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The Criteria Establishment for Dumping Site Route Selection of Urban Metro Construction

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Abstract

The problems of transporting unwanted excavated soil from construction sites in Bangkok, Thailand include heavy traffic, narrow working space, and the limited transport time. Consequently, the researcher tried to establish weighted criteria in selecting a transportation route for unwanted soil from urban metro construction sites to a dumping site. From expert interview and some existing researches, the researcher preliminarily got 35 criteria which then, screening to 10 resulted from using IOC technique. Finally, after conducting Delphi Technique and Analytic Hierarchy Process (AHP) together with in depth interview with the experts until getting consensus agreement, the weighted criteria in selecting a transportation route for unwanted soil from urban metro construction sites to a dumping site have been reduced to 4, i.e. 1) defiance (opposition from community along the transportation route) at 65.8%, 2) transportation cost at 14.1%, 3) transportation duration at 11.6%, and 4) truck drivers' stress at 8.5%.

Keywords: *Decision criteria, IOC, Delphi Technique, AHP, Urban Metro construction*

1. Introduction

The Office of Policy and Transportation and Traffic Plan (OTP) is an organization responsible for studying, analyzing and conducting both main plan and master plan for the investment of transportation and traffic of the country. The construction of mass rapid transit system in Thailand has been started from 2004 with two routes of 44 km total distance, i.e. the Elevated Train in Commemoration of HM the King's 6th Cycle Birthday (Bangkok Mass Transit System-BTS) and the Metropolitan Rapid Transit (MRT). In 2013 there were 7 routes with 291 km total distance, i.e. Light Red, Dark Red, Orange, Violet, Blue, Light Green and Dark Green Line. However, from the study of OTP, it was found that these lines have not yet covered most area with high density of population in Bangkok. Therefore, the rapid transit lines have been proposed to extend to Ratchadaphisek Ring Road area with linking routes to main communities with high population located along 20 km radius of the outer ring road. The recent proposal endorsed by the cabinet includes extension of existing rapid transit line network and new line construction with total 508 km distance of which 65 km is underground (metro) causing unwanted excavated soil more than 6 million cubic meters.

Two main factors needed to be considered in selecting a transportation route for unwanted excavated soil from urban metro construction sites are traffic condition and urban limited transportation time. Most existing researches which tried to analyze and give explanation on the phenomena in selecting the transportation route revealed the final integrating result of rather difficult in implementation, i.e. most selected factors were the factors of cost and time [3],[4],[5],[6],[7],[15],[17],[22],[26],[27],[28], [29],[30] e.g. the research of Androutsopoulos & Zografos (2009) showed the steps of algorithm of estimating the least transportation time along the most appropriate route with the lowest cost. Konstantinos N. suggested that, to get the best solution, the time used in the calculation should be real time of that particular case. However, at present we found that there are also other important factors which must be taken into our

consideration especially when transporting through the city with uncertain congested traffic, i.e. social and environmental factors. Society recognition and care of society interest are more important in selecting transportation route than finding out transportation cost and real transportation time.

Moreover, the research of Mousavi, et al, (2013) revealed an efficient tool, i.e. the integration of Delphi, AHP, and PROMETHEE method to choose necessary factors of both quantity and quality for decision making of factory site selection which could be implemented in real life without any difficulty.

Presently, Mass Rapid Transit Authority of Thailand (MRT) reserves Rama Ninth area as a dumping ground for unwanted excavated soil from urban metro construction sites. Rama Ninth area is now also a downtown resulted in tight transportation planning with less room for schedule readjustment. In case of construction acceleration, there will be a big problem to transport the excavated soil from the tunnel because of limited transportation time for big trucks, downtown traffic congestion, and limited space in the tunnel to temporarily pile up the excavated soil. This problem will result in the construction delay, extension of construction complete date, and huge cost accumulation. Both government sector and relevant construction contractors must be aware of and get ready to handle with this kind of problem properly because a lot of additional urban metro construction is expected in the near future [20]. To resolve this problem, well planning together with good decision making is crucial.

This research aims at establishing the weighted criteria in selecting a transportation route for unwanted excavated soil from urban metro construction sites to the dumping site.

2. Criteria Establishment for Dumping Site Selection

To select any information, it is important to have the experts select the best criteria. In this research, 6 experts in the field of soil transportation joined Delphi Technique to set up the criteria using IOC technique.

2.1 Objective Congruence Index (IOC)

This step the experts were asked to screen the factors relating with the real work. This was done by calculating the congruence between questions and objectives with the following criteria:

+1 = The question is congruent with the objective.

0 = It is doubtful whether the question is congruent with the objective or not.

-1 = The question is not congruent with the objective.

After the experts completed the IOC forms, the scores were calculated through Rovineli and Hambleton's Formula [23] as follows:

$$IOC = \frac{\sum_{i=1}^{n} R_i}{n} \quad (1)$$

$\frac{\sum_{i=1}^{n} R_i}{n}$ = Total scores from the experts

n = Number of the experts

2.2 Modified Delphi Technique

Delphi Technique is the method or process in collecting the ideas or decisions in various items in the future, from the expert group or related professionals, to conclude the research from the searching to be congruent and correct, without the brainstorming meeting, but let each expert express his idea from each round of questionnaire answering. This method could collect the ideas from the experts in several places and time without limitation – each expert could express idea freely, screen his own idea carefully, without the influence of the group suggestion and not under the other's influence;

thus, making the data trustworthy, saving research time and cost. For Delphi research technique, the sufficient member of the experts that would give the correct and trustworthy answers was not determined [9],[21], but it is normally accepted that with less number of member, the decision-making would not cover and not be good representative. However, with high number of member, the research would face the time problem and it is difficult to control the information from the experts. Consequently, in order to increase the quality and the accuracy of the asking, the questionnaire or the interview should be made with clear and easy questions. Moreover, the questionnaires should be sent to the experts for each round not too long interval period of time because the experts might forget the answer reason of the previous round.

2.3 Analytic Hierarchy Process (AHP)

AHP is the process used in "measuring the level" of the decision-making in various matters with high efficiency. The advantage of AHP is that it gives more trustworthy research result than other methods since it employs the pair-wise comparison in decision-making before giving the answer. There is a hierarchy system imitating the human thinking process making it easy to use and understand. The result obtained is in figures making it easy for the importance arrangement and could be compared for benchmarking with other interesting matters. This method could eliminate the bias or unbalanced decision-making. Since this process was invented, it has been applied in many decision-making matters such as the decision-making about business management – raw material ordering, selection of places for management or goods distribution [13]. The establishment of marketing strategies or the selection of giving logistic service etc. [28], including the application of the personal resource management in the organization - the arrangement of the staff ability, selection assessment of vocation linear staff attitude survey etc. [10] or used in the selection of weighing places of truck on highways [2] and in the decision-making of location selection of solar energy plant in Thailand [14].

The AHP has 3 mains components as follows.

1. The defining problem target is the decomposition of complicated problem in the hierarchy structure. Each level consists of decision-making criteria related with those problems. The top level is called the overall target with only one factor. The second level might have many factors depending on how many levels in the chart. It is crucial that each factor in the same level should be at equal importance.

2. The comparative judgment is made by comparing each pair of relationships from the factors which affect the decision-making criteria in each hierarchy structure by pair-wise comparison. The judgment will be expressed in the form of the satisfaction level scales as shown in equation (2) and Table 1.

3. Tables, Figures and Equations

$$A = |a_{ij}| = \begin{vmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{vmatrix} \qquad (2)$$

Matrix table is the most suitable in the pair comparison or matching. Apart from explaining the comparison, it can test the conformity of the judgments and can analyze the sensitivity of the important levels when the judgment changes.

Table 1 Importance comparison with AHP

Level	Definition
1	Equally Preferred
2	Equally to Moderately Preferred
3	Moderately Preferred
4	Moderately to Strongly Preferred
5	Strongly Preferred
6	Strongly to Very Strongly Preferred
7	Very Strongly Preferred
8	Very Strongly to Extremely Preferred
9	Extremely Preferred

3. Synthesizing

The process of AHP starts from weighing the criteria and then they will be put in order by considering all important levels to select the most alternative. Finally, the pair-wise comparison will be tested to ensure the quality of the experts' answers.

The congruence values of the reason in AHP are the consistency index (C.I.) and the consistency ratio (C.R.) calculated from equation (3) and (4)

$$C.I. = \frac{\lambda_{max} - n}{n-1} \quad (3)$$

$$C.R. = \frac{C.I.}{R.I.} \quad (4)$$

n = number of criteria in the study

R.I. = Random Index, which the research [1] showed the details

If the calculated C.R. is higher than 0.1, there must be re-assessment until the value reaches the acceptable point.

3. Research Methodology

The steps in selecting the criteria started from the literature review and then, expert interview. After that, there was another criteria screening to get the most appropriate one. Due to the similarity of the criteria characteristics, determinant and prioritization of the criteria were used to select the proper route of excavated soil transportation from urban metro construction site. Jun, et al, (2013) encountered the same problem. The suggestion was on employing the mentioned criteria to achieve the target or decision making.

Figure 1 demonstrates the research methodology in this study resulted from literature review and interviewing 6 experts related with the dumping site route selection in metro construction presenting 35 criteria as follows:

1. General population expose
2. Occupational population expose
3. Sensitive environment expose
4. Accident rate
5. Emergency response
6. Site layout
7. Gradient
8. Risk assessment
9. Environment Rules of Soil Transport
10. Land use frontage
11. Defiance
12. Housing density
13. The access day
14. The client demand
15. Transportation cost
16. Temporary facilities
17. Storage area
18. Waiting time
19. The capacity of vehicles
20. The fleet size of vehicles
21. The maximum available time for each car to do services in each day
22. Transport cost or Transshipment cost
23. Distance
24. Transportation duration
25. Route quality
26. Security of product
27. Reliability and punctuality
28. Traffic means
29. Amount material to be shipped
30. Accessibility or available route
31. Loading and unloading
32. Number of interchange
33. Quantities and types of materials being carried
34. Car speed in travelling
35. Stress of Driver

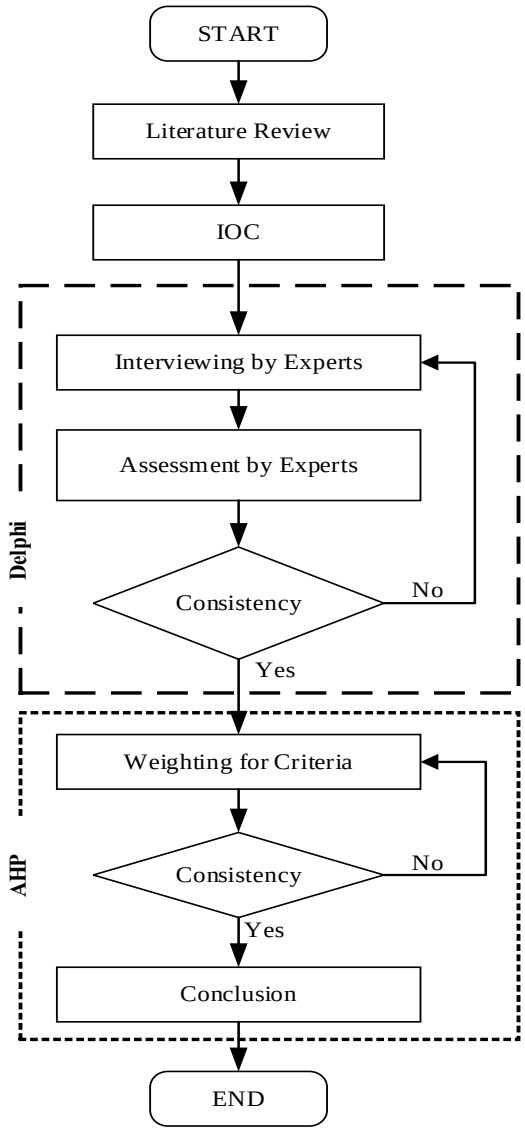

Fig 1. Research process

After that the data were sent back again to the experts for the IOC with the results shown in Table 2. Therefrom, Figure 2, Delphi technique attempts to make effective use of informed intuitive judgment out of experts.

Table 2 Questionnaire for the expert to assess with IOC

Criteria No.	IOC					
	EP_1	EP_2	EP_3	EP_4	EP_5	EP_6
C_1	+1,0,-1	+1,0,-1	+1,0,-1	+1,0,-1	+1,0,-1	+1,0,-1
C_2	+1,0,-1	…	…	…	…	…
C_3	+1,0,-1	…	…	…	…	…
C_4	+1,0,-1	…	…	…	…	…
C_5	+1,0,-1	…	…	…	…	…
C_6	+1,0,-1	…	…	…	…	…
⋮	⋮	⋮	⋮	⋮	⋮	⋮
C_{35}	+1,0,-1	+1,0,-1	+1,0,-1	+1,0,-1	+1,0,-1	+1,0,-1

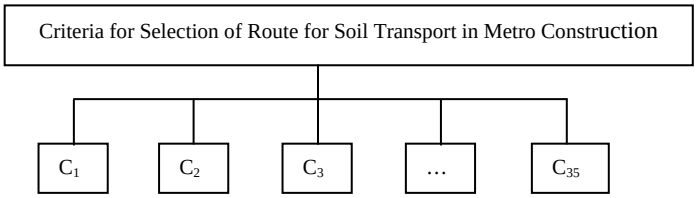

Fig 2. Delphi Form for Criteria Screening

Finally, the evaluation results of AHP Technique reported by the experts were reexamined for C.R. value. If the value is in unacceptable level, the experts have to reassess the evaluation until reaching the acceptable value [8]. The summation of the experts' report is calculated to find geometric mean to show the importance of each parameter.

4. Results of the study

The objective of this research is to set up the criteria related to the selection of a transportation route for unwanted soil from urban metro construction sites to a dumping site by screening the closest factors related to this work. After that, the selected data were screened again for more accurate through Delphi Technique by the experts. Finally, the importance of each parameter was illustrated through AHP Technique with details as follows.

4.1 Screening Results with IOC

Based on the interview with 6 experts, the researcher selected the questions with the IOC values higher than 0.5 meaning that every question is consistent with the content and

covers the objective of the research. According to the results of the IOC values, 35 criteria were screened to 10 criteria as shown in Table 3.

Table 3 IOC Values

Content Topics	IOC Values
1. Occupational population expose (C_1)	0.83
2. Environment Rules of Soil Transport (C_2)	0.67
3. Defiance (C_3)	1.0
4. The client demand (C_4)	0.67
5. Transportation cost (C_5)	1.0
6. The fleet size of vehicles (C_6)	0.67
7. Transportation duration (C_7)	1.0
8. Reliability and punctuality (C_8)	0.67
9. Accessibility or available route (C_9)	0.67
10. Stress of Driver (C_{10})	1.0

4.2 Screening Results with Delphi Technique Round 1

Prior to the interview, the researcher asked the 6 experts on the selection of a transportation route for unwanted soil from urban metro construction sites through direct interview. From the 1st round interview, it was found that most of the experts agreed with the criteria on Environment Rules of Soil Transportation, Defiance, Transportation cost, Transportation duration, Accessibility or available route and Stress of Drivers which were then, accounted for the 2nd round interview after 2-week interval.

4.3 Assessment Results with Delphi Round 2

In the 2nd round, the 6 experts concentrated on in depth analysis of the screened questions with the additional strategies or new aspects related to those questions anonymously. In this round, the communication had been done carefully to obtain those new strategies and ideas. All 6 experts gave importance on the 1st criteria that the transportation route must not affect the local community followed by the transportation cost and the transportation duration and last but not least, the stress of the truck drivers. In conclusion, the criteria selected by the experts included Defiance (opposition from community along the transportation route), Transportation cost, Transportation duration and Stress of the Drivers.

4.4 Assessment Results with Delphi Round 3

The 4 criteria were discussed again by the 6 experts with the final consensus agreement.

4.5 Result of the weighted criteria in selecting a transportation route for unwanted excavated soil from urban metro construction sites

After the 3rd round Delphi, the researcher interviewed the 6 experts again. Those experts were in the field of related construction consisting of 2 project managers (PM), 2 project engineers (PE), and 2 excavated soil transportation contractors (EST). Each expert was interviewed again to give the weight using AHP Technique converted the experts' opinions into figures for the pair-wise comparison which would be ended when the C.R. value reached 0.1 or lower as shown in Table 4 - 9.

Table 4 The 4 Criteria Relative Weight of Project Manager 1[a]

	Cost	Time	Stress	Defiance
Cost		1	6	3
Time			5	7
Stress				9
Defiance				

a. C.R. = 0.07

Table 5 The 4 Criteria Relative Weight of Project Manager 2[b]

	Cost	Time	Stress	Defiance
Cost		1	3	7
Time			6	3
Stress				7
Defiance				

b. C.R. = 0.08

Table 6 The 4 Criteria Relative Weight of Project Engineer 1[c]

	Cost	Time	Stress	Defiance

Cost		1	4	7
Time			5	7
Stress				9
Defiance				

c. C.R. = 0.08

Table 7 The 4 Criteria Relative Weight of Project Engineer 2[d]

	Cost	Time	Stress	Defiance
Cost		1	4	6
Time			5	5
Stress				8
Defiance				

d. C.R. = 0.06

Table 8 The 4 Criteria Relative Weight of Excavated Soil Transportation Contractors 1[e]

	Cost	Time	Stress	Defiance
Cost		3	3	7
Time			5	7
Stress				3
Defiance				

e. C.R. = 0.05

Table 9 The 4 Criteria Relative Weight of Excavated Soil Transportation Contractors 2[f]

	Cost	Time	Stress	Defiance
Cost		1	3	7
Time			5	7
Stress				3
Defiance				

f. C.R. = 0.02

From Table 10 and Figure 3, it can be concluded that the weighted criteria can be shown relatively in Table 11.

Table 10 Criteria relative weights from the experts

Criteria	Relative Weights (%)					
	PM1	PM2	PE1	PE2	EST1	EST2
1.Defiance	62.1	60.6	69.4	64.7	59.2	59.4
2. Cost	18.8	20.3	12.7	14.5	10.5	7.9
3. Time	15	13.9	13.7	16.1	5.4	7
4. Stress	4.1	5.2	4.2	4.7	24.9	25.7

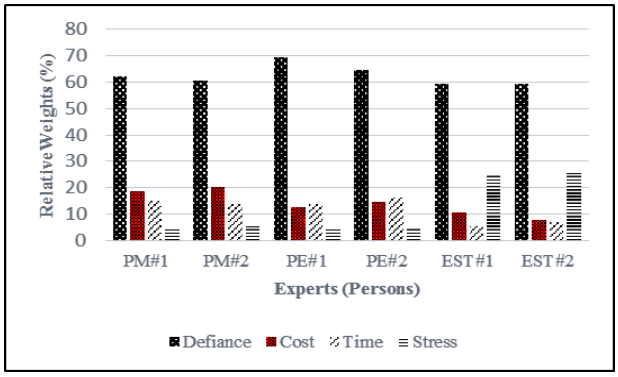

Fig 3. Relative weight from 6 experts

The weighted criteria from AHP were then, calculated to find geometric mean revealing that the mean of the 4 criteria were less than 1 meaning that they were not comparable. As a consequence, normalization technique was conducted as shown in Table 11 which can be used to select a transportation route for unwanted soil from urban metro construction sites to the dumping site.

Table 11 Relative weight of the criteria

Criteria	Relative Weight
Defiance	0.658
Transportation Cost	0.141
Transportation Time	0.116
Stress of Drivers	0.085

5. Conclusions

In the near future in Thailand, many lines of metro mass rapid transit are going to be constructed to serve the people needs and for long term sustainable development of the country. This will create a huge amount of unwanted excavated soil from the metro construction sites mostly located in urban area which needs to be disposed through appropriate planning and good decision making. However, the government sector and related construction contractors have not yet set up the proper criteria in selecting transportation route for dumping unwanted excavated soil from urban metro construction sites. As a result, the existing selected transportation routes cannot cope with current continuously changing situation, e.g.

fluctuating oil price, traffic congestion, lack of skilled labor, inefficient workforce, uncertain political situation, etc. Consequently, establishment of the criteria in selecting a transportation route for the unwanted soil from urban metro construction sites to the dumping site is crucial to resolve the said problem.

In this study, firstly, decision-making criteria affecting the route selection had been defined and established by integrating methods and principles of cause and effect. 35 criteria had been obtained from preliminary screening through literature review and expert interview. The experts were in the field of construction related with soil work, e.g. project managers, project engineers, and soil transportation contractors. Their high experience ensured the significant relationship between these criteria and the selected transportation route.

Then, IOC was employed to screen out the unrelated criteria leaving only 10. However, the opinions of 6 experts towards the 10 criteria were not unanimous because the meanings of some criteria were ambiguous or too close with others'. As a consequence, Delphi Technique, the scientific method to collect data from many experts to serve and analyze the deep-down knowledge (Olaf, 1967)., had been employed to find the most appropriate criteria applicable with transportation route selection. The reasons for using Delphi Technique can be concluded as follows: 1) this method can investigate whether the experts assess the criteria according to their real knowledge and experience or not. 2) Each expert can be interviewed individually without meeting with others. This can reduce bias against other experts in answering the questions. 3) This method can be conducted repetitively until obtaining the harmony conclusion from all experts.

From the employment of Delphi Technique on the 10 criteria, 3 rounds of assessment had been conducted to get the group consensus by the 6 experts and the criteria had been reduced to 4, i.e. 1) defiance (opposition from community along the transportation route), 2) transportation cost, 3) transportation duration, and 4) truck drivers' stress.

Table 10 and Fig 3 show various importance and weight of each criterion according to particular expert. Most of the 6 experts put the highest weight (about 62.6%) on defiance (opposition from community along the transportation route); then, followed by transportation cost (14.1%), transportation duration (11.6%), and truck drivers' stress (8.5%) respectively.

All experts saw the importance of the defiance because if they could not get along well with the community nearby, the opposition from the community may stop them from working causing a long work delay followed by huge accumulating cost. They have to prepare a resolution for the problems created by transportation trucks which might be both direct and indirect serious effects on the community, e.g. falling excavated soil along the road, road damage, noise of operating trucks, more traffic congestion, pollution from trucks' exhaust smoke, etc. Other two classical criteria repetitively mentioned in most study on transportation route selection, i.e. transportation cost and transportation duration were also presented in this research as well. However, another important criterion needs to be notified here is truck drivers' stress. From the interview of 2 excavated soil transportation contractors, both put more importance on this criterion than the other experts. They raised their concern that the stress of truck drivers can cause a serious sequel, i.e. vehicle accident. Stress of the truck drivers especially along urban route may come from many reasons, e.g. health problem, too many shifts per day, conflicts with others such as peers or employer, personal problem, family problem, gamble addiction, restless, etc. New driver recruitment is only a short term resolution because the same problems may repeat or a new problem about trust may occur. So, the contractors must try to capture the root causes of

truck drivers' stress and resolve them as soon as possible before it is too late.

In conclusion, the weighted criteria established from expert interview can help relevant organizations plan and make decision in selecting transportation route effectively and efficiently especially the route to transport unwanted excavated soil from urban metro construction sites to the dumping site.

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