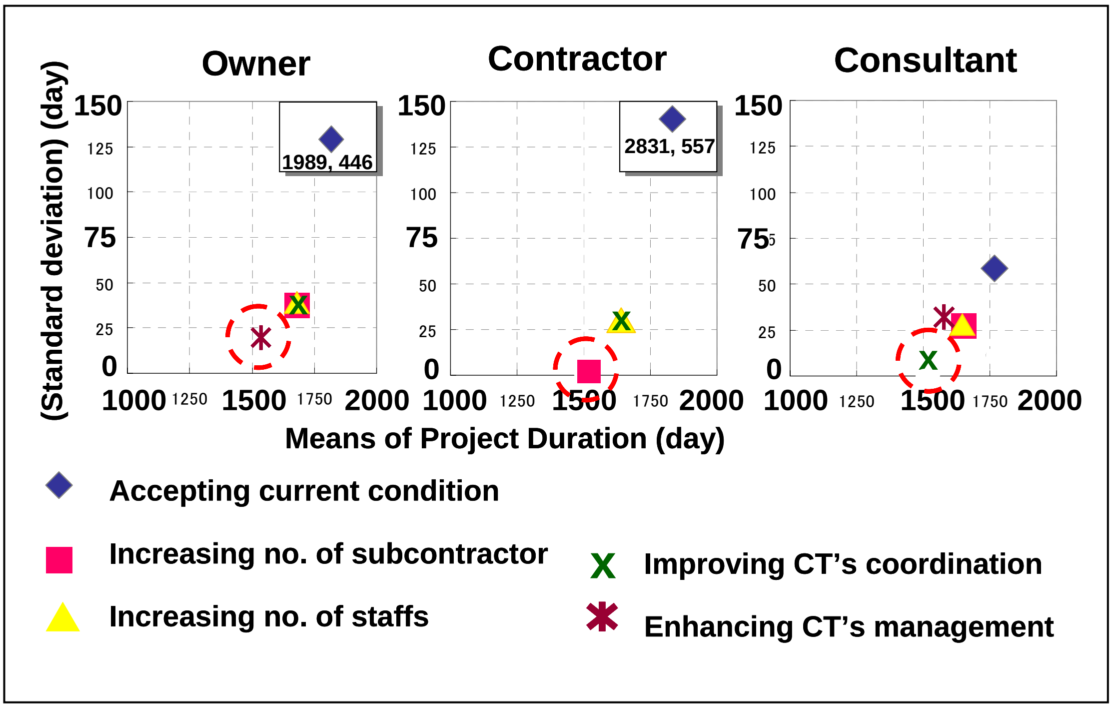


Figure 8 Duration-risk map associated with risks/uncertainties related to causations from contractor

The owner perceived the 'enhancing contractor's managerial capability' was the most efficient response. Based on the owner's view, to enhance contractor's managerial capability meant to replace the new management staff of the contractor. However, the consultant perceived that by implementing this solution, there was a high possibility to induce subsequent uncertainties including poor coordination among parties and low performance of new staffs.

In the case of the consultant, to improve contractor's coordination was perceived as the most efficient response because not only coordination among contractors but also mobilization of subcontractor and staffs condition could be also improved.

Nevertheless, the contractor himself perceived differently. The contractor perceived that to immediately increase the number of subcontractors was the most efficient. By implementing this solution, contractor seemed to be confident that the current situation would be improved very much although they had limitation on working space and cost. On the other hand, the consultant perceived that if contractor increased only the number of subcontractors by not considering the number and workloads of staffs, there was still a high possibility of problem to occur.

Considering the result from this application, the MRUMP provided an opportunity to discuss priority of reactive responses for responsible party based on efficiency conditions of responses together with possible subsequent risks/uncertainties from integrated RSDs. This result would be beneficial for involved parties to further analyze the implementation plan to solve the problem.

According to practitioners' comments on the MRUMP, they perceived its usefulness in using as communication and problem preventing and solving tool among relevant parties in construction stage.

5. CONCLUSIONS

The MRUMP is designed for proactively solving problem through problem awareness, problem identification and problem solving. From the application, it could illustrate the MRUMP's benefits at least in following aspects i.e., 1) facilitating problem solving by integration of multiple parties' views, 2) increasing attention on uncertainty, 3) enhancing assessment by valuation of probability and impact and 4) realizing efficient management measures of uncertainty. Moreover, the MRUMP can be used as a post-evaluation study to draw lessons learnt for similar projects in future as well as for inexperienced practitioners.

It is further expected that the MRUMP is applicable for contract evaluation, assistance in policy making, planning, and problem preventing at early stage of project and problem solving at later stage of project.

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