Risk Response Analysis Model for Construction Method
Using the Forced-Decision Method and Binary Weighting Analysis

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Abstract

Although the selection of a construction method for each type of work is an important factor in determining the quality of a building, the construction duration, costs, and methods are currently being selected according to the subjective judgment of the person in charge, without sufficient consideration of the characteristics of the work type. As a response to this issue, this study proposes a process model to support decision making when selecting the most suitable construction method for major types of construction work. The study used the risk response level model, which connects the conditions of the order and the site, the constructability of the type of work within the site, a review of the economic efficiency of the work site, the forced-decision method, and binary weighting analysis in the construction planning phase. As a result of the application of this model to the construction method selection process for the construction of soil-retaining walls, the factors to be preferably considered in the field cases were analyzed in the order of the environmental, ground, design, construction, structural, and site conditions. Further, the risk response level of each construction method was calculated via risk response level analysis, subject to four applicable construction methods.

Keywords: selection of a construction method; decision-making; process model; risk response level analysis

1. Introduction

1.1 Background and Purpose

Since buildings have become more complex and have increased in scale, various construction methods are being proposed to accommodate this development. Consequently, more attention is now being paid to the importance of the selection of the construction method for major types of construction work. The choice of the construction method to be applied to a construction work significantly influences the quality of the building, the construction duration, and the construction costs. Nevertheless, construction methods are still being selected simply by comparing the applicable construction methods based on the experience of the person in charge of the construction planning phase, without sufficiently considering the characteristics of the construction work type. As a result, a change in the previously selected construction method in the course of the construction becomes unavoidable, usually resulting in lower building quality, higher construction costs, and longer construction duration. Moreover, selecting the construction method without sufficiently considering the conditions of the construction site can result in excessive levels of noise and dust, as well as an increased possibility for civil appeals and conflicts to arise. To prevent these problems, a method of selecting the appropriate construction method for a work type must be developed by analyzing the constraints in the construction work and the factors that affect the selection of the construction method in the construction planning phase. The aim of this study is to propose a process model to support the decision making on the selection of the construction method for major work types, through a review of the constraints in and constructability of the project site, a review of the economic efficiency of the construction method, and a risk response level analysis.

1.2 Literature Review

Many studies have been carried out on the selection of construction methods for non-specific and specific processes in construction work. For example, a study has been performed on the development of a construction method selection system for cut-and-cover tunneling, using the knowledge-based decision-making theory (Russell & Al-Hammad, 1993). Subsequent studies have been conducted on the method of selecting an appropriate construction method at the site by analyzing the constraints (Chun et al., 2000; Yoon, 2008).
& Yang, 2001), and on the combination of construction methods through a process that uses correlation analysis between the preceding and following processes (Chun & Oh, 2001). A study has also been carried out on the computerization of the construction method selection model (Chun, 2000), as well as on the use of the nerve network theory (Kim et al., 2000) and the case-based reasoning theory (Yau & Yang, 1998; Kim et al., 2006). The aforementioned studies mostly sought to improve the construction method selection process by connecting various theories to it. There is, however, a dearth of studies that propose construction method selection techniques considering the risks generated when applying the method using a quantitative model.

### 1.3 Scope and Method

The objective of the present study is to propose a model that will analyze the capability of various construction methods to respond to the risks in construction sites. This has not yet been dealt with in the previous studies. In this study, an analysis was carried out to determine the characteristics of the site to be considered in the implementation of a construction project, and the key factors in selecting a construction method. A basic process model for the selection of a construction method for major types of construction work was then proposed.

The major objectives of this study are as follows:

1. **Review the problems with the existing construction method selection system in planning a construction project, and set directions for improvement.**
2. **Determine the factors that must be considered in selecting a construction method.**
3. **Propose a method of exerting priority control over the factors that serve as risks in the construction method selection process, including the method of evaluating the response to the risks of the selected construction method.**
4. **Review the applicability of the construction method selection process model proposed in this study by applying it to the soil-retaining wall selection process in the underground construction planning of a newly constructed commercial-use building.**
5. **Propose a direction for future studies.**

### 2. Construction Method Selection Process Model

The construction method selection process model proposed in this study was designed for use in the selection of a construction method according to the work type. Several applicable construction methods are selected by analyzing the project constraints, reviewing the construction methods' stability and economic efficiency, and analyzing the methods' risk response levels. The construction method to be applied is then finally selected.

The construction method selection process model was performed through seven phases. The composition of the model is as follows.

1. **Classification of the work type and its subject**
   - The types of work demanded by the project were classified using the construction work information classification system proposed by the Ministry of Land Transport and Maritime Affairs. Major and sub-classifications of the work types were made, and a classification was chosen that enabled the easy selection of a construction method for the corresponding work type. For example, building ground construction was classified as "excavation and back filling" and "soil retention," and the construction methods for ground construction were classified into construction methods for excavation, such as the "open-cut method" and the "island method," and construction methods for soil retention.

2. **Project constraints**
   - The constraints of a construction project can be divided into the order and site conditions. The order conditions refer to the reduction of the construction duration, the required works, and the client's requirements.

### Table 1. Classification of Work Types in the Integrated Classification System for Construction Information (Partial)

| Code  | Name of Work Type                          |
|-------|--------------------------------------------|
| W301  | Building ground construction               |
| 3011  | Excavation and back filling                |
| 3012  | Soil-retaining work                        |
| W302  | Foundation work                            |
| 3021  | Sand, gravel and broken stones foundation work |
| 3022  | Concrete foundation work                    |
| W303  | Reinforced concrete work                    |
| 3031  | Production and placing of concrete         |
| 3032  | Forming and timbering                      |
| 3033  | Reinforcing bar and stiffening members     |
| 3034  | Joint                                      |
| 3035  | Post-tension pre-stressing                 |
| 3036  | Precast concrete                           |
| 3038  | Concrete appurtenant work                  |
requirements, whereas the site conditions refer to the constraints of the subject site, such as the conditions of the surroundings and of the ground.

(3) Selection of several applicable construction methods for the given work type

A search was performed for cases that had similar conditions to the case project and the corresponding work type. The project's constraints and the constructability of the corresponding work type were reviewed, and several applicable construction methods for the corresponding work type were selected.

(4) Stability review

This factor should be prioritized as it affects the safety of the construction work and of the building users. The structural stability and construction safety of the selected construction methods were reviewed, and only the construction methods that passed the stability review were used in the next phase.

(5) Economic efficiency review

The rough construction costs of the construction methods that passed the stability review were calculated.

(6) Risk response level analysis

The risk factors of the work type involved were determined during the construction planning stage, followed by the priority control risk items. The risk response level of each applicable construction method was then calculated using the induced priority control.

The risk factors of major types of construction work were classified into design, foundation, site, environmental, construction, structural, and economic conditions. The priority control of the risks to be focused on during the performance of the corresponding work type was determined through the forced-decision method, while considering the order and site conditions of the project. The risk response level of each applicable construction method for the corresponding work type was then measured using binary weighting analysis, based on the priority order of the risks.

The risk response level was calculated as follows.

① Determination of the risk priority order using the Forced-Decision Method

The forced-decision method was used to determine the priority order of the risk factors in the performance of the construction work. The forced-decision method determines the relative priority of each factor as 1 or 0 then calculates a total for these and evaluates the total (Fasal, 1965) to determine which factors should be considered first.

② Calculation of the risk response level using Binary Weighting Analysis

This method is used to assess the risk response level of the selected applicable construction methods. If the construction method accurately responds to the corresponding factor, it is given a "Yes" and assigned a value of 1; if it does not accurately respond, it is given a "No" and assigned a value of 0. The values are then converted into binary numbers and changed into the equivalent decimal numbers to calculate the response level.

③ Correlation between the Forced-Decision Method and Binary Weighting Analysis

Binary Weighting Analysis is proposed for the calculation of the priority control of the considered subject risks determined by the forced-decision method and the risk response level of the subject construction method, for the application of the risk analysis method proposed in this study to different types of construction work within the same project.

Also, the construction method applied to a certain work type is fed back and utilized as data for case-based reasoning when projects with similar risk factors are performed in the future.

The priority control determined by the forced-decision method becomes the standard for weighing in the Binary Weighting Analysis. In addition, the risk assessed as the suitable priority by the forced-decision method is placed higher in the list for the performance of the Binary Weighting Analysis and is given a higher binary number value than the other risk factors, creating the risk response data for the construction method to be applied to the corresponding work type.
(7) Selection of the construction method to be used

Based on the results of stability, economic efficiency, and risk analysis for the applicable construction methods, the construction method to be used in the corresponding work type was selected. Although only one construction method was chosen, several methods may be used for complex construction work. In this case, the combined complex construction method was reviewed.

3. Case Study: Selection of the Soil-retaining Wall

There has been an increase of late in the number of construction works that utilize underground spaces as parking spaces or commercial facilities. Consequently, various related construction methods are being considered, and such construction methods are increasingly being used professionally. The selection of the method of constructing the soil-retaining wall in underground construction, which is one of the largest types of construction work, accounting for 20~40% of the total building construction costs, is an important factor in the success of the construction project, although it requires prudent construction planning and prudent selection of the appropriate construction method, which is currently based on the intuition and experience of the project engineer via a simple comparison and review of the data in the construction planning phase, without quantitative standards. As such, soil-retaining walls that are inappropriate for the site are often selected, which often causes problems, such as higher construction costs, construction delay, and the collapse of the soil-retaining wall. To address these problems, this study aims to apply a suitable construction method selection process model in the planning phase to assess the practicability of the selection of the soil-retaining wall for underground construction.

(1) Existing soil-retaining wall construction methods

The selection process for the soil-retaining wall in terms of safety, heaving, boiling, underground water control, and prevention of damage to the surroundings depends on the site conditions, but is based on the individual experience and subjective judgment of the people in charge of the site, through a simple comparison of construction methods.

(2) Construction method selection process model

This model selects several soil-retaining walls that are considered applicable to the site by reviewing the order and site conditions as well as the stability and economic efficiency of the methods, and by analyzing the risk response level of the construction methods that have passed the stability review. The results of the assessment of the construction methods are then compared, and the construction method to be applied to the corresponding work type is selected. If a complex construction method is needed, the stability of the method is again reviewed to ensure its safety.

(3) Project constraints

To select the soil-retaining wall for underground construction, the order conditions were surveyed based on the client's requirements, building scale, construction duration, etc. The site conditions were also surveyed, including the neighboring buildings, the height difference of the site from the surrounding sites, and the surrounding pavement conditions.

This data pertains to a newly built 6,950m² commercial facility in the center of Seoul Korea, with eight underground and 16 aboveground stories. The project requires the establishment of a connection path to the neighboring subway from the 1st and 2nd basements of the building, and the shortening of the construction durations to six months.

(4) Constructability review

In this phase, the ease of construction of the soil-retaining wall at the site was assessed. The conditions were classified into topography, neighboring structures, and project constraints.

Table 2. Order of the Project Constraints (Partial)

| Order Conditions          | Reduction of the construction durations (36 months → 30 months) |
|---------------------------|---------------------------------------------------------------|
| Client's requirements     | Colorful                                                      |
| Building structure        | Steel and Reinforced Concrete                                 |
| Underground structure     | Reinforced Concrete                                           |
| Depth of the excavation of the foundation | 35 m                                                         |
| Depth of the excavation of the foundation | 35 m                                                         |
| Area of the excavation of the foundation | 6,139m²                                                        |
| Building scale            | Eight stories under the ground, 16 stories on the ground      |
| Building area             | 4,072.85 m²                                                   |
| Land area                 | 6,950.70 m²                                                   |
conditions of the location, buried structures, weather conditions, road conditions, etc. In addition, each factor was classified into further detail for assessment. Table 5 shows the factors in the review of the constructability of the soil-retaining wall for underground construction at the site.

(5) Selection of several applicable construction methods

A survey revealed that the H pile+ lagging wall, the cast-in-concrete pile (hereinafter, CIP), the soil cement wall (hereinafter, SCW), and the diaphragm wall (hereinafter, D/Wall) are the applicable soil-retaining walls for the case site, based on the constraints of the project, the ground survey results of the case site, and the constructability review results at the site.

(6) Stability review

SUNEX was used to review the stability of the
soil-retaining wall. SUNEX is general safety check software used in the engineering field. The stability review of the applicable soil-retaining wall showed that although the maximum displacements of the construction methods differed, they did not have stability problems if appropriately designed.

(7) Economic efficiency review

It was difficult to calculate the cost of each construction method in each construction planning phase. Thus, if the construction costs had been simply compared in the calculation of the general construction costs for the applicable soil-retaining walls in the economic efficiency review, for the construction methods in which the materials can be recycled, the recycling cost was considered, it would then have been found that the diaphragm wall needed large-scale construction equipment and a large plant for sully treatment. It would thus have been assigned a slightly higher construction cost than in the other construction methods. But since its perpendicularity was sound, it could be used as a soil-retaining wall after the construction, which would have reduced the construction duration. Consequently, it was evaluated as being more economical than the other construction methods.

(8) Risk review

① Setting of the risk factors

The possible risk factors in the construction of the soil-retaining wall were classified into design, ground, site, environmental, construction, structural, and economic conditions. Detailed items were then identified for each factor.

② Application of the Forced-Decision Method to determine the risk priority control

Table 6. Results of the Stability Review of the Applicable Soil-Retaining Wall

| Review Factors | Details |
|----------------|---------|
| Economic conditions | Construction durations, construction costs, materials management, productivity |
| Structural conditions | Flexible rigidity of the soil-retaining wall, water resistance, characteristics of the structure |
| Site conditions | Height difference within the site, plane figure (determinate/indeterminate), scale of the site, relationship with the neighboring land |
| Design conditions | Working load, reliability of the soil-retaining wall, reliability of the auxiliary construction method |
| Construction conditions | Ground collapse, change in the workload, earthquake, neighboring construction, flood, water leakage, excavation, low side collapse phenomenon |
| Ground conditions | Characteristics of the ground, condition of the support story, depth of the support story |
| Environmental conditions | Noise, vibration, settlement of the surroundings, treatment of the discharged muddy water, pollution of the underground water |

To determine the priority control for the possible risk factors at the site, five experts analyzed the risks to be preferably considered, using the forced-decision method. They also calculated the group weight by averaging each item. As a result, economic condition 1, structural condition 2.8, site condition 2, design condition 3.2, construction condition 3, ground condition 4.4, and environmental condition 4.6 were calculated, and the environmental conditions were evaluated as the highest. This result was considered indicative of the rising interest in the environment and in the consideration of civil disturbances and conflicts.

③ Risk response level analysis using Binary Weighting Analysis

In this study, detailed items were listed for the possible risk factors during the construction of the soil-retaining wall, and weights were given to each of the items by applying the risk priority control determined from the forced-decision method and binary weighting analysis. In addition, a risk response level analysis was conducted to understand the level of responses to the risks of the four applicable construction methods. The diaphragm wall, with a weight of 0.071, was found
to be the most appropriate construction method for the risks at the case site, while the soil cement wall and H pile and lagging obtained weights of 0.046, respectively, and the cast-in-concrete pile 0.043.

\[
EDV = \sum_{i=1}^{n} (w_i \times 2^{i-1}) = 118
\]

(4)

\[
MEDV = \sum_{i=1}^{n} (1 \times 2^{i-1}) = 127
\]

(5)

\[
RV = \frac{\sum_{i=1}^{n} (1 \times 2^{i-1}) - \sum_{i=1}^{n} (w_i \times 2^{i-1})}{\sum_{i=1}^{n} (1 \times 2^{i-1})} = 0.071
\]

(6)

4. Conclusion

Diversification of technology development is also required in construction. Various construction methods have been developed for building construction. The selection of the construction method for each type of construction project has been found to be important. Although such selection is the success factor in a project, it is, however, being subjectively made from the experience of the person in charge, without sufficiently considering the characteristics of the work type. Consequently, in this study, the conditions at the sites that influence building construction in the construction planning phase were determined; a method of systematically analyzing the factors that influence the selection of the construction method was proposed; and a process for selecting a construction method was likewise proposed, which consisted of a review of the order and site conditions, stability, economic efficiency, and risks of the method. In particular, as the study focused on risk analysis using the forced-decision method and binary weighting analysis, a model was proposed for analyzing the level of response of a construction method to the possible risk factors in the application of the selected construction method. As the AHP method evaluates the level of importance of the compared subjects using the values of 1/9 to 9, the range of the evaluated values is too wide to verify if the assigned values are appropriate. The proposed model, however, classifies all the compared subjects into 0 and 1 to evaluate their relative priority, making it possible to reduce the evaluation errors, and making it easy to summate the importance levels. Furthermore, by applying the proposed basic process model to the soil-retaining wall selection phase of an underground construction work, the practicability of the proposed model was evaluated. This study is a basic study on the selection of a construction method for major types of building construction work. Although the results of this study are applicable in practice, it is necessary to assess the appropriateness of the model by expanding it and applying it to other types of construction work. In addition, it is necessary to accumulate data to develop

Table 8. Priority Control Assessment Data by Experts

| Expert | A  | B  | C  | D  | E  | F  | G  | Total | PCO |
|--------|----|----|----|----|----|----|----|-------|-----|
| A      | 0  | 0  | 0  | 0  | 0  | 0  | 0  | 0     | 7   |
| B      | 1  | 0  | 1  | 0  | 0  | 0  | 2  | 3     | 6   |
| C      | 1  | 0  | 0  | 0  | 0  | 1  | 5  | 5     | 10  |
| D      | 1  | 1  | 0  | 0  | 0  | 3  | 4  | 7     | 11  |
| E      | 1  | 1  | 1  | 0  | 0  | 4  | 3  | 8     | 12  |
| F      | 1  | 1  | 1  | 1  | 0  | 5  | 2  | 8     | 10  |
| G      | 1  | 1  | 1  | 1  | 1  | 6  | 1  | 7     | 8   |

Note: A - Economic conditions, B - Structural conditions, C - Site conditions, D - Design conditions, E - Construction conditions, F - Ground conditions, G - Environmental conditions, PCO - Priority Control Order

Table 9. Results of the Risk Response Assessment of the Diaphragm Wall

| Priority Order | Factors                  | Yes | No |
|----------------|--------------------------|-----|----|
| 1              | Environmental conditions  | √   |    |
| 2              | Ground conditions        | √   |    |
| 3              | Design conditions        | √   |    |
| 4              | Construction conditions  | √   |    |
| 5              | Site conditions          | √   |    |
| 6              | Structural conditions    | √   |    |
| 7              | Economic conditions      | √   |    |
the model as a case-based reasoning model for use in the selection of construction methods for certain types of construction work, whose risks must be similar to those in this study. A study on the mutual influence between the selected construction method and the construction methods of the preceding and following types of work should be consistently conducted.

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