Development of Risk Analysis Method for Building Projects

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Abstract
In the past decade, both inside and outside of Japan, a lot of studies and researches have been done on the problems concerning the risk management process, the contract relation, and the development of risk analysis technique. But, there are very few studies discussing the project risk from the viewpoints of jobsite engineers. Especially, risk management, which has been usually processed in the empiricism, is not considered deeply on the construction sites in Japan. However, it is necessary to understand the quantitative mechanism of project risk to proceed risk management in the construction site properly, and set up the risk strategies by trade-off of risk and cost to reduce the project risk. This study started with using FTA to develop a quantitative analysis method, and using the data from the stakeholders of project to prove this method is useful. And, 650 risk occurrence causes in concrete description were emerged in a discussion with 40 project managers by brainstorming. Then, 32 risk occurrence causes were extracted by the method of two-dimension evaluation. Finally, the decision support system of risk management in a dialogue way was developed.

Keywords: project risk; risk management; risk strategy; risk analysis; decision support system

Introduction
The project managers should operate the project in the uncertainties of environmental conditions, and control the risk of schedule delay or cost overrun. The building projects are becoming large-scale and complicated, how to process qualitative/quantitative analysis of project risks and how to deal with the results of project risks are more and more important for the stakeholders of project (Tsai et al., 2001). However, risk management has not been established as a theory on the construction site, and usually has been proceeded in empiricism by project managers. And, the viewpoints of the risks and the considerations of risk management from the engineers of construction sites are hardly discussed in Japan. Therefore, it is necessary to understand the current situation of project risks and the realities of risk management, and to develop the decision support system which can support the stakeholders of project to consider various risk strategies (Tsai et al., 2001).

Mainly, there are three parts in this study. In order to evaluate the effectiveness of risk strategies, the first part is development of quantitative analysis for project risk. In the case study, other stakeholders tend to transfer most of risks to the general contractor in construction phase. In order to clarify the realities of risk management in Japan, the second part is risk analysis in construction phase. And, 650 risk occurrence causes in concrete description concerning risk results and project stages were emerged in a discussion with 40 project managers by brainstorming. The 105 risk categories and 251 risk occurrence causes were classifies in abstraction description. Then, 32 important risk occurrence causes were extracted by the method of two-dimension evaluation. In the third part, these 32 important risk occurrence causes were used to investigate the basic data of project risks from 70 project managers, and to develop the decision support system of risk management.

Past Studies Review
In the past decade, both inside and outside of Japan, a lot of studies and researches have been done on risk management process, contract relation, and risk analysis technique.

The studies of risk management process are mainly discussing the body of knowledge in risk management, and the studies of contract relation are mainly discussing the reasonable allocation of responsibilities for the stakeholders of project. Normally, these studies use the qualitative methods like influence diagram, game theory, AHP (analytic hierarchy process), etc. to identify the risk occurrence causes and to evaluate the
The main purpose is to build a body of knowledge in the risk management for all stakeholders of project. But the studies of risk analysis technique are mainly discussing the cost overrun and schedule delay of the activities concerning the client and contractor of project. Normally, these studies use the quantitative methods like sensitive analysis, fuzzy theory, Monte Carlo simulation, etc. to build a model and simulate the probabilities and deviations for the realities and planning. The main purpose is to develop the quantitative technique of risk analysis for certain stakeholder of project. (Tsai, et al. 2001)

However, most of the past studies are discussing the project risk from general viewpoint of all stakeholders to build a body of knowledge, but not from the viewpoints of jobsite engineers. Especially, the studies of risk management in Japan are still focusing on the contract relation of stakeholders in qualitative discussing.

**Development of Quantitative Analysis**

**Fault Tree Analysis**

In order to develop the quantitative analysis of this paper, the authors use FTA (Fault Tree Analysis) to analyze project risks. FTA is an analysis method to find out the major causes of failures and to assess the probabilities of failures in systems or facilities. It is widely used in safety engineering of mechanic and aviation industry. Basically, it uses logic gates of AND gate and OR gate to describe the relationship of these failure factors by FT (Fault Tree)(Fig.1). FT can establish a causal scenario that is called accident sequence, which is composed of various failure interactions among devices, software, material, human and environment (Kumamoto and Henley, 1996). When the probabilities of failure causes are given as input, the occurrence probability of top event can be assessed, and the quantitative/qualitative importance of failure causes can be identified in the same time.

**Basic Algorithm in Fault Tree Analysis**

**Minimal Cut-Sets:** Normally, there are a number of cut-sets in an FT, but minimal cut-sets mean these sets are the necessary and sufficient conditions for the occurrence of top event. For example, “*” denotes logic intersection of AND gate and “+” denotes logic summation of OR gate. The minimal cut-sets of Fig.1 can be identified by Boolean algebra as \( T = A_1 + A_2 = X_1 + X_2 + X_3 \cdot X_4 \) to be minimal cut-sets \( \{ X_1, \{ X_2 \} \) and \( \{ X_3, X_4 \} \)

**Quantitative Analysis:** In the premise that the basic events of risk causes are independent one another, the probability of risk occurrence is defined as Eq. (1) in FTA (Inoue 1979). As the interpretation in minimal cut-sets, the meaning of Eq. (1) is when every risk cause \( X_i \) in any minimal cut-set \( K_j ( j=1,\ldots,k ) \) occurs, then risk will occur.

\[
g(q) = \prod_{j=1}^{k} \prod_{i \in K_j} q_i,
\]

where \( g(q) \): Probability of risk occurrence  
\( q_i \): Probability of risk cause \( X_i \)

**Dual Structure of FTA and RGA**

In order to evaluate the effectiveness of risk strategies, the authors use dual structure of FTA and RGA (Reliability Graph Analysis) to compare the difference of risk strategies. Every FT can be mutually transferred with RG (Reliability Graph) due to the character of dual structure of FTA and RGA (Inoue, 1979), that is, OR gate in FT is the series allocation of RG and AND gate in FT is the parallel allocation of RG. For example, the failure causes of \( X_1, X_2, X_3 \) and \( X_4 \) in the FT of Fig.1 can be transferred to the activities labeled with 1, 2, 3 and 4 in the RG of Fig.2. By comparing the failure probabilities of different FTs, the effectiveness of risk strategies can be assessed.
Analysis Steps

Step 1. Risk identification and risk relationship:
The risk causes of the projects can be categorized into internal risks and external risks (Zhi, 1995). Normally, the rational plans are used to deal with the internal risks in project management, and emergent plans are adapted to external risk of external environment. So the risk occurrence of project associates to two major risk modes. They are failure of project management and failure of adaptation to external environment (Fig.3). And, these risk modes can be divided in detail to subsequent risk modes and risk causes by the concept of RBS (Risk Breakdown Structure). In order to clearly interpret and demonstrate the analysis steps, the authors use the method of modularization that considers partial FT as a cut-set or a basic event of top event. Then the analysis level is closed to the independent risk causes of X1 to X6. By the classification of Fig.3, the 29 of normal risk causes for construction projects are identified in hierarchy (Table 1). In the case study, these 29 risk causes are used to survey the data of all stakeholders and analyze the project risks.

Step 2. Preparing and analyzing FT:
Step 2 describes the causal scenarios of risk occurrence, risk modes and risk causes by AND gates and OR gates. And the concept of top-down approach is used to build FT of risk occurrence. The probabilities of risk causes $q_i$ are derived from surveying to estimate the probability of risk occurrence $g(q)$.

Further, the character of dual structure between FT and RG is facilitated. The risk strategies of project can be regarded as the redundancy devices of system in reliability engineering. So the risk strategies of project should be the partial processes of project, and the new RG of the project with risk strategies can be built. Transferring each new RG to a responding FT, the amount of risk reduction can be assessed by FTA.

Step 3. Comparing the effectiveness of risk strategies:
There are four types of risk strategies quoted from past studies. The contingency planning cannot reduce the risk probability of risk causes, but mitigation can reduce some of the probability. And allocation is to put some redundancy on risk causes, but deflection is to replace this risk cause. Comparing the results of step 2, it is possible to evaluate the changes of risk factors and the effectiveness of different risk strategies.

Case Study
Profile of the Project: The project of the case study constructed from Dec. of 1993 to Sep. of 1996, which is an office building of 28 floors in Osaka. The project phase of FED (Front-End Debates) is from Apr. of 1988 to Apr. of 1990, and major job is to investigate the requirement of rental market of office building. SPD (Strategic Project Definition) is from Apr. of 1990 to Feb. of 1992, and major job is to negotiate with government for compensation of floor area by providing some open space on the ground floor. EPC (Engineering, Procurement, Construction) is from Feb. of 1992 to Sep. of 1996, and the major jobs are to design and to construct the project. Major stakeholders are definite to the owner, the consultant, the designer and the general contractor (GC).

Data Examination: A questionnaire is built to investigate the probabilities of 29 risk causes. The probabilities of risk causes are shown in Table 1. And, the other parties who are the risk causes to be contracted out and the risk strategies those are adopted by stakeholders in every project phase for every risk cause are investigated. The probabilities of these risk strategies are incorporated to the probabilities of Table 1, and the final probabilities of risk occurrence after adopting risk strategies were assessed.

Simulation and Interpretation: Fig.4 shows the cumulation of the probabilities of risk occurrence for the stakeholders before adopting risk strategies. There are very similar total values evaluated during all the project phases. That means each stakeholder predicted the probability of risk occurrence on the beginning of project phase in some consensus. Fig.5 shows the cumulation of the probabilities of risk occurrence for the stakeholders after adopting risk strategies. The larger proportion of risk probabilities for the GC in EPC can be found. That means other stakeholders transfer most of risks to the GC in EPC. The project operation of this case study is a very popular way in Japan, which is so called single responsibility of lump-sum contract.
### Table 1. Probabilities of Risk Causes of Project Phases before Adopting Risk Strategies

| Item | Description                                      | Owner | Consultant | Designer | GC |
|------|--------------------------------------------------|-------|------------|----------|----|
|      |                                                  | FED   | SPD EPC    | SPD EPC  | EPC|
| X111 | Failure of Project Definition                    | 0.020 | 0.001      | 0.070    | 0.140| 0.021| 0.114| 0.010| 0.066|
| X112 | Failure of Resource Allocation                   | 0.050 | 0.004      | 0.008    | 0.140| 0.021| 0.265| 0.020| 0.044|
| X121 | Failure of Concept Design                        | 0.1   | 0.010      | 0.024    | 0.675| 0.060| 0.120| 0.050| 0.036| 0.045|
| X122 | Failure of Detail Design                         |       |            |          |      |      | 0.232| 0.036| 0.020|
| X131 | Failure of Labor Acquisition                      | 0.167 |           | 0.026    |      |      |      |      |      |
| X132 | Failure of Material/Equipment Acquisition        | 0.067 |           | 0.007    |      |      |      |      |      |
| X211 | Failure of Labor Execution                       | 0.100 |           | 0.010    |      |      |      |      |      |
| X311 | Failure of Quality Planning                      | 0.005 | 0.005      | 0.032    | 0.070| 0.016| 0.245| 0.026| 0.020|
| X312 | Failure of Quality Control                       |       |            |          |      |      | 0.040| 0.047|      |
| X321 | Failure of Cost Planning                         | 0.2   | 0.030      | 0.070    | 0.065| 0.060| 0.120| 0.063| 0.035| 0.070|
| X322 | Failure of Cost Control                          | 0.010 | 0.020      | 0.007    | 0.120| 0.063| 0.050| 0.100|      |      |
| X331 | Failure of Schedule Planning                     | 0.120 | 0.040      | 0.020    |      |      | 0.245| 0.026| 0.050|      |
| X332 | Failure of Progress Control                      | 0.120 | 0.160      | 0.045    |      |      | 0.040| 0.050|      |      |
| X411 | Failure of Scope-Change Management               | 0.014 |           | 0.014    |      |      |      |      |      |
| X412 | Failure of Design-Change Management              | 0.020 |           | 0.070    | 0.225| 0.060| 0.110|      |      |
| X413 | Failure of Technology-Change Management          | 0.014 |           | 0.030    | 0.100| 0.040| 0.043|      |      |
| X511 | Failure of Adaptation to Inflation               | 0.004 | 0.003      | 0.055    | 0.030| 0.010| 0.134| 0.043|      |      |
| X512 | Failure of Adaptation to Currency Change         | 0.005 |           |          |      |      |      | 0.022|      |      |
| X513 | Failure of Adaptation to Environmental Impact    | 0.005 |           |          |      |      |      | 0.022|      |      |
| X514 | Failure of Adaptation to Market Change           | 0.7   | 0.030      | 0.034    | 0.440| 0.250| 0.080| 0.070| 0.134| 0.087|
| X515 | Failure of Adaptation to Social Impact           |       |            | 0.170    |      |      |      | 0.043|      |      |
| X516 | Failure of Adaptation to Tax Change              | 0.004 | 0.005      | 0.055    | 0.032| 0.010| 0.100| 0.067|      |      |
| X611 | Failure of Adaptation to Postulated              | 0.004 | 0.005      | 0.055    | 0.032| 0.010| 0.100| 0.067|      |      |
| X612 | Failure of Adaptation to Natural Hazards         | 0.004 | 0.001      | 0.025    |      |      |      | 0.010|      |      |
| X613 | Failure of Adaptation to Unanticipated Government Intervention | 0.030 | 0.001  | 0.030 | 0.200 | 0.050 | 0.020 |      |      |
| X614 | Failure of Adaptation to Unexpected Side Effects | 0.004 | 0.001  | 0.070 | 0.100 | 0.025 | 0.040 |      |      |
| X615 | Failure of Adaptation to Completion Failure      | 0.002 |           |          |      |      | 0.050| 0.020|      |      |

**Risk Analysis in Construction Phase**

**Risk Strategy and Risk Result**

In order to clarify the current situation of risk management, the risk occurrence causes were analyzed from the viewpoints of risk strategy and risk result. Generally, the risk strategies of “Negotiation” and “Contract out” are used for the risk occurrence causes which are uncontrollable; the risk strategies of “Using human resources” and “Negotiation” are used for the risk occurrence causes which are controllable. In addition, to examine the relationship of risk strategy and risk result in detail; Fig.6 was obtained by the following method. That is, certain risk strategies should be considered by project managers to prevent the generation of risk result because the occurrence of certain risk occurrence causes. The relation between risk strategies and risk results was derived by this consideration. The risk strategy of “Schedule postpone” is hardly used because of the restriction of keeping contract schedule on time strictly on the jobsite in Japan. And, the risk strategy of “Using human resources” is widely used for all the risk results. Because all of the project risks can be reflected on the cost in a certain degree (Raftery, 1994; Isaac, 1995), most of risk occurrence causes are related to the risk result of “Cost overrun” (Fig.6).
Fig.6. The Risk Strategies for the Risk Results

Ranking Analysis

The evaluation method of two-dimension which is normally used to the ranking of the risk is introduced to evaluate the risk (Zhi, 1995; Marshall, 2001). In the two-dimension, each of the impact and probability is made in a scale between 0 and 1. The impact is taken in one axis, and the probability is taken in another axis (Fig.7), then the risk is evaluated at the same time for these two axes. In other words, as shown in the Eq. (2), "Risk is probability multiplied by impact". The probability in this research indicates a simple relative frequency, where the risk occurrence cause happened according to the experience of the respondents. And, the impact indicates the size of influence given to the project when the risk occurrence cause happened. The risk occurrence cause strongly appearing at a stage of the project was evaluated by Eq. (3) for the value of $R_{ij}$. The five stages are defined as follows: “Before commence of construction”, “Structure work”, “Finish work”, “After final inspection”, and “Entire construction phase” of the project. The ranking of risk occurrence causes shows the relationship, strong with the stage of “Before commence of construction”, is also strong with each stage afterwards. But the relationship, strong with the stage of “After final inspection”, is not strong with other stages. For instance, the relationship of “C102 Inappropriate contract term to the content of construction, cost overrun seems to happen” is strong with every stage, but the relationship of “C801 It is difficult to hold the maintenance fee” is only strong with the stage of “After final inspection”. Strength of the relationship with the risk results was evaluated by the same method. The relationship, strong with the risk results of “Schedule delay” and “Cost overrun”, is also strong with each risk result. But the relationship, strong with the risk result of “Safety problem”, is not strong with other risk results. For instance, the relationship of “C101 Inappropriate contract term to the content of construction, delay seems to happen” is strong with every risk result, but the relationship of “F702 The safety check is insufficient to the height works” is only strong with the risk result of “Safety problem”. Generally, the risk occurrence causes having strong relationship with every stage and every risk result, which are C101 and C102 of “C1 Unequal stipulation”, “Gb303 Recognition to the schedule of client is weak” of “Gb3 Headquarter”, “Hc202 There is no clear answer from the designer due to the lack of the detail drawings” of “Hc2 Consultant (designer)”, etc. The project managers on the jobsite are expecting the designer to have a fair viewpoint and a contract without biases. Moreover, the risk strategy of “Schedule postpone” cannot be used in reality, and the risk strategies of “Negotiation” and “Using human resources” are used frequently even if a severe schedule is recognized.

\[ R_i = P_i \times I_i \]  
\[ R_{ij} = P_i \times I_i \times \frac{N_{ij}}{N_i} \]

Where
$R_i$: The risk of risk occurrence cause i
$P_i$: The average probability of risk occurrence cause i
$I_i$: The average impact of risk occurrence cause i

Extraction of Important Risk Occurrence Causes

In order to extract the risk occurrence causes not biased to the importance for each risk result, the risk occurrence causes with the R values in the top 10 of
each risk result were collected in Table 2. The decision support system in risk management is proposed to these 32 risk occurrence causes. The principle is to keep the independence of these risk occurrence causes. By comparing the distribution of controllability of these 32 risk occurrence causes with the distribution of 251 risk occurrence causes, the average probability concentrates on [0.35, 0.8] and the average impact concentrates on [0.4, 0.8] as shown in Fig.7. This means the risk occurrence causes with the consensus are settled to the upper right of the two-dimension. One of the main purposes of the risk strategies is to change the risk occurrence causes located on the upper right to the lower left (Marshall, 2001). Therefore, it means that the excellent risk strategy can reduce the probability and the impact of the risk occurrence causes at the same time. The decision support system is necessary to select such risk strategies.

Decision Support System of Risk Management

One of the main purposes of the decision support system is to support the selection of a better alternative for the decision-maker. However, Arai (1998) claimed that it is very difficult to clearly separate the process of “Making the alternatives” from the process of “Selecting from the alternatives” in decision making. In this research, “Making the alternative” and “Selecting from the alternatives” in user's decision making are supported in the dialogue mode by a comprehensible analysis process. And, the framework of the decision support system in risk management was proposed from two viewpoints of the risk data search and risk analysis as written below (Fig.8).

![Fig.8. The Framework of the Decision Support System](image)

| No | Risk occurrence cause |
|----|-----------------------|
| 1  | A203. The collapse of the ground seems to happen in the construction site |
| 2  | A402. There are dangerous material to be used and kept |
| 3  | A701. Damage because of the crash and the falling down |
| 4  | C101. Inappropriate contract term to the content of construction, delay seems to happen |
| 5  | C102. Inappropriate contract term to the content of construction, cost overrun seems to happen |
| 6  | C103. The estimation is less than actual amount, but can not be claimed |
| 7  | C602. Because the description of contract documents is insufficient, the interpretation of the scope of work is different between the client and contractor |
| 8  | E101. The noise, the vibration, and the dust are troubled to neighbors |
| 9  | E201. The responsibility of the industrial waste is asked |
| 10 | E401. The large amount of traffic around the site, the disaster to third party seems to happen |
| 11 | E403. The collapses of heavy equipment, scaffold, steel structure, and formwork seem to happen |
| 12 | E902. Because the understanding is not obtained from the neighbors, the work time and work method are restricted by the agreement |
| 13 | F701. Because a lot of openings in the building the accident like falling happens |
| 14 | F708. The plan is forced to change due to the incompleteness of scheme on the way of execution |
| 15 | F903. The construction can’t be processed on time due to the late approval of working drawing |
| 16 | Ga104. There is incompleteness in working drawings, the check system is not enough in the site |
| 17 | Ga206. Take time to keeping of the test data, photograph, and test result |
| 18 | Gb101. The human allocation and the support of headquarter are not enough as require |
| 19 | Gb102. Various conditions of the site are not considered, the headquarter demands the same profit improvement |
| 20 | Gb202. The management of the subcontractor is a weak (e.g. bankruptcy) |
| 21 | Gb204. The decrease in the quality is not permitted as for the deficit contract |
| 22 | Ha201. The improvement of the quality becomes a problem by workman's skill |
| 23 | Hb6. Because the fact of the site is not understood by subcontractor with low mobilization ability, the situation of the workers is difficult to handle |
| 24 | Hc101. The priority of concept is insisted by the designer makes the problems of construction, structure, finish and maintenance, etc. |
| 25 | Hc202. There is no clear answer from the designer due to the lack of the detail drawings |
| 26 | Hc4. The working drawings and materials cannot be appropriately approved due to the shortage of management capability of design supervisor |
| 27 | Hc501. A lot of design changes with late instruction from designers in construction |
| 28 | Hc601. Excessive construction accuracy is demanded by the designer |
| 29 | Hd301. There are a lot of nominated subcontractors from the client and the designer |
| 30 | Hd401. The increase of the cost by the design change cannot be reflected in the change order |
| 31 | Hd601. The communications between client and designer are bad |
| 32 | Hd901. The client has an excessive demand for the grade |
Risk Data Search System

The system of risk data search is composed in three parts which are “risk data base”, “analysis support”, and “expression of search/analysis”. For the decision support system to be used easily on the jobsite, the spreadsheet (for instance, Microsoft Excel) is mainly adopted as the interface for the expression of search and analysis. The data is retrieved from the data base by the analysis support, which was designed by the VBA (Visual Basic for Application Edition) programming, and the result is shown on the spreadsheet in a dialogue mode. The risk data retrieval is divided into hierarchies. Moreover, these hierarchies are linked mutually. First, some elements of risk occurrence causes concerning the project are retrieved. For instance, risk occurrence causes often generated for some project types can be selected from the elements of project usage, project scale, and project location, etc. And, possible risk results and the value of the risk reduction are presented by the risk strategies, which often used for these risk occurrence causes. Also, other risk occurrence causes, which relate to these risk results, can be displayed according to user's requirement. In addition, the scenario of the trade-off of risk and cost in the project is simulated from the relations among the risk, the cost of the forecast damage, the risk strategies, and the strategies cost, etc. by the selection in a dialogue mode. In other words, a primary/qualitative analysis concerning each risk occurrence cause in the project risk is proceeded according to historical data.

Risk Analysis System

The main purpose of the risk analysis system is to do quantitative analysis. The system of risk analysis is composed in three parts which are “process of optimization”, “analysis support”, and “expression of search/analysis”. The result of the analysis is presented on the spreadsheet. The computational algorithm of the data exchange with the data base in the optimization process is supported by mainly using the VBA programming in the analysis support. Optimization is divided into two levels. The first level of optimization is called partial optimization, which is by the selection of risk strategies against individual or multiple risk occurrence causes. The second level of optimization is called total optimization, which is to search the proper risk strategies by the combination of constrained conditions with the project risk. The optimization process is a process for which the alternative is made by certain constrained conditions.

First, the data used for the analysis should be identified by the elements concerning the project. For instance, the elements may be the project usage, the project scale, and the project location, etc. And, the risk data about risk occurrence causes, often generated for such project type, should be inputted.

Next, the user selects whether to use historical data of data base. And, the user should judge whether to use relations among the risk occurrence cause, the cost of the forecast damage, the risk strategies, and the strategies cost, etc. from the data base, or to reset the data directly. In addition, the constrained conditions concerning the project and the objectives of the analysis are set. For instance, the risk strategies may be chosen under the condition of certain cost or the necessary cost in order to keep certain level of project risk, etc. From quantitative analysis, whether the results meet the requirements are judged by these conditions.

Finally, the alternatives, which meet the constraints, are presented to support the decision making of user.

Selection of Risk Strategies

In order decrease the project risk; the combination of risk strategies and the cost are evaluated by the risk analysis system as mentioned above. The condition is to search for the combination risk strategies by the risk strategies cost is between 3.5 and 6.1 million yen. Fig.9 shows the result. Basically, the combination of type 27 can reduce the project risk maximally, comparing with other types. On the other hand, the combination of type 1 uses the minimum money.

![Combination Type of Risk Strategies](image)

**Fig.9. Combination Type of Risk Strategies**

Which combination is considered better, it depends on the judgment of user. Normally, the combination of risk strategies which costs little money and reduces most project risk is regarded as the best. The combination of type 25 is assumed to be an example, and the risk strategies are shown in Table 3. In this case, about 3.8 million yen was spent to reduce 20 percents of project risk by using the risk strategies. There are two risk strategies of “Examination of the specification change such as VE·CR” and “Review of the execution budget” are used to C103 at the same time which risk occurrence cause is concerning the
budget of project. And, there are two risk strategies of “Severe cost control” and “Report at the early stage of the target profit” are used to Gb102 at the same time which risk occurrence cause is concerning the possibility to become an adverse budget of project.

In other word, it is understood to have to control the project risk, which is not only concerning the construction technique, but also widely concerning the contract and management of project.

Table 3. Risk Strategies of Type 25

| Risk strategy | Contract out |
|---------------|-------------|
| C102          | Participation at the estimation and review of the execution budget. Site office |
| C103          | Examination of the specification change such as VE・CR. Site office |
| C602          | Making of questions/the minutes. Site office |
| E101          | The soundproofing panel and sheet are set up in external scaffold. Subcontractor |
| E902          | Limitation of working hours. Subcontractor |
| Gb102         | Severe cost control. Report at the early stage of the target profit. Site office |
| Gb204         | The price cooperation is requested to the cooperative subcontractors. Subcontractor |
| Hc101         | Meeting with the designer beforehand. Owner |
| Hc202         | Meeting with the designer beforehand. Owner |
| Hc4           | Meeting with the designer beforehand. Owner |
| Hc501         | Meeting with the designer beforehand. Owner |
| Hd301         | Confirmation of recommendation rank. Owner |
| Hc401         | Submit the estimation of change order at early stage and get approvals in every case. Site office |

Conclusion

In this study, the fundamental data of the project risk was analyzed from some viewpoints through the investigation of actual situations of the construction site. And, the realities of risk management in Japan were clarified based on the analysis. In addition, the important risk occurrence causes have been extracted for the decision making system by examining the ranking of each occurrence cause in each stage and risk result.

As a result, the following four achievements were obtained.

1) The quantitative analysis method of project risks was proposed.
2) The fundamental data concerning the project risks in the construction phase was collected, and analyzed.
3) The current situation of the project risk and the realities of risk management were clarified.
4) The decision support system of risk management in building projects was developed.

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