THE PRIORITIZATION OF IMPROVEMENT NEEDS FOR UNDERGROUND CONSTRUCTION ENVIRONMENT

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ABSTRACT: Underground construction requires long construction duration and a variety of equipment, and environmental management and improvement of its activities are considered necessary. For the purpose of the environmental improvement of underground construction activities, the appropriate development of technologies to reduce generated pollutants is mandatory. However, the analysis of the needs of technology development and the evaluation of development priorities should take precedence. In this research, the needs for the improvement of each construction activity are analyzed as a preliminary study for a proposed technology development plan to improve the environmental performance of underground construction. Firstly, environmental problem factors caused by underground construction activities are determined while underground construction types, methods, and activities are classified. A questionnaire survey to determine the needs for the improvement of each activity is then carried out. The survey indicated that the most urgent activity to be improved is that of cutting excavation, which causes environmental problems associated with flying dust. This study could be used as a basis for a technology development plan for the environmental improvement of underground construction activities. The result of this study, the priority of improvement needs, contributes to the effective allocation of a limited Research and Development (R&D) budget.

Keywords: Improvement needs; Environmental improvement; Underground construction

1. INTRODUCTION

A variety of pollutants such as noise, vibration, flying dust, and wastes are generated during the underground construction of buildings, and these require the intensive management of construction pollution by construction managers [1][2][3]. While previous studies have been carried out to assess or manage environmental impacts up to now, in-depth studies for the practical operation or the development plans of technologies are insufficient [4][5][6]. To accomplish the ultimate goal of low-impact construction sites, activities which require the development of technologies for environmental improvement should be investigated. A basis for the practical development plan of technologies will therefore be prepared in this study by evaluating the priority of needs. Thus, to establish a development plan of technologies for the environmental improvement of underground activities, this study identifies the key management factors for each activity, and quantifies their levels of influence. Underground construction activities are then finally prioritized.

2. METHODOLOGY

In this study, the Analytic hierarchy process (AHP) and frequency analyses are used for the purpose of measuring and quantifying the necessity of environmental improvement for each activity.

First, the possible environmental problem factors were determined through a review of existing literature. These factors were then filtered to determine the key factors based on the opinions of experts. In this step, the AHP was adopted to determine the relative importance of multiple factors. AHP is one of the most popular multiple criteria decision making tools for formulating and analyzing decisions [7].

Meanwhile, preliminary underground construction activities are selected, and those which are not preferentially improved are eliminated by professional consultants. At this stage, frequency analysis is used to categorize the activities according to priority. This means that the survey reflects the number of answers for each activity. Lastly, the holistic priority of activities is calculated by considering the weight of environmental problem factors and the frequency of answers. Fig. 1 presents the research process and methodology used in this study.

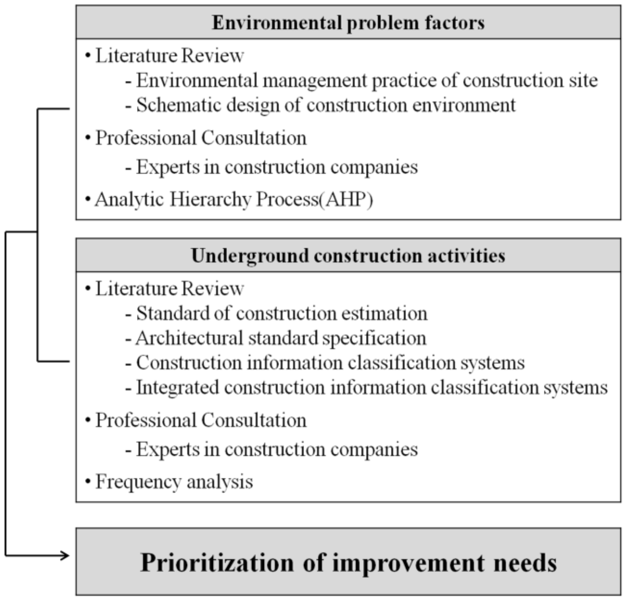

Fig. 1. Research process and methodology

3. ENVIRONMENTAL PROBLEM FACTORS

As shown in Table 2, the 'Environmental management practice of construction site' and the 'Schematic design of construction environment' are analyzed to extract the environmental problem factors generated from construction activities [8][9].

Table 2. Environmental problem factors identified in existing literature

Environmental problem factor	Environmental management practice of construction site	Schematic design of construction environment
flying dust	√	√
noise and vibration	√	√
odor	√	
traffic problems	√	
energy consumption		√
waste	√	√
gases which cause climate & ecological change	√	√
water pollution	√	
change of waterway & water level	√	
land pollution	√	
soil consumption	√	√
nervousness	√	

The key factors are determined by considering experts' advice. Factors which are not strongly associated with underground construction activities are eliminated. Five key factors are then selected as crucial factors for underground construction: flying dust, noise, vibration, traffic problems, energy consumption, and air pollution.

4. UNDERGROUND CONSTRUCTION ACTIVITIES

The underground construction types are classified according to classifications used in previous research: 'Standard of construction estimation', 'Architectural standard specification', 'Construction information classification systems', and 'Integrated construction information classification systems' [10][11][12][13]. Underground construction types include the following: soil investigation, earthworks, pile foundation and piling, retaining wall construction, ground improvements, and soil stabilization. These six construction types in large scale works are classified in detail according to their working procedures and methods. From discussions with experts in construction companies, they are then converted to the construction methods which are often used in practice. Table 3 presents the six construction types and 30 methods/activities.

Table 3. Underground construction types and their methods/activities

Types of underground construction	Construction methods and activities
soil investigation	boring
	drilling
	plate bearing test
	standard penetration test
earthwork	site clearing
	cutting excavation
	filling and backfilling
pile foundation & piling	PRD (percussion rotary drill)
	Barrette
	RCD (reverse circulation drill)
	hydraulic hammer
	SIP (soil-cement injected precasting pile)
	T4
	SDA (separation doughnut auger)
retaining wall construction	H-pile retaining wall
	CIP (cast in place)
	slurry wall (diaphragm wall)
	SCW (soil cement wall)
	sheet pile
	strut supporting
	earth anchor
	soil nailing
	SPS (strut as permanent system)

	BRD (bracket supported R/C downward)
	DBS (double beam system)
ground improvements	SGR (space grouting rocket)
	LW (labiles waterglass)
	JSP (jumbo special pile)
soil stabilization	sand, gravel and crushed stones
	lean concrete

5. PROIROTIZATION OF ACTIVITIES

A questionnaire survey on environmental problem factors was conducted in this study. Questionnaire sheets were collected by 34 managers who are working in major construction companies in Korea and whose working experience ranges from 1 to 20 years.

The questionnaire consists of two questions. The first question uses pairing to investigate the relevant importance among environmental problem factors. In the second question, the participants indicate the activities that are strongly related to the environmental problem factors. The participants were able to check several or no factors for each activity. The collected data was then analyzed to determine the relevant importance (weighting) of each factor, using the AHP method for the first question. It is important to secure the logical consistency of participants' responses because there may be a deficiency in the consistency during the pairwise comparison. For this reason, only 21 questionnaires, of which the consistency rate (CR) is smaller than 0.1 with a 1.12 random index (RI), are selected and analyzed. The average CR used in this study is 0.008. Weightings for the factors of flying dust, noise, vibration, traffic problems, energy consumption, and air pollution are 0.241, 0.396, 0.176, 0.077, and 0.110, respectively. Noise and vibration are recognized as the factor that most influence the environment (Table 4).

Table 4. Weighting of environmental problem factors

Environmental problem factor	Weighting	Rank
flying dust	0.241	2
noise and vibration	0.396	1
traffic problems	0.176	3
energy consumption	0.077	5
air pollution	0.110	4

The participants' opinions on the necessity of improvement for each factor of activities were then gathered from the second question. Table 5 shows the frequency of answers of each activity.

When integrating the results of AHP and frequency analyses, the underground construction activities are prioritized by reflecting the overall answers from the two questions. Equation (1) is used to calculate the Improvement Needs Score (INS) for prioritization.

$$INS_x = \sum_{y=y_1}^{y_n} (F_{xy} \times W_y) \quad (1)$$

F_{xy} refers to the frequency of answers for the activity x in regard to environmental problem factor y, while W_y is the weighting of environmental problem factor y.

Table 5. Priority of needs according to Improvement Needs Score (INS)

Priority	Activity	INS
1	cutting excavation	17.219
2	filling and backfilling	13.692
3	PRD (percussion rotary drill)	13.452
4	soil stabilization with sand, gravel and crushed stones	13.331
5	boring	13.188
6	T4	13.013
7	drilling	12.980
8	earth anchor	12.742
9	RCD(reverse circulation drill)	12.004
10	hydraulic hammer	11.886
11	sheet pile	11.219
12	slurry wall (diaphragm wall)	11.001
13	soil nailing	10.930
14	SIP (soil-cement injected precasting pile)	10.654
15	CIP (cast in place)	10.383
16	SDA (separation doughnut auger)	10.166
17	site clearing	10.066
18	H-pile retaining wall	9.889
19	JSP (jumbo special pile)	8.975
20	Barrette	8.458
21	SCW (soil cement wall)	8.274
22	SPS (strut as permanent system)	7.338
23	soil stabilization with lean concrete	7.315
24	LW (labiles waterglass)	7.273
25	SGR (space grouting rocket)	7.086
26	strut supporting of retaining wall	6.939
27	standard penetration test	6.799
28	DBS(double beam system)	5.603
29	BRD(bracket supported R/C downward)	5.516
30	plate bearing test	2.088

6. CONCLUSION

In response to today's strong need for environmental improvement, the priority of needs for the environmental improvement of underground construction activities is calculated in this study. The weightings of each environmental problem factor are calculated from the AHP analysis. These are then multiplied by the frequencies of answers, the sum of which is defined as the INS (Improvement Needs Score) which indicates the numerical quantification of priority.

From the results, cutting excavation shows the highest INS, followed by filling and backfilling, and then PRD. Plate bearing test, BRD, and DBS were given the lowest score of 2.088, 5.516, and 5.603, respectively. When comparing the six construction types, earthworks and pile foundation & piling are relatively in more urgent need of improvement.

The priority calculated in this study will form the basis for planning the environmental development of technologies for underground construction activities. In addition, this study will be helpful for more effectively allocating a limited R&D budget.

However, this study only considers the types of environmental problem factors and their significance, while the amount of generated pollutants is not numerically reflected. If this limitation is overcome, further studies will be able to prioritize the needs of improvement more reasonably and reliably.

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